Guidelines for Developing Travel Demand Models: Small Communities

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16. Abstract

This research develops guidelines to simplify and standardize travel demand modeling in terms of a community size, needs and issues. The focus is on smaller communities with populations less than 10,000. Instead of using the usual computerized network-based model for all communities regardless of size, the guidelines recommend appropriately scaled approaches to reduce time and cost, yet provide adequate estimates of traffic volumes and impacts. Methods include trend line traffic forecasts, context sensitive solutions (CSS), geographic information systems (GIS), and/or manual travel allocation. As the size of the study area grows, sketch planning and quick response computer methods are suitable. The guidelines suggest available sources for model data including national and state average trip rates, and whether new travel behavior surveys are necessary. The guidelines also point to new tools for CSS evaluation, land development potential, manual trip allocation, trip distribution, and mode choice. Case studies demonstrate the guidelines and models.

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Preface

This report documents the first phase of a two phase project to develop guidelines for travel demand modeling in North Carolina. The first phase effort focuses on transportation modeling concepts for small communities with populations up to 10,000. The second phase of the project will document travel demand model guidelines for communities with populations greater than 10,000.

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EXECUTIVE SUMMARY

Background

Most major travel demand models developed and used by North Carolina Department of Transportation (NCDOT) are long range, urban travel demand models applying the traditional four-step process. In smaller areas, sketch tools or hand allocation models are used. This research provides various levels of tools available that can be used based on an agency's staff constraints. Building upon the exciting collaboration among the Triangle Regional Model Service Bureau, NC State University and UNC-Chapel Hill, and upon on-going travel demand modeling research at the two Universities and Institute for Transportation Research and Education (ITRE), we developed guidelines for best guidelines for developing travel demand models and sub-models in order to simplify, streamline and standardize the travel demand modeling process.

Problem

Transportation professionals must select appropriate methods and tools for analysis in terms of a community's size, needs, features and development, during the course of the analytical and outreach activities. Transportation planning activities in small and medium urban areas is becoming increasingly important since the popularity of these areas has risen over the past several decades. In addition, while large metropolitan areas are usually able to dedicate significant effort to their transportation budget, small communities often do not have or need such magnitude of resources and must search for ways to handle transportation issues in the town area while streamlining their expenditures. Therefore, it is critical for NC communities, especially for those smaller ones, to develop good guidelines and tools for best modeling practices. The products and associated tools will help assure that transportation planning staffs efficiently use their time and resources to carry out their transportation planning and modeling activities on a local, regional and statewide basis.

Scope and Objectives

There are two phases in the three-year project. Phase I focuses on the smaller areas with population less than 10,000 in North Carolina. Phase II focuses on larger NC communities. This report addresses the research efforts conducted in Phase I. The project goal in Phase I is to improve and simplify the on-going conventional planning process while making it a more efficient and less time consuming process for smaller areas with population less than 10,000. Tools for Phase I rely on U.S. census and North Carolina data, simplified travel demand modeling approaches and GIS tools that allow integration of multiple factors that affect community travel.

The objectives of Phase I of the research are:

- To improve, yet simplify, the transportation modeling process for small NC communities with population less than 10,000.
- To develop guidelines and tools for best modeling practices for small NC communities consistent with their features, needs and concerns.
- To test the option of developing long term partnerships for research and transportation demand modeling using North Carolina expertise and data sets.

Approach

The research methodology follows the common travel demand modeling approach: data collection, network development, trip generation, trip distribution, mode choice, trip assignment and deficiency analysis. Professionals apply this methodology with customized methods depending on the scope and size of the study areas.

In Phase I, we define two distinct categories for small urban areas in North Carolina:

- Category A – population < 5,000
- Category B – population between 5,000 and 10,000

Instead of using the same detailed modeling, air quality and deficiency analysis approach for all communities, we develop appropriately scaled approaches that reduce time and cost, yet provide adequate estimates of traffic volumes and impacts resulting from new transportation projects. The different travel forecasting approaches (context sensitive solution, trend line analysis, manual travel allocation, TransCAD Quick Response and GIS display tools) are evaluated and matched to the study area based on its size, issues and transportation needs. We determine available sources for model data including default national or state averages, and determine whether new surveys (of all types) are necessary. Furthermore, appropriate sub-models for trip generation, distribution, mode choice, traffic assignment, and external trip analysis are developed and tested against newly collected data and available data sets.

Findings and Recommendations

In Phase I, the research work follow on previous efforts and extend them to cover models, sub-models, tools and guidelines for best practice for the spectrum of small urban areas. There are many planning tools in the "toolbox", and they can be applied to the variety of communities based on size and needs. The summary travel demand model guidelines for small communities are presented by the matrix and the decision tree below.

The matrix and decision tree represent guidelines to help transportation planners and engineers apply appropriate methods, data sources and sub-models to simplify their efforts. The authors also believe that the guidelines will help make the models be compatible with the community and environmental issues, as well as transportation needs.

TDM Guideline Matrix

Part I: Data for Travel Demand Models
(Categories A and B are documented in this report. Categories C and D are in a separate report.)

Category	Size	Issues	Community Characteristics	Data, Rates, Parameters	Data Sources	Network Complexity / Zones	Tools ( ) ~ Appendix
A (Phase I)	< 5,000	Economic Development, New Roads, Truck Traffic; Community & Environmental Impacts, Hazard Mgt.	Income Level; Rural, Fringe; Vacation, Retirement; Industry; Attractions; Regional Center; CBD Vitality; Growth Rate; Nearby Interstate or Other TIP Projects Outside Study Area; Size & Type of TIP Improvements; RPO; No MPO	Default NC	Census CD 2000 Short Form Blocks; USGS GIS; CTPP; Amer. Fact Finder; Google Earth; FEMA, aerial photos, NC Demographics office	Major Roads; Census Blocks or User Defined TAZs Coarse zones, no more than 5 – 10 and the major roadway system.	CSS (A); GIS Land Supply (B); Trend Line (C); Manual Travel Allocation (D)
B (Phase I)	5,000 – 10,000	Cat A +; New Bypass	Cat A	Default NC Rates, NCHRP	CTPP, census, GIS, Data Sources Table	Cat A + Streets, Census Tracts or User Defined TAZs Number of zones should range between 10 and 15. Roadway system should reflect major roadway system plus important connector routes.	TransCAD NC QR (E); CSS; GIS
C (Phase II)	10,000 – 50,000	Cat B +; CBD Revitalization;	Cat A + Suburbs; RPO; No MPO	Default NC Rates, NCHRP	CTPP, NCHRP 365, Data Sources Table	Cat B + bus transit Guidelines on network selection and zone compatibility.	TransCAD NC QR & Ph. II report; CSS; GIS
D (Phase II)	> 50,000	Cat B+; Air Quality + Federal Planning Requirements	Cat C; MPO	Local Data, Surveys	CTPP, Surveys, Data Sources in Table B-1 and E-1	Cat C See guidelines	TransCAD, Ph. II report; CSS; GIS
E	Regional	Cat B+; CBD & Area Development; Interstate Loops; Rail Transit	Cat D for All Communities in Region; Homogeneous Region; Multi-Nucleated Region; MPO	Local Data, Surveys	Surveys, Data Sources Table	Cat C + rail transit See guidelines	TransCAD; CSS; GIS

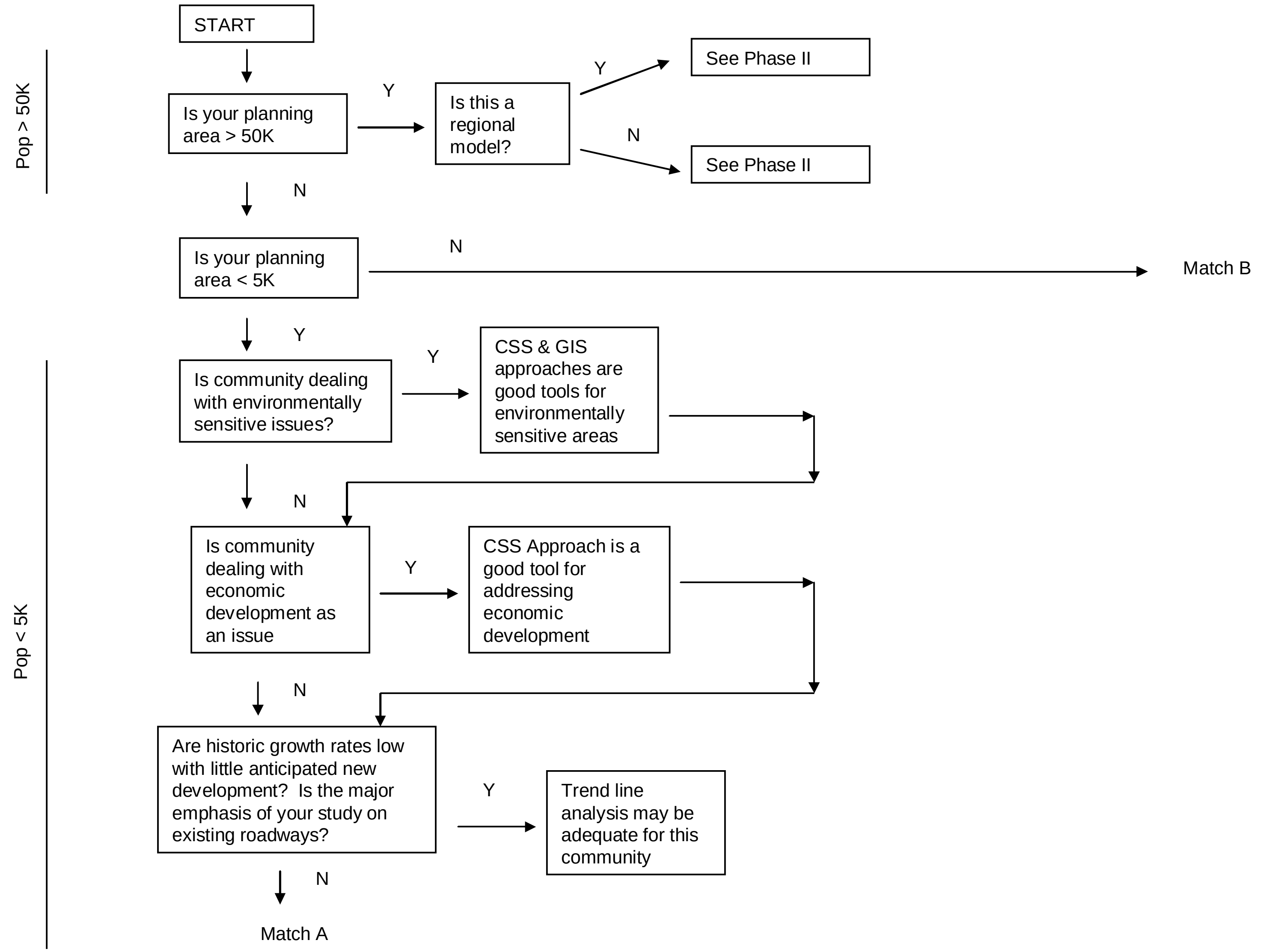
Part II: Sub-models for Travel Demand Modeling
(Categories A and B are documented in this report. Categories C and D are in a separate report.)

Category	**Size**	**Land Use** ( ) ~ Appendix	**Trip Generation** ( ) ~ Appendix	**Trip Distribution** ( ) ~ Appendix	**Mode Choice** ( ) ~ Appendix	**Network Assignment** ( ) ~ Appendix	**External Trips** ( ) ~ Appendix	**Tools** ( ) ~ Appendix
A (Phase I)	< 5,000	Comprehensive Plan; Land Supply Analysis (optional); (B)	US or NC Average Rates; If low income use US rates; If high income use NC rates; NCHRP 187 or NCHRP 365; CTPP Rates; Local Survey Rates; Consider 1 or 2 Trip Purposes; Consider NHB2; (H)	Distribute manually (spreadsheet) based on total employment; (D, F)	TCRP B3 for Demand Responsive Transit; (J)	Trend Line & Growth Factor Ratio Forecast for Single Routes; Manual Travel Allocation for Simple Nets; (D)	Manual Travel Allocation; Synth; (G) Consider all external trips are through trips	CSS (A); GIS Land Supply (B); Trend Line (C); Manual Travel Alloc. (D,F); NuSynth (G); NC rates (H); Distr (I); Transit (J); Assig (E)
B (Phase I)	5,000 – 10,000	Cat A; Land Supply Analysis; (B)	Cat A; If fringe, use Metro Rates; (H)	Mean travel time from skims and zone-zone travel times; (E)	Cat A, GIS Analysis; (J)	QR Stochastic Method Daily; (E)	Synth with local adjustments (E) or NuSynth (G)	Cat A tools or NC QR (E)
C (Phase II)	10,000 – 50,000	Cat A + Land Supply Analysis; Land Use Scenarios	Cat A or Local Rates from Survey; Use 3 Trip Purposes	Cat B	Cat B and MNL Models for Fixed-route Transit	QR Stochastic Method Daily	Cat B	Cat B
D (Phase II)	> 50,000	Cat C; Concentric Zone Model; Sector Model	Local Rates from Survey		Cat C or MNL Model with TransCAD	Equilibrium Method Hourly	External Station Survey	Ph. II report
E	Regional	Cat C + Land Use Models; Metro Plng; Multiple Nuclei Model & Polycentric Model	Cat D		TransCAD and MNL Model	Equilibrium Method; Hourly	External Station Survey; Separate AON Assignment for Commercial Vehicles	

Part III: Reasonableness Checks in Travel Demand Model Approach
(Categories A and B are documented in this report. Categories C and D are in a separate report.)

<table>
<tr><th>Category</th><th>Size</th><th>Land Use Data and Transportation Networks</th><th>Trip Generation</th><th>Trip Distribution</th><th>Mode Choice</th><th>Network Assignment</th><th>Validation Targets</th><th>Tools
( ) ~ Appendix</th></tr>
<tr><td>A
(Phase I)</td><td>< 5,000</td><td>Compare Land Use Results for Manual Travel Allocation to Land Supply Analysis</td><td>NCHRP 365 rates;</td><td>Professional judgment</td><td>Professional judgment</td><td>Traffic counts/ Professional judgment</td><td>NC Guidelines</td><td>(B)
(C)
(D)</td></tr>
<tr><td>B
(Phase I)</td><td>5,000 – 10,000</td><td rowspan="4">Overall visual inspection with a focus on speed ranges, capacity ranges, and facility types. Check for network connectivity, missing nodes, missing links, one-way links going the wrong direction. Use minimum path techniques to check for coding errors. Traffic counts should be reviewed using measures such as volume per lane and historic growth rate trends. Land use data checks should be performed at the zonal, regional, and aggregate levels. Basic checks should review all land use variables, population/household ratio, population/employment ratio, and plots of densities and density changes for future year data.</td><td rowspan="2">Ratio of unbalanced Ps and As should be between 0.9 and 1.0. Review percent of trips by purpose and compare to typical ranges outline in Table E-3.</td><td rowspan="2">Plot average trip length distribution for each trip purpose and review based on your knowledge of the area. Review average trip length by trip purpose.</td><td rowspan="2">Compare mode splits to those reported for your county or community from the US Census long form data or CTPP data.</td><td rowspan="2">Traffic count data that has been validated and VMT data if available. For recommended data summary checks refer to Validation Targets column for recommended references.</td><td rowspan="2">Calibration and Adjustment of System Planning Models, FHWA Dec. 1990 Model Validation and Reasonableness Checking Manual, TMIP June 2001.</td><td></td></tr>
<tr><td>C
(Phase II)</td><td>10,000 – 50,000</td><td></td></tr>
<tr><td>D
(Phase II)</td><td>> 50,000</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>E</td><td>Regional</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Decision Tree (0 < Population < 10K)



Pop < 5K

A

Do you anticipate future growth that may stress the existing transportation system?

Y → A manual allocation procedure is recommended for this community

N ↓

No clear issues have emerged for your community. Please review the benefits, requirements, and uses for recommended tools for this size community and select the one you believe best suits your needs.

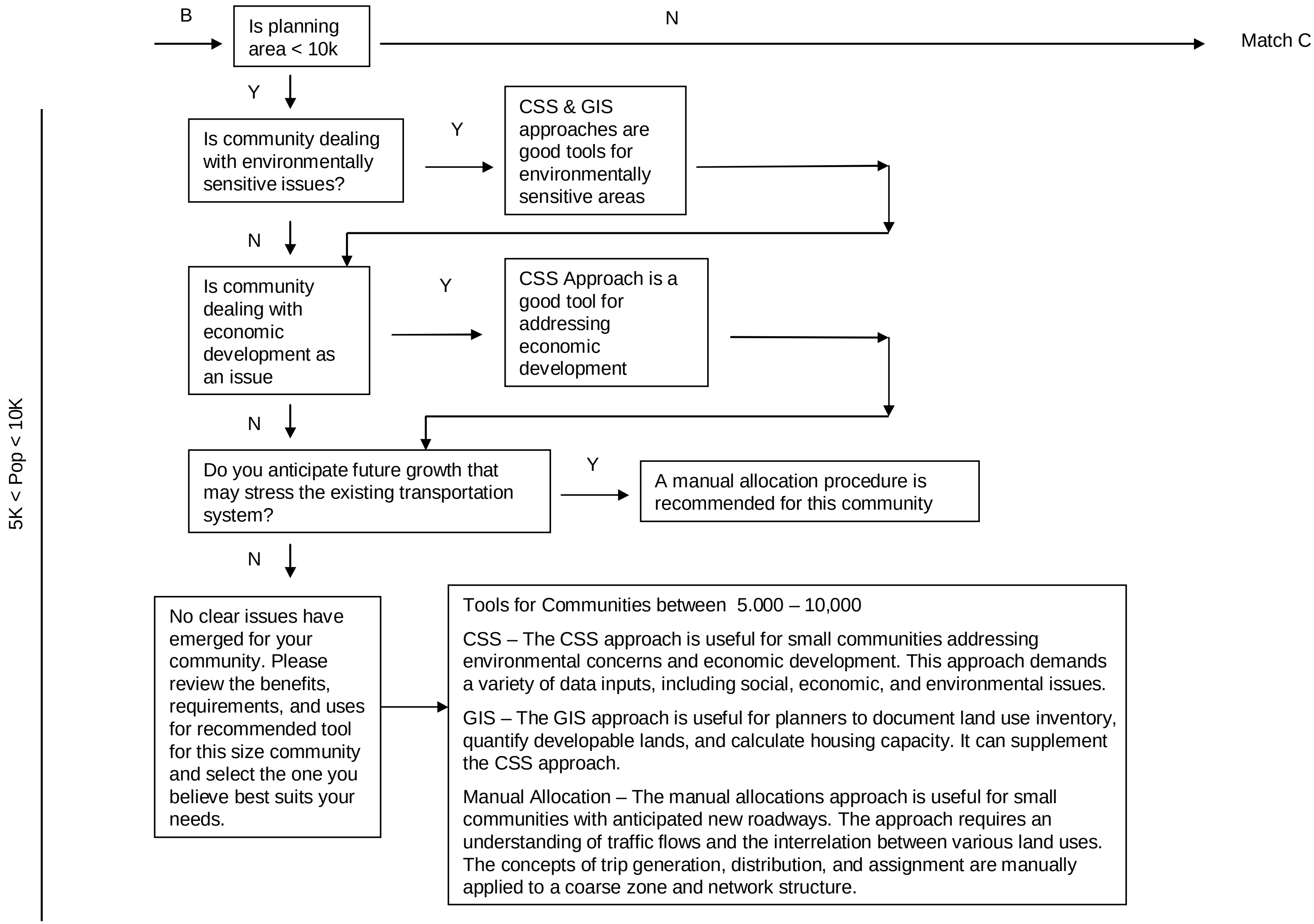
Tools for Communities less than 5,000

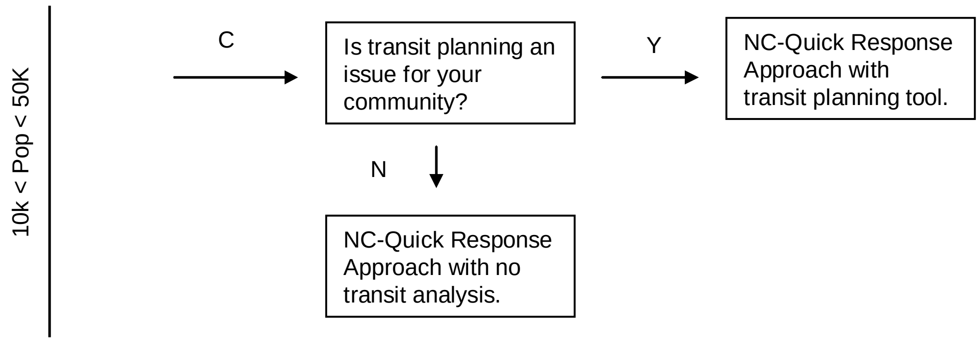
CSS – The CSS approach is a useful analysis tool for small communities addressing environmental concerns and economic development. This approach demands a variety of data inputs, including social, economic, and environmental issues. The output will also support trend line, manual allocation, etc.

GIS – The GIS approach is useful for planners to document land use inventory, quantify developable lands, and calculate housing capacity. It can supplement the CSS approach. The output will also support trend line, manual allocation, etc.

Trend Line – The trend line analysis is useful for small communities where new location roadways are not anticipated. The benefits of this approach are that it requires very little data and is easy to apply.

Manual Allocation – The manual allocations approach is useful for small communities with anticipated new roadways. The approach requires an understanding of traffic flows and the interrelation between various land uses. The concepts of trip generation, distribution, and assignment are manually applied to a coarse zone and network structure.


B
Is planning area < 10k
N
Match C
Y
Is community dealing with environmentally sensitive issues?
Y
CSS & GIS approaches are good tools for environmentally sensitive areas
N
Is community dealing with economic development as an issue
Y
CSS Approach is a good tool for addressing economic development
N
Do you anticipate future growth that may stress the existing transportation system?
Y
A manual allocation procedure is recommended for this community
N
No clear issues have emerged for your community. Please review the benefits, requirements, and uses for recommended tool for this size community and select the one you believe best suits your needs.
Tools for Communities between 5.000 – 10,000
CSS – The CSS approach is useful for small communities addressing environmental concerns and economic development. This approach demands a variety of data inputs, including social, economic, and environmental issues.
GIS – The GIS approach is useful for planners to document land use inventory, quantify developable lands, and calculate housing capacity. It can supplement the CSS approach.
Manual Allocation – The manual allocations approach is useful for small communities with anticipated new roadways. The approach requires an understanding of traffic flows and the interrelation between various land uses. The concepts of trip generation, distribution, and assignment are manually applied to a coarse zone and network structure.
5K < Pop < 10K


10k < Pop < 50K
C
Is transit planning an issue for your community?
Y
NC-Quick Response Approach with transit planning tool.
N
NC-Quick Response Approach with no transit analysis.

CHAPTER 1: INTRODUCTION

Background

Federal Requirement for TDMs

The transportation planning process is based on the systems approach to problem solving and is quite general in its structure. The most common application of travel demand forecasting is in urban areas since 1962. The Federal Aid Highway Act of 1962 created the federal requirement for urban transportation planning and required that all transportation projects in urbanized areas with populations of 50,000 or more be based on a transportation planning process that was continuous, comprehensive, and cooperative [1].

Most recently, in reaction to the requirements of the 1990 Clean Air Act Amendments (CAAA) and the 1991 Intermodal Surface Transportation Equity Act (ISTEA) [2], there has been renewed activity in travel forecasting. In fact, implementation of most of the factors outlined in the ISTEA legislation is applied in the context of this research for small town transportation planning. Those factors are:

- Energy use;
- Efficient use of existing facilities;
- Traffic congestion reduction; and
- Efficient movement of commercial vehicles.

These planning factors have been consolidated in the Transportation Equity Act for the 21st Century (TEA-21) of 1998 [3], and they emphasize the need for small town transportation planning, as well as for larger cities.

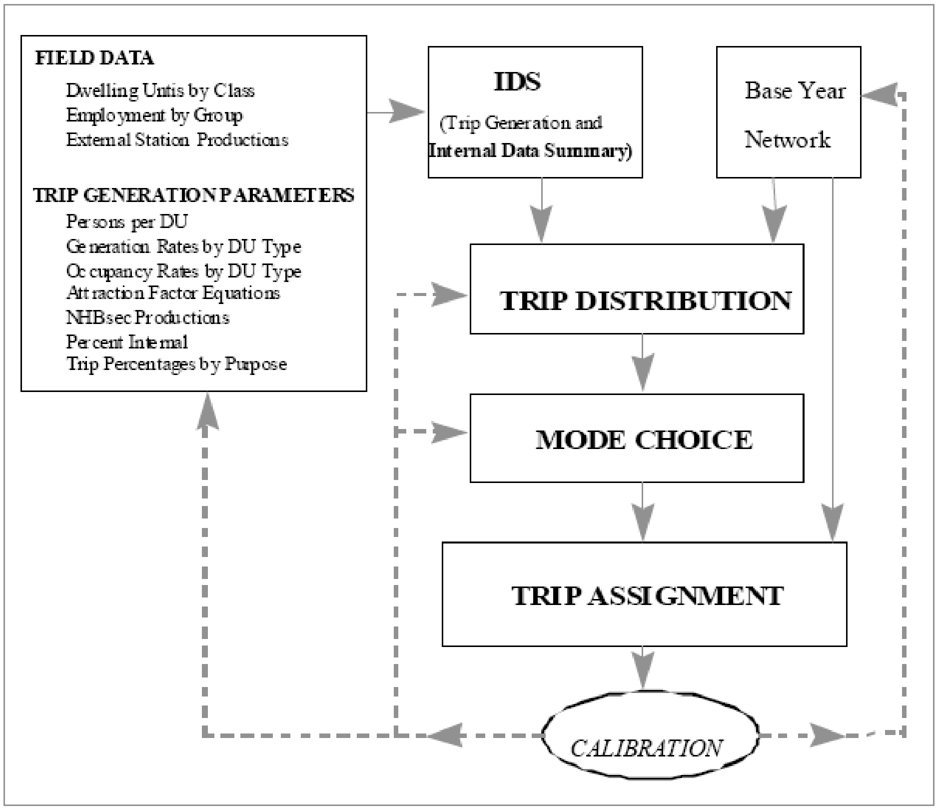
According to these acts, local plans, community values, financial restrictions and obligations, land uses, environmental issues and regional commitment should be incorporated into the transportation planning process. Small towns and cities can have a strong voice in prioritizing transportation projects in their areas of jurisdiction instead of allowing those decisions to fall to statewide officials alone. However, relatively little national guidance exist for transportation plans for communities under 50,000 population. North Carolina utilizes some forms of travel forecasting for all urban areas, even small ones. But the development of travel demand models is often more suited to larger urban areas. For smaller areas, more appropriate methods are available as shown in this research.

NCDOT Practice

The North Carolina Department of Transportation (NCDOT) provides technical assistance to local communities in the development of travel demand tools and their comprehensive transportation plans (CTP). To address the transportation system needs of communities in North Carolina, NCDOT transportation engineers develop analyses for forecasting future travel by automobile, truck and transit vehicles. Contributions of pedestrians and bicycles to traffic and the direct effects of land use choices and patterns are also examined.

The major travel demand models developed and used by NCDOT in larger urban areas are long range travel demand models that apply the “traditional” four-step process: 1) trip generation, 2) trip distribution, 3) mode choice, and 4) trip assignment as seen in Figure 1-1. To accomplish varied planning needs and missions for different NC communities, the professionals of the Transportation Planning Branch have developed urban travel demand models, and special sub-models (SWP Trip Generation and Synthetic External Trip Distribution) to simplify the modeling process, especially for larger study areas.

Figure 1-1. NCDOT Travel Model Development Process (NCDOT, 1997)



As before, NCDOT is continuing to expand GIS applications to travel demand modeling because GIS collection and analysis of environmental, land use as well as network data is more efficient, quicker, less costly and improves the communication and consensus process between NCDOT, regulatory agencies and the public. NCDOT has begun to develop specialized display tools for the results of the process so that community leaders can intuitively see and interpret tradeoffs between alternative transportation projects and environment. Recently, NCDOT professionals have adopted TransCAD as their standard modeling tools, because it offers more powerful modeling functions in a GIS-oriented environment.

In addition to the well defined urban transportation modeling procedures, engineers in the Transportation Planning Branch have made lots of efforts to improve the techniques for project-level traffic forecasts. These efforts yielded various analysis tools for traffic forecasting, such as Trend Analysis Spreadsheet (TAS), Balanced Turning Movement (BTURNS) and Screenline Spreadsheet (SS), etc. All of these tools can improve or simplify the travel demand forecasting procedures for isolated highway projects in small communities and rural areas, and thus benefit the on-going standard transportation planning procedures in NCDOT. The techniques discussed above refer to a recently completed research project, *Guidelines for NCDOT Project-Level Traffic Forecasting Procedures* [4]. Using two general methods: hand allocation method and TransCAD, the process documents a methodology and related procedures to accomplish project-level traffic forecasting for NCDOT. While the methodology is general and can guide an engineer through various steps including field visits, local discussions, data collection, analysis and documentation, the procedures provide explicit analytical tools appropriate for the forecasting task. This research recommended a synthesis of hand methods augmented by spreadsheet applications to quickly produce an accurate forecast for small projects. This idea provides a good approach to travel demand modeling in small areas without regional models.

In addition to the significant NCDOT efforts on travel demand modeling, NC State University and UNC-Chapel Hill completed several research projects to help create improved tools and sub-models for the travel demand modeling in North Carolina. The new Triangle Regional Model (TRM) Service Bureau is also making contributions through the development and maintenance of the triangle regional model. In addition, the TRM Service Bureau serves as a focal point for student and faculty research on projects of mutual interest.

According to modeling needs and expectations of NCDOT, Transportation Planning Branch personnel, an explicit interest has been identified to use more simplified travel demand models than TransCAD if the planning area is sufficiently small or other criteria are met. In this multi-year project, Phases I and II will focus on the smaller urban areas and larger urban areas in North Carolina, respectively. This report covers Phase I.

Practices at Other DOTs

There are three different approaches to travel forecasting that are of interest to planners in state DOTs: statewide, corridor and project [5].

Many states expended a significant amount of time and expense, especially in the late 1970s and early 1980s, to develop their own statewide travel demand models. Some succeeded in developing a working model, but most did not. Statewide forecasts most often require a full “four-step” simulation. These statewide travel demand models were developed with a modeling procedure borrowed almost wholly from the urban transportation planning (UTP) process. This is likely a function of the ready availability of urban modeling software and personnel trained to use it. The climax of developing statewide travel demand modeling took place in the late 1960s and soon waned in early 1970s, however, whether due to funding cuts or to frustration with the model results [5]. Only Connecticut [6, 7], Kentucky [8] and Michigan [9] have been continuously developing models from the earlier period. In addition to the three states mentioned above, significant efforts on the development of statewide travel demand models have been done in Florida [10, 11], Indiana [12], New Hampshire [13], New Jersey [14, 15], Ohio [16], Vermont [17], Wisconsin [18] and Wyoming [19, 20]. Statewide model development, however, is undergoing a renaissance currently. As a result of exponential increase in truck freight traffic new attention is being paid to freight shipments statewide and across US.

According to corridor travel forecasts, the total demand in the corridor by time of day is often considered constant or estimated externally. Thus, the forecast becomes an exercise in mode split and traffic assignment. Based on state DOTs’ practices, mode split models of some sophistication are often chosen to give precise estimates of modal shares.

Project level forecasting is often of shorter term with few unforeseen intervening factors. In many cases, project level forecasts can be made by time series methods. As noted above, the forecasts that most state DOTs make are not based on models, but are instead based on project level forecasts by applying the extrapolation of trends observed in historical data. For rural and small urban areas formalized trend analyses have been developed in Minnesota [21] and Wisconsin [22].

Problem

While the fundamental NCDOT problem is one of estimating future travel demand for different land use scenarios and transportation options, NCDOT must also estimate environmental impacts, costs and benefits of proposed transportation projects. Of particular concern are air quality impacts because of health issues, federal mandates for clean air, and linkages to federal transportation funds. Other community impacts are also important, especially those related to the environment, economic development, and the neighborhood access and identity. Therefore, throughout the analytical and outreach activities of the transportation planning process, NCDOT professionals must select appropriate methods and tools in terms of communities' specific size, needs, features and development. They must also evaluate mitigation options and balance conflicting objectives of diverse interest groups.

Development of urban areas guidelines and tools for best modeling practices within North Carolina will be critical for all NC urban areas, especially for those smaller ones. First of all, transportation planning activities in small and medium urban areas are becoming increasingly important since the popularity of these areas has risen over the past several decades. Currently, almost 40 percent of the United States population lives in communities with a population between 2,500 and 50,000 [23]. In North Carolina, most municipalities are small towns and cities, and around 36 percent of the population lives in "non-MPO" areas with population less than 50,000, according to 2000 census data [24]. This growth of residence selecting smaller communities has resulted in a greater awareness of transportation problems in these areas as the populations continue to increase.

Furthermore, while large metropolitan areas are usually able to dedicate significant effort to their transportation planning budgets, small communities often do not have or need such magnitude of resources and must search for streamlined ways to handle transportation issues. Or, they can rely on state DOTs' support as do meet small urban areas in North Carolina. Small towns and cities also may not have the need for the same scope of work as larger municipalities. Still, small urban areas rely on safe and efficient transportation systems to allow residents access to jobs and services, provide local opportunities for economic growth and development, and link to larger metropolitan areas. Yet, smaller urban areas often experience travel patterns and traffic problems that are much different and maybe less complicated than those in large metropolitan areas. Obviously, it is necessary to develop appropriate, smaller scale analysis tools and guidelines for travel demand modeling in terms of a smaller community's context for travel, economic development and other issues.

Most conventional modeling processes are designed for large urban areas and metropolitan areas. Thus, they are usually complicated and expensive. As noted above, by designating TransCAD as the accented modeling program, the NCDOT-TPB uses the traditional four-step process for urban travel forecasting. Model development requires intensive data input and work efforts. Although NCDOT professionals have developed special sub-models to simplify the modeling process for large study areas, more needs to be done regarding sub-models for trip generation and for other steps including trip distribution, mode choice, network assignment, air quality and benefit/cost analysis. In particular, in this report, simplified approaches will be developed and verified for small urban areas consistent with their needs.

Besides travel demand models, NCDOT has developed custom display tools for larger communities to support decision-making. The tools combine the development of map-based data with ArcView and the travel forecasting tool TransCAD. These specialized techniques help decision makers to visually evaluate transportation improvement scenarios and their effects on environmental and community resources. This research will examine more broadly applicable, standard GIS tools that can be applied to small urban areas without customization. They, too, will capture and communicate efficiently the results of the modeling process for local citizens and public officials to consider.

While the NCDOT Transportation Planning Branch has the ultimate responsibility to carry out the transportation planning process for communities, it relies on technical support (though not fundamental travel modeling) from other units in NCDOT, local agencies and consultants. The current heavy planning responsibilities and the expectation of increasing future responsibilities have forced NCDOT to consider other options to accomplish its mission. Indeed, NCDOT Transportation Planning has approached its own “cross roads” in transportation planning and modeling as “demands” for assistance exceed the resource and time “capacity” of its dedicated staff. It has several transportation modeling options:

1. Continue to accomplish virtually all transportation models, impact assessments, and plan evaluations in-house with high level tools that require large investments of resources even for small communities,
2. Develop and use in-house a variety of appropriate sub-models and tools that fit the size and transportation needs of communities,
3. Sub-contract model development and plan evaluation for some communities to outside agencies and consultants, and/or
4. Develop partnerships to accomplish modeling research, appropriate sub-model and tool development, and plan evaluation.

These options are not mutually exclusive, and they can be simultaneously implemented. As discussed above, NCDOT is currently following a combination of Options 1 and 2. Outreach to Triangle consultants and subsequently to the TRM Service Bureau represents a first step toward Option 3. This project emphasizes the synergism that can result from Option 4 and the collaboration of NCDOT, the TRM Service Bureau and the Universities. By integrating comprehensive resources which can contribute to the research goal, this kind of research partnership will be attempted in the research project. Furthermore, Option 4 offers the future prospect of attracting graduate student interns and research assistants to build the professional capacity for modeling and planning that North Carolina needs.

Research Scope and Objectives

The research has two phases. Phase I focuses on the smaller areas with population less than 10,000. Phase II focuses on larger communities in North Carolina. This interim report will address the research efforts conducted in Phase I.

The research project will build upon previously successful project relationships between NCDOT, NC State University, and the University of North Carolina-Chapel Hill. It also depends on the anticipated expertise offered by the TRM Service Bureau. Previously enumerated efforts have been completed in a variety of NCDOT in-house and sponsored research projects. In Phase I, the research work will build on previous efforts and extend them to cover models, sub-models, tools and guidelines for best practice for the smaller communities with population less than 10,000.

The project goal of Phase I is to improve and simplify the on-going conventional planning process while making it a more efficient and less time consuming process for smaller areas. Phase I relies on US census and North Carolina database, the methodology of context sensitive solution (CSS), trend line analysis, proven sketch-planning/quick response methods, and appropriate GIS tools that allow integration of multiple factors that affect travel. There are a variety planning tools in the “tool box”, and they will be applied to the variety of communities based on size and needs.

The objectives of the Phase I in the multi-year travel demand research are:

- To improve, yet simplify, the transportation modeling process for smaller urban areas (population less than 10,000) in North Carolina.
- To develop guidelines and tools for best modeling practices for smaller NC communities consistent with their needs and issues regarding transportation, economic development, the environment, and other considerations.
- To test the option of developing long term partnerships for research and transportation demand modeling using North Carolina expertise and data sets.

Chapter Summary

The major travel demand models developed and used by North Carolina Department of Transportation (NCDOT) are long range, regional travel demand models that apply the traditional four-step planning process. This research project addresses apparent resource constraints within NCDOT as staff members in the Transportation Planning Branch attempt to meet transportation modeling needs of NC urban regardless of size. The project goal (Phase I) is to improve and simplify the on-going conventional modeling process while making it a more efficient and less time consuming process for smaller areas. Phase I relies on US census and North Carolina databases, context sensitive solutions (CSS), trend line analysis, proven sketch-planning/quick response methods, and appropriate GIS tools that allow integration of multiple factors that affect community travel. There are many planning tools in the "tool box", and they will be applied to a sample of small communities based on size and needs.

Subsequently Chapter 2 of this report reviews the literature to determine the state of current practice for small urban areas travel demand modeling. Chapter 3 presents recommended guidelines in matrix format and in a decision tree. Chapter 4 develops special tools and sub-models for small urban areas and Chapter 5 states conclusions and recommendation resulting from the research and case study applications. A set of detailed appendices develop tools and sub-models, and illustrate the recommended guidelines for two small communities.

CHAPTER 2: LITERATURE REVIEW

Introduction

Most of the conventional travel forecasting modeling processes were designed for use in large urban and metropolitan areas, and less research efforts have been aimed at facilitating the modeling needs in the small urban areas. The characteristics of small urban areas require the modeling techniques be less data intense, less expensive, and less time consuming to implement when compared with traditional transportation modeling methods. Development and improvement of appropriately scaled travel forecasting tools for small urban areas have been a hot issue in recent years.

The NCDOT *Multi-Year Travel Model Research* has a flexible research schedule. It has two phases: the first phase (18 months) is for small urban areas and the second phase (18 months) is for larger urban areas. Therefore, this chapter firstly addresses the area definition and provides a standard which can be used to develop area categories in this research. The chapter also reviews the broad aspects and some principals of travel forecasting in small urban areas that have developed through efforts of USDOT. Included are modeling practices and efforts for small communities in North Carolina and other states.

Many software packages are available to aid in travel forecasting. They range from simple spreadsheets to complex modeling packages. A review of these programs is conducted to build a pool from which the appropriate tools can be selected for planning purposes in small urban areas in North Carolina.

Area Definition

Urban classifications are generally considered in the context of places with population of 5,000 or more [25]. However, the concept of a small community, also known as a rural community, cannot be narrowly defined. In practice, the USDOT defines rural in two ways: first, for highway functional classification and outdoor advertising regulations, rural is considered anything outside of an area with a population of 5,000; second, for planning purposes, rural is considered to be areas outside of metropolitan areas 50,000 or greater in population [26]. This definition leaves a lot of room for significant differences within these categories. Therefore, it is prudent to describe rural based upon what is seen across the country. For the purpose of this research, "small urban area" is to be a non-metropolitan community with population less than 50,000.

In Phase I of this research project, we will study areas with population less than 10,000. It is clear that they fall into the category of small urban areas.

Broad Aspects and Principals of Planning in Small Communities

Several books (Beatley, Brower and Brower 1988 [27]; Coates and Weiss 1976 [28]; Daniels 1995 [29]; EPA 1994 [30]; Hall and Porterfield 2001 [31]; Malizia 1981 [32]; Nelessen 1994 [33]; TRB 1977 [34]) have been published focusing on planning and design in small communities. Most of them acknowledged the limited financial and personnel resources in small communities, provided applicable step-by step planning guidelines, and developed comprehensive planning principles including economic, environmental, and social factors. For example, Nelessen (1994) advocates design by democracy and public involvement for small community planning. He developed a seven step planning and design process for creating three basic types of traditional small communities—hamlets, villages, and neighborhoods. He also outlined ten design principles—ranging from humanism and ecological responsibility to open space design and community focus—to help small community planning. The ten design principles Nelessen suggested for small community planning involve human scale, ecological responsibility, pedestrianism, open spaces, core, streetscapes, variation, mixed and multiple uses, design vocabulary, and maintenance. Nelessen introduced technologies that planners can use to help the public create their vision, including the Visual Preference Survey and Hands-on Model Building.

United States Environmental Protection Agency (USEPA) (1994) developed a guide for environment planning in small communities. This guide suggests that small communities can carry out environmental protection by considering the community as a whole including its resources, economy, public opinion, and all other needs. This guide for environmental planning follows the general steps of developing a comprehensive plan, including identifying the environmental issues, building a planning team, developing a shared vision, defining the community needs, figuring out appropriate planning technologies and strategies, setting priorities for planning action, and implementing the plan.

Daniels, Keller, and Lapping (1995), in their *Small Town Planning Handbook* provided useful solutions and coping advice to common problems in small communities, such as industrial decline or population growth. The authors focused on describing the practical tools that are sensitive to local character and the reality of limited financial and personnel resources. They suggested the integration of economic development, land use design, housing, transportation, and strategic planning. They also identified and listed the potential information and resources for the mini-plan in small communities.

In *Community by Design: New Urbanism for Suburbs and Small Communities*, Hall (2001) developed different suggestions for creating true neighborhoods within the context of the existing suburban landscape—in an illustrated, step-by-step, case-study format. He pointed out that for the development of a community, accumulation of buildings with interstate highway access is not sufficient. Community design also includes creating maximum livability, cohesiveness, and style. This book provided guidance to understand the differences between conventional suburban development and more walkable, human-scale neighborhoods.

Our review indicates that the general planning principles emphasize the integration of safety, mobility, environment, and community, and the consideration of a comprehensive view of the entire system within which transportation planning will occur.

Efforts by USDOT and FHWA

In 1978, the Transportation Research Board (TRB) published *NCHRP Report* 187, *Quick-Response Urban Travel Estimation Techniques and Transferable Parameters* [35]. It described transferable parameters, factors, and manual techniques for a simple planning analysis. That report and its default data were used widely in many transportation studies and became the best-known approach at that time for quick-response techniques which are suitable for smaller urban areas. It was then replaced by *NCHRP Report* 365, *Travel Estimation Techniques for Urban Planning* [36], completed in 1998. In addition to a thorough review of the four-step travel demand process with common extensions, *NCHRP Report* 365 provides new transferable parameters for use when area-specific data are not available or need to be checked for reasonableness. The material focuses primarily on the needs of smaller urban areas. The techniques and parameters are organized to be easy to use in many of the widely available travel demand forecasting programs (e.g. TransCAD Quick Response Method). However, this report did not address its application in extremely small urban areas. For example, although it contained a wide range of trip generation rates between small and large urban areas, no specific values are suggested for urban areas with population under 50,000.

In 1999, FHWA published the *Guidebook on Statewide Travel Forecasting* [37]. The Guidebook reviews the state-of-the-practice of statewide travel forecasting. Three different approaches (statewide level, corridor level and project level) to travel forecasting and associated data sources, software, GIS implementation and math concepts were addressed in detail. This effort focused on techniques that have been considered essential to good travel demand modeling especially for larger urban areas. The common data sources and simple analysis techniques discussed in the Guidebook can be borrowed by smaller urban areas.

Rural transportation planning examines travel and transportation issues and needs in non-metropolitan areas. Under the auspices of the FHWA, the USDOT provides rural area planners with several resources to analyze alternatives to meet projected future demands and to provide a safe and efficient transportation system that meets mobility without adversely impacting the environment. The FHWA topic of *Rural and Small Community Transportation Planning* offers a variety of technical resources, publications, training, educational programs, and links to internet sites [38]. One such publication is the *Transportation Toolbox for Rural Areas and Small Communities* [39], for which the USDOT and Department of Agriculture partnered in 1998 to provide assistance to "public and private stakeholders in planning, developing, and improving rural areas and small communities, especially through transportation and related projects." Though it is not exclusively focused on travel demand modeling or traffic forecasting, the "Transportation Toolbox" is a good resource for smaller municipalities.

In 2004, FHWA reissued *Planning for Transportation in Rural Areas* [40], a paper intended to be a resource for engineers, planners, stakeholders, public officials, and all other decision-makers associated with the transportation planning process. The report provides general guidance based on local circumstances and gives examples of case study profiles for rural planners to use as references for general planning, though not travel demand modeling.

The Travel Model Improvement Program (TMIP) [41], sponsored by the USDOT and FHWA, states as its mission to "support and empower planning agencies through leadership, innovation, and support of planning analysis improvements to provide better information to support transportation and planning decisions." It focuses on outreach and training to the travel modeling community, research on models and model quality assurance. The TMIP database contains a variety of efforts for travel demand modeling, sub-model development and data sources. Improved modeling will help all levels of government meet large transportation challenges with limited budgets. TMIP concepts and guidance can be certainly used in small urban areas. The TMIP contributions include reports such as *Calibrating & Testing A Gravity Model for Any Size Urban Area*, which includes transportation system planning techniques that are applicable to small urban areas [42]. The *Technical Report Small/Medium Size Urban Area Issues: Metropolitan Planning* [43], a project report funded by Texas Department of Transportation, used the modified Delphi process to establish a procedure for allocating projected growth at the zone level. The research showed that the Delphi process can provide good results in a short time frame, which provides the benefit of accelerating the overall planning process. Another report found through the TMIP clearinghouse is *Time-of-Day Modeling Procedures Report* [44], which outlines the necessity and methods by which planning organizations can incorporate specific travel behaviors by time of day into their travel demand model. Though this report may be most useful to larger metropolitan areas that experience effects of peak congestion during various time periods, it may also help smaller municipalities conform to the federal guidelines for analyzing air quality or off-peak-time travel choices.

Practice in North Carolina

NCDOT accomplished various projects to improve travel forecasts in small urban areas. In 1989, Marion Poole developed a hand allocation model [45]. This model is useful for small urban areas with populations less than 5,000 where new growth is anticipated and new thoroughfares are anticipated. The hand allocation model has been used in some small area studies and appears to produce estimates of future travel patterns in a fast, low cost, and easy to apply manner. However, many engineers and planners continue to use the full modeling capabilities of TransCAD and Tranplan for small towns.

In 2002, John Stone developed *Guidelines for NCDOT Project-Level Traffic Forecasting* [46]. The author concluded that "NCDOT uses a variety of quantitative and qualitative methods to perform project-level forecasts, and the selection of which method to use often depends on the analyst's preference and expertise rather than guidelines as accepted by NCDOT." Recommendations for forecasting procedures for non-urban areas included development of "standardized spreadsheet templates and methods that can be tempered by professional judgment for smaller isolated projects." A similar statement for travel demand models may claim that guidelines and tools for small areas need to be developed.

NCDOT has developed efficient in-house tools to simplify the overall travel demand modeling process in North Carolina. These sub-models focus on external trip estimation and trip generation. The current research will develop additional tools for small urban and rural areas. The developed sub-models are discussed as below.

Twenty years ago, David Modlin [47] created an empirical relationship for the structure of a through trip table. The principle methodology was a formidable achievement at that time. Based on Modlin's work, *NCHRP Report* 365 [36] published a set of well-known regression models to estimate through trips at external stations and the distribution of through trips between external stations. They are still the most widely used through trip estimation technique for small urban areas.

In 2003, John Stone developed a methodology to estimate trip generation by using property tax data [48]. This research found that if good property tax is available in geographic information system (GIS) format, it can replace expensive, time consuming and potentially error prone windshield surveys. Applications of this method to more communities will help validate its value.

NCDOT engineers and planners apply the internal data summary (IDS), which uses trip rates for different residential and employment types to estimate trip generation productions and attractions. IDS is separate from, but can be merged with, Tranplan (Urban Analysis Group, 1995) and TransCAD (Caliper, 2000). IDS relies on average, time invariant trip rates for North Carolina cities. The trip rates are the coefficients of the IDS model for trip productions and attractions. During travel model validation, the trip rates are changed as necessary to improve the comparison between estimated link volumes and actual ground counts. Although IDS can be applied to estimate trip generation, it uses three or four trip purposes which increase data collection and validation, thus may not be appropriate for small urban areas because the simplified models are desirable in small towns.

Practice in Other States

Travel forecasting in small urban areas is also becoming an important issue in some other states. DOT engineers and university researchers have conducted studies to develop new methodologies or simplify travel demand models to fit transportation planning needs in small urban areas.

The Kentucky Transportation Cabinet uses consultant resources to conduct Small Urban Area (SUA) Transportation Studies [49] to assist small urban areas. Studies include an analysis of existing and future traffic conditions with the goal of identifying needs for a transportation network efficiently moving people and goods as rapidly and safely as possible. Typical products from completed studies include operational improvement plans, travel demand models, and recommended highway improvements. Some completed SUA transportation study reports are available online from the Cabinet.

In Kansas, Russell and Landman developed a methodology for quick response community planning [50]. This research project formulated a GIS procedure for travel demand modeling for small cities or urban areas with populations less than 15,000. The major focus was to determine the level of detail of the network. By comparing a high-density-zoning structure with a low-density-zoning one, the research concluded that the travel demand model developed from the high-density level network provided better results as compared to the low-density network. However, in regard to the values of traffic volume assigned to the proposed bypass, the travel demand models for the two levels essentially performed the same. It was also determined that the GIS/TransCAD platform provides useful tools for data organization and analysis of results through graphical features. It was concluded that there is a need of updating technical resources for applying these modern methods of travel demand forecasting.

Sarasua and Clarke (et al) calibrated and validated the quick response forecasting parameters for rural cities in South Carolina [51]. It focused on developing transferable travel demand forecasting parameters having diverse populations and low incomes. The findings of the project allow planners throughout rural areas of South Carolina and similar states to make more reliable estimates of future traffic identified in long range plans. The calibrated parameters are also useful for cities with populations less than 50,000 in other states.

Trip generation is very data intensive, and one of the most time-consuming steps in developing a travel demand modeling. In Alabama, Anderson evaluated the performance of using a single internal trip purpose in small urban areas [52-56]. He compared the Quick-Response method (NCHRP 365) with single trip purpose techniques, and concluded that, for smaller urban community travel models, where different trip purposes are assumed to have similar trip lengths, both the Quick-Response and the single trip purpose techniques produced similar results for the total productions and attractions in a traffic analysis zone. His work showed that different trip purposes are not vital for trip distribution in small networks, and it substantiated the use of the simplified single trip purpose technique for trip generation.

The study of the through trip patterns is important in small areas because such areas have a comparatively larger amount of through traffic. Anderson studied the effects of nearby major cities and transportation facilities on the through trip split at the external stations in small urban areas. He developed a through trip rate methodology based on a combination of the community characteristics, facility type, and economic characteristics of surrounding communities. In addition, Horowitz and Patel [57] developed a through trip model by accounting for the effects of barriers to travel and geographic location relationships among external stations on the through trip distribution. These efforts will improve the travel demand modeling in small urban areas, because through trips are a significant part of the total trips in these areas. Such studies lay the ground work for an update of Modlin’s original Synth for synthetic external trip distribution.

Travel Forecasting Software

NCDOT planners and engineers develop long range, regional travel forecasts by applying the “traditional” four-step planning process. For the past decades or more, they have implemented the process with Tranplan [58]. Recently, they have adopted TransCAD [59], and they are converting their regional models from Tranplan to the new, more GIS-oriented environment that TransCAD offers.

Another approach for smaller scale projects is to use computer-aided “sketch” methods for traffic impact analysis. These packages such as TransCAD Quick Response and QRS II [60] can evaluate urban and small area travel forecasting problems. Given a network and zone characteristics, sketch methods can accomplish the traditional four-step travel forecasting process including trip generation, trip distribution, mode choice, and network assignment. They can also be simplified to accomplish project level traffic impact analysis. Most sketch methods have graphical network editing features and data import capabilities. They represent simplifications in data collection, analysis and time savings compared to traditional methods.

Site planning software packages like Traffix [61] and SITE [62] are another type of interactive computer program that systematizes short term traffic forecasting studies for local land developments. They can accommodate large and small projects, import turn movements from other studies, and forecast traffic impacts for new developments, etc. They are not as complicated as Tranplan, TransCAD, or sketch methods and do not compute the standard four-step process. Rather, site-planning programs rely on "known" trip distributions to "external" zones at the boundaries of its corridor or study area.

Besides the travel forecasting packages listed, the customized spreadsheet is a favored tool used by engineers and planners, because it is more flexible, user-oriented and efficient. When finical resources are limited for a planning project, especially in the extremely small communities, the spreadsheet is a good candidate to be used.

Chapter Summary

The practice for developing transportation plans varies across the U.S. Some states do not model communities with less than 50,000 populations as allowed by the USDOT. Relatively simple traffic forecasting procedures are used for project-level and corridor level traffic forecasts. The future traffic estimates are developed in a relatively short time ranging from days to weeks.

North Carolina, on the other hand, models communities with population as low as 5,000 or fewer people. The models reflect land use at the zone level and a transportation network of significant streets and highways. The models include the traditional four steps – trip generation, trip distribution, mode choice (if appropriate) and traffic assignment. TransCAD is the usual computer software used to develop the model over a relatively long period of time.

Various state and federal efforts have developed short cut procedures and recommendations for small area transportation planning. Notable among these is the Travel Model Improvement Program (TMIP) sponsored by the USDOT and FHWA. Its mission is to "support and empower planning agencies through leadership, innovation, and support of planning analysis improvements to provide better information to support transportation and planning decisions." The TMIP database contains a variety of efforts for travel demand modeling, sub-model development and data sources. Improved modeling will help all levels of government meet large transportation challenges with limited budgets. TMIP concepts and guidance can be certainly used in small urban areas. TMIP and other concepts provide the foundation for this research for North Carolina.

CHAPTER 3: TDM GUIDELINES FOR SMALL COMMUNITIES

Two systematic displays provide guidelines in travel demand modeling (TDM) for communities of various sizes. One display is a guideline matrix and the other is a decision tree. The two displays attempt to capture the various community needs and issues, sizes and other considerations, which determine the complexity and type of TDM to prepare for a community. For small isolated communities with relatively few transportation-related issues, a relatively simple context sensitive solutions (CSS) may suffice. For more issues and complexity in the network and land use, more complicated TDM approaches involving manual, spreadsheet or computer-based modeling are necessary. Besides appropriate TDM approaches, potential data sources, analysis tools, and zone structures are also recommended to transportation professionals.

The **TDM guideline matrix** discusses alternative travel demand model approaches for small communities from the perspectives of (Part I) Data, (Part II) Sub-models, and (Part III) Reasonableness Checks (Table 3-1). The TDM matrix uses five Population Categories for organization. Corresponding to each category, the TDM matrix provides possible data issues related to transportation planning. The TDM matrix has three parts described as below:

- TDM matrix Part I summarizes community characteristics, data and parameters, data sources, network complexity and zones, and TDM approaches.
- TDM matrix Part II presents sub-models for travel demand modeling, including land use, trip generation, trip distribution, mode choice, network assignment, and external trips.
- TDM matrix Part III introduces reasonableness checks in travel demand model approach, which summarizes various methods and techniques in the validation and calibration of land use model, trip generation, trip distribution, mode choice, and network assignment.

The last columns in the three parts of the TDM matrix refer transportation engineers and planners to the corresponding appendices in this report for detailed case study applications of different TDM analysis tools.

In the **decision tree**, categories for NC transportation study areas are defined based on population size (Figure 3-1). A total of five distinct categories of study areas are identified:

- Areas of less than 5,000 population,
- Areas of 5,000-10,000 population,
- Areas of 10,000-50,000 population,
- Areas of 50,000 - 1,000,000 population,
- Regional areas with population exceeding 1,000,000.

Planning tools vary in terms of their appropriateness for these areas. After categorization, different travel forecasting analysis tools (CSS approach, GIS approach, trend line travel forecasting, manual travel allocation, quick response using TransCAD, full development using TransCAD, etc.) are suggested to match with the demands of the relevant area.

Matrices for TDM Guidelines

<u>Category A: Small Urban and Rural Town Guidelines (< 5,000 population)</u>

Small communities face various development and growth situations. For example, a small community can be characterized as having little anticipated growth, being near a major highway corridor, or having little potential for economic development. Four appropriate TDM approaches are identified for this category of small communities, including context-sensitive solution (CSS) approach (Appendix A), GIS land supply approach (Appendix B), trend line travel forecasting approach (Appendix C), and manual travel allocation model approach (Appendix D).

The CSS approach is a nationwide movement with objectives rooted in safety, mobility, environment, and community, and an innovative planning approach that takes the whole picture of a transportation improvement into consideration. Since the CSS approach considers the total context of a transportation improvement, this approach demands a variety of data inputs, including demographic and spatial structure, current transportation/land use related factors, transportation features and issues, current planning process, economic development, environment and safety concerns, community values and issues, and so on. The data can be obtained from several sources that include U.S. Census Bureau, U.S. Geological Survey, Census Transportation Planning Package (CTPP), American Fact Finder, Google Earth, Federal Emergency Management Agency (FEMA), Traffic Engineering Accident Analysis System (TEAAS) from NCDOT, and NC Demographics Office. See Appendix A for a detailed discussion and guidelines for the CSS approach. To further demonstrate this approach, Pilot Mountain, NC is selected as a case study in Appendix A. Narrative and graphic analysis tools are introduced in this case study.

The GIS land supply approach aims at documenting land use inventory, quantifying developable lands, and calculating housing capacity. Appendix B introduces the land supply analysis process for the test-case of Pilot Mountain, NC. Main public geographic sources that are useful in the GIS approach include USGS Seamless Data Distribution System, US Census Bureau, American Fact Finder, National Atlas, and Federal Emergency Management Agency. To identify and calculate suitable land area for further development, the following variables such as census block, raw land area, developed land area, public land area, land area with a slope of 15% or more, underwater land area, inaccessible land area, flood zone area, and wetlands are needed. The final results of the GIS land supply approach can adjust and calibrate the results of trend line forecasting analysis by using housing capacity as a constraint.

The trend line travel forecasting approach can be used to predict travel on the critical arterial in small urban and rural towns. Data inputs include historical traffic data and related demographic and economic information. Compared to the CSS approach and the GIS approach, the trend line travel forecasting approach has less extensive data demands. After data collection, various trend line models can be applied, including growth factor, linear regression, moving average, and Box-Jenkins methods, etc. Traffic counts and professional judgment are possible methods of validation and calibration for the forecasting results from trend line models. Appendix C presents a detailed description about the process of trend line travel forecasting. The demonstration case for this approach is Pilot Mountain, NC.

The travel allocation model approach provides the analyst with "hands-on" knowledge of existing and future travel patterns and flows. This approach is able to produce estimates of existing and future travel patterns for a small urban area in a fast and easy-to-apply manner. In general, this approach is suitable for small communities with up to 5000 population, 10 internal TAZs, and 12 external stations. The demonstration case for this approach is Pilot Mountain, NC (Appendix F).

<u>Category B: Small Urban and Rural Town Guidelines (5,000-10,000 population)</u>

Communities in this category might have new or anticipated facilities nearby, significant potential for economic and population growth, and community network of streets and thoroughfares. As such, a simple trend line analysis or CSS approach is not sufficient for the additional scenario testing that may be required.

For this category of urban communities, a traditional three-step travel forecast model is an accepted and efficient method. Based on the basic three-step model, we developed a recommended best practice approach which we refer to as the North Carolina Quick Response Method. Besides trip generation, trip distribution, and trip assignment, this approach is considered best practice because it provides guidelines for model validation and reasonableness checking throughout the development of the model.

Model validation and reasonableness checking begin with the zonal land use data and transportation supply data, and follow through trip generation, trip distribution, and finally with trip assignment. Model validation and reasonableness checking is an iterative process and each step may need to be revisited several times before a final robust model has been developed. Zonal data sources and checks are recommended with GIS as the foundation for managing and reviewing this data. Highway network data is also managed and validated using GIS tools. The trip generation model relies on a standard regression model with a North Carolina default trip rate table. Results are checked against standard performance measures and modifications are made to the rate table as needed to achieve reasonable results. Trip distribution relies on the gravity model and a recommended approach for estimating initial friction factors is provided. As with trip generation, results are checked against standard performance measures and modifications to the friction factors are made to achieve reasonable results. The recommended trip assignment algorithm for this sized community is a stochastic assignment. Initial parameters are suggested and numerous measures for evaluating the trip assignment are provided. The external station analysis relies heavily on the analyst knowledge of the community and available land use data. Reasonableness checks for the external station analysis are also covered.

Appendix E explains in more detail the strategy for developing each model component from determining the study area and network to defining traffic analysis zones. Data sources are discussed in Appendix B and E.

In Appendix E, the North Carolina Quick Response Method is applied to a case study for the small community of Wendell, North Carolina.

Decision Tree for TDM Guidelines

The decision tree (Figure 3-1) for the TDM guidelines matrix elements (Table 3-1) attempts to formalize a systematic procedure for selecting TDM tools that are appropriately scaled for the complexity of the study area. For simplicity of illustration, the decision tree recognizes population as the first consideration because the larger the study area, the more likely it will require a more complicated tool or set of sub-models and databases. If the study area is larger than 10,000 population, recommended procedures will be covered in Phase II of this project. This report examines procedures for the small communities.

After population, primary study area issues are the deciding factors that guide the selection of the appropriate tool or tools. For example, for a community with less than 5,000 population that has significant environmental issues, a CSS/GIS case study may suffice to define the context sensitive issues, their geographic areas, and alternative transportation and other solutions. CSS/GIS may also be adequate to evaluate economic development issues, as well as environmental issues. However, if the community anticipates significant traffic growth as a result of the development, a trend line forecast of traffic on major roadways will complement the CSS/GIS analysis.

It is important to note that CSS and GIS analysis is often a good starting point for any community's consideration of transportation problems. Issues will be defined and geographically located in easy to read maps. Also, the decision tree must be used with common sense in that all the appropriate issues and tools should be considered and used according to the needs of the study area. Just because the decision tree "says" that only CSS analysis is needed does not mean to exclude a trend line traffic forecast that may be helpful. Most communities have multiple issues involving transportation, and multiple issues will likely require multiple tools.

Summary

This chapter presented and discussed guidelines for developing travel demand models for small communities with population less than 10,000 people. Depending on the population and a variety of issues and other community characteristics, a decision tree and a matrix suggest helpful guides to choosing data sources, developing the network and zones, and choosing sub-models. To support the guidelines, Appendix A through E describe methods including CSS case studies, land supply analysis, trend line traffic forecasting, manual travel allocation, and TransCAD NC Quick Response.

Table 3-1. TDM Guideline Matrix

Part I: Data for Travel Demand Models
(Categories A and B are documented in this report. Categories C and D are in a separate report.)

Category	Size	Issues	Community Characteristics	Data, Rates, Parameters	Data Sources	Network Complexity / Zones	Tools ( ) ~ Appendix
A (Phase I)	< 5,000	Economic Development, New Roads, Truck Traffic; Community & Environmental Impacts, Hazard Mgt.	Income Level; Rural, Fringe; Vacation, Retirement; Industry; Attractions; Regional Center; CBD Vitality; Growth Rate; Nearby Interstate or Other TIP Projects Outside Study Area; Size & Type of TIP Improvements; RPO; No MPO	Default NC	Census CD 2000 Short Form Blocks; USGS GIS; CTPP; Amer. Fact Finder; Google Earth; FEMA, aerial photos, NC Demographics office	Major Roads; Census Blocks or User Defined TAZs Coarse zones, no more than 5 – 10 and the major roadway system.	CSS (A); GIS Land Supply (B); Trend Line (C); Manual Travel Allocation (D)
B (Phase I)	5,000 – 10,000	Cat A +; New Bypass	Cat A	Default NC Rates, NCHRP	CTPP, census, GIS, Data Sources Table	Cat A + Streets, Census Tracts or User Defined TAZs Number of zones should range between 10 and 15. Roadway system should reflect major roadway system plus important connector routes.	TransCAD NC QR (E); CSS; GIS
C (Phase II)	10,000 – 50,000	Cat B +; CBD Revitalization;	Cat A + Suburbs; RPO; No MPO	Default NC Rates, NCHRP	CTPP, NCHRP 365, Data Sources Table	Cat B + bus transit Guidelines on network selection and zone compatibility.	TransCAD NC QR & Ph. II report; CSS; GIS
D (Phase II)	> 50,000	Cat B+; Air Quality + Federal Planning Requirements	Cat C; MPO	Local Data, Surveys	CTPP, Surveys, Data Sources in Table B-1 and E-1	Cat C See guidelines	TransCAD, Ph. II report; CSS; GIS
E	Regional	Cat B+; CBD & Area Development; Interstate Loops; Rail Transit	Cat D for All Communities in Region; Homogeneous Region; Multi-Nucleated Region; MPO	Local Data, Surveys	Surveys, Data Sources Table	Cat C + rail transit See guidelines	TransCAD; CSS; GIS

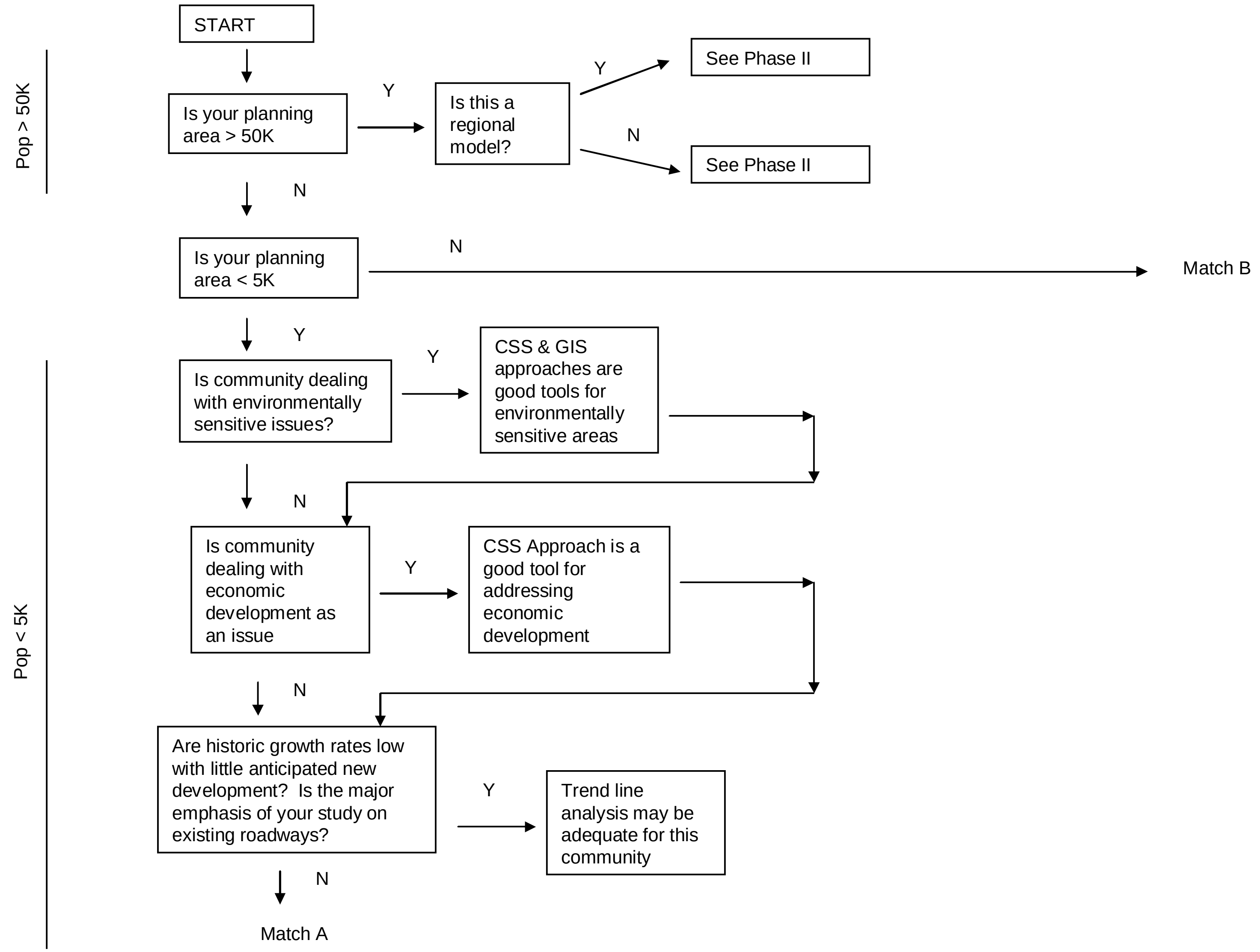
Part II: Sub-models for Travel Demand Modeling
(Categories A and B are documented in this report. Categories C and D are in a separate report.)

Category	**Size**	**Land Use** ( ) ~ Appendix	**Trip Generation** ( ) ~ Appendix	**Trip Distribution** ( ) ~ Appendix	**Mode Choice** ( ) ~ Appendix	**Network Assignment** ( ) ~ Appendix	**External Trips** ( ) ~ Appendix	**Tools** ( ) ~ Appendix
A (Phase I)	< 5,000	Comprehensive Plan; Land Supply Analysis (optional); (B)	US or NC Average Rates; If low income use US rates; If high income use NC rates; NCHRP 187 or NCHRP 365; CTPP Rates; Local Survey Rates; Consider 1 or 2 Trip Purposes; Consider NHB2; (H)	Distribute manually (spreadsheet) based on total employment; (D, F)	TCRP B3 for Demand Responsive Transit; (J)	Trend Line & Growth Factor Ratio Forecast for Single Routes; Manual Travel Allocation for Simple Nets; (D)	Manual Travel Allocation; Synth; (G) Consider all external trips are through trips	CSS (A); GIS Land Supply (B); Trend Line (C); Manual Travel Alloc. (D,F); NuSynth (G); NC rates (H); Distr (I); Transit (J); Assig (E)
B (Phase I)	5,000 – 10,000	Cat A; Land Supply Analysis; (B)	Cat A; If fringe, use Metro Rates; (H)	Mean travel time from skims and zone-zone travel times; (E)	Cat A, GIS Analysis; (J)	QR Stochastic Method Daily; (E)	Synth with local adjustments (E) or NuSynth (G)	Cat A tools or NC QR (E)
C (Phase II)	10,000 – 50,000	Cat A + Land Supply Analysis; Land Use Scenarios	Cat A or Local Rates from Survey; Use 3 Trip Purposes	Cat B	Cat B and MNL Models for Fixed-route Transit	QR Stochastic Method Daily	Cat B	Cat B
D (Phase II)	> 50,000	Cat C; Concentric Zone Model; Sector Model	Local Rates from Survey		Cat C or MNL Model with TransCAD	Equilibrium Method Hourly	External Station Survey	Ph. II report
E	Regional	Cat C + Land Use Models; Metro Plng; Multiple Nuclei Model & Polycentric Model	Cat D		TransCAD and MNL Model	Equilibrium Method; Hourly	External Station Survey; Separate AON Assignment for Commercial Vehicles	

Part III: Reasonableness Checks in Travel Demand Model Approach
(Categories A and B are documented in this report. Categories C and D are in a separate report.)

<table>
<tr><th>Category</th><th>Size</th><th>Land Use Data and Transportation Networks</th><th>Trip Generation</th><th>Trip Distribution</th><th>Mode Choice</th><th>Network Assignment</th><th>Validation Targets</th><th>Tools
( ) ~ Appendix</th></tr>
<tr><td>A
(Phase I)</td><td>< 5,000</td><td>Compare Land Use Results for Manual Travel Allocation to Land Supply Analysis</td><td>NCHRP 365 rates;</td><td>Professional judgment</td><td>Professional judgment</td><td>Traffic counts/ Professional judgment</td><td>NC Guidelines</td><td>(B)
(C)
(D)</td></tr>
<tr><td>B
(Phase I)</td><td>5,000 – 10,000</td><td rowspan="4">Overall visual inspection with a focus on speed ranges, capacity ranges, and facility types. Check for network connectivity, missing nodes, missing links, one-way links going the wrong direction. Use minimum path techniques to check for coding errors. Traffic counts should be reviewed using measures such as volume per lane and historic growth rate trends. Land use data checks should be performed at the zonal, regional, and aggregate levels. Basic checks should review all land use variables, population/household ratio, population/employment ratio, and plots of densities and density changes for future year data.</td><td rowspan="2">Ratio of unbalanced Ps and As should be between 0.9 and 1.0. Review percent of trips by purpose and compare to typical ranges outline in Table E-3.</td><td rowspan="2">Plot average trip length distribution for each trip purpose and review based on your knowledge of the area. Review average trip length by trip purpose.</td><td rowspan="2">Compare mode splits to those reported for your county or community from the US Census long form data or CTPP data.</td><td rowspan="2">Traffic count data that has been validated and VMT data if available. For recommended data summary checks refer to Validation Targets column for recommended references.</td><td rowspan="2">Calibration and Adjustment of System Planning Models, FHWA Dec. 1990 Model Validation and Reasonableness Checking Manual, TMIP June 2001.</td><td></td></tr>
<tr><td>C
(Phase II)</td><td>10,000 – 50,000</td><td></td></tr>
<tr><td>D
(Phase II)</td><td>> 50,000</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>E</td><td>Regional</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Figure 3-1. Decision Tree (0 < Population < 10K)



Pop < 5K

A

Do you anticipate future growth that may stress the existing transportation system?

Y → A manual allocation procedure is recommended for this community

N ↓

No clear issues have emerged for your community. Please review the benefits, requirements, and uses for recommended tools for this size community and select the one you believe best suits your needs.

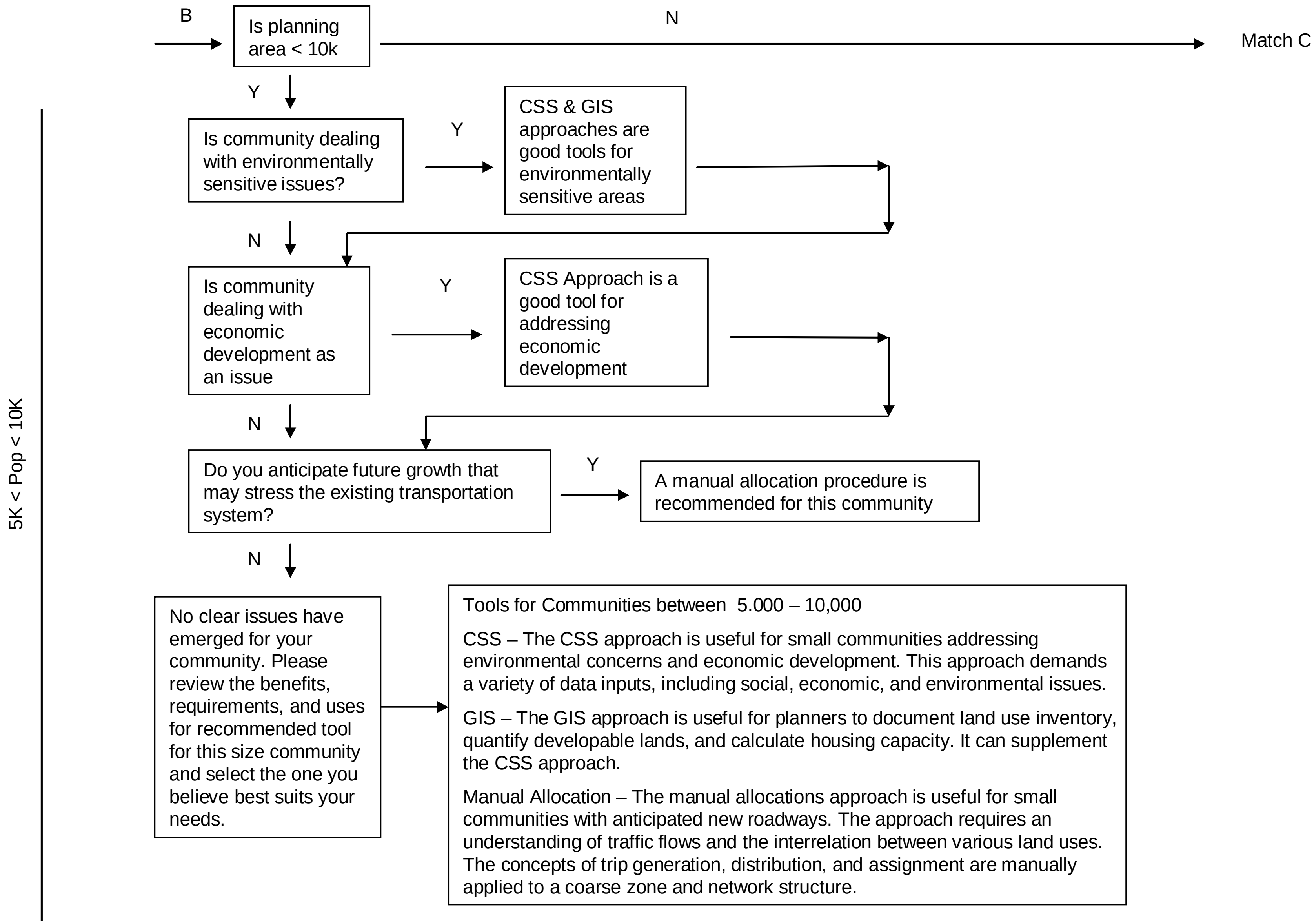
Tools for Communities less than 5,000

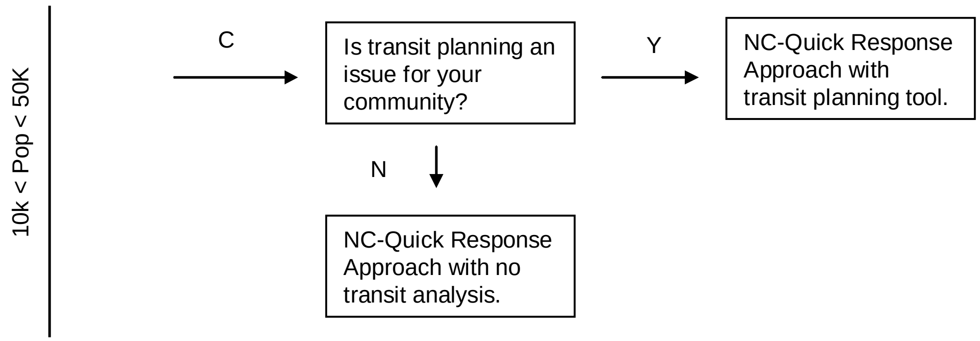
CSS – The CSS approach is a useful analysis tool for small communities addressing environmental concerns and economic development. This approach demands a variety of data inputs, including social, economic, and environmental issues. The output will also support trend line, manual allocation, etc.

GIS – The GIS approach is useful for planners to document land use inventory, quantify developable lands, and calculate housing capacity. It can supplement the CSS approach. The output will also support trend line, manual allocation, etc.

Trend Line – The trend line analysis is useful for small communities where new location roadways are not anticipated. The benefits of this approach are that it requires very little data and is easy to apply.

Manual Allocation – The manual allocations approach is useful for small communities with anticipated new roadways. The approach requires an understanding of traffic flows and the interrelation between various land uses. The concepts of trip generation, distribution, and assignment are manually applied to a coarse zone and network structure.


B
Is planning area < 10k
N
Match C
Y
Is community dealing with environmentally sensitive issues?
Y
CSS & GIS approaches are good tools for environmentally sensitive areas
N
Is community dealing with economic development as an issue
Y
CSS Approach is a good tool for addressing economic development
N
Do you anticipate future growth that may stress the existing transportation system?
Y
A manual allocation procedure is recommended for this community
N
No clear issues have emerged for your community. Please review the benefits, requirements, and uses for recommended tool for this size community and select the one you believe best suits your needs.
Tools for Communities between 5.000 – 10,000
CSS – The CSS approach is useful for small communities addressing environmental concerns and economic development. This approach demands a variety of data inputs, including social, economic, and environmental issues.
GIS – The GIS approach is useful for planners to document land use inventory, quantify developable lands, and calculate housing capacity. It can supplement the CSS approach.
Manual Allocation – The manual allocations approach is useful for small communities with anticipated new roadways. The approach requires an understanding of traffic flows and the interrelation between various land uses. The concepts of trip generation, distribution, and assignment are manually applied to a coarse zone and network structure.
5K < Pop < 10K


10k < Pop < 50K
C
Is transit planning an issue for your community?
Y
NC-Quick Response Approach with transit planning tool.
N
NC-Quick Response Approach with no transit analysis.

CHAPTER 4: SPECIAL TOOLS AND SUB-MODELS

Introduction

Special tools and sub-models simplify travel demand modeling in small communities. In addition to the traditional four-step TDM methodology, this research promotes other systematic approaches such as case studies of context sensitive solutions (CSS) that focus on qualitative as well as quantitative descriptions of issues and solutions, GIS evaluation and visualization, and land use assessment of development potential. For the context of community issues that suggests a traditional TDM approach, the research developed and tested special applications for external trip estimation, trip generation, trip distribution, mode choice, and network assignment.

As indicated by the TDM guidelines for small communities in Chapter 3, special tools and sub-models match different communities in terms of size, issues, needs, or other characteristics. The TDM guidelines matrix and decision tree offer easy ways to describe and choose options for data, tools, sub-models and reasonableness checks. Sub-models play important roles in travel demand modeling process for different sized study areas. Sub-models do the critical analysis in the travel demand modeling process – external trip distribution, trip generation. While the traditional travel demand modeling approaches address large cities and require intensive data, special tools and sub-models are less data intensive, less expensive, and less time consuming.

To accomplish their varied and demanding transportation planning mission, NCDOT professionals have developed modeling tools and process to facilitate the modeling process for larger urban areas. This research identifies and verifies alternative and simplified approaches for smaller urban areas.

Trend Line Travel Forecasting

Trend line analysis is a common approach to forecast traffic at project or corridor levels. Because it is less data intensive and easy-to-use, it is a good tool for the travel demand modeling for critical arterials in the small urban areas. Standard statistical procedures may be used such as those documented and tested by Stone [4, 63]. Appendix C provides a detailed example applied to US 52 in Pilot Mountain, NC.

The major findings and recommendations from the case study include:

- Trend line travel forecasting yields reliable results for major arterials in a small town with errors within 10%.
- The trend line approach works better than the manual allocation model (Appendix D) for critical arterials in small communities.
- The trend line approach is an efficient tool to forecast traffic for critical arterials in a small community, because it is less data intensive and easy to use.
- A constraint on the trend line forecasting approach may be the availability of historical traffic counts for the roadways of interest. However, data is usually available for major roadways.

<u>Manual Travel Allocation</u>

The manual Travel Allocation model is a good tool to forecast travel demand in small communities with population less than 5,000. The context of the community includes anticipated growth and new transportation facilities. Working with the travel allocation model can help the analyst develop “hands-on” knowledge of existing and future travel patterns and flows. This knowledge leads to better decisions with respect to facility location decisions, design requirements, and estimates of user benefits for proposed improvements. A spreadsheet facilitates the manual travel allocation model for a small urban area with population less than 5,000 and with up to 10 internal zones and 12 external stations. Appendix D uses Pilot Mountain to demonstrate the method. Appendix F provides details on the development of the manual travel allocation model.

Synthetic Through Trip Estimation

NCDOT planners use the original SYNTH program to forecast through trips in the travel demand modeling process. However, the SYNTH program has some obvious deficiencies. For example, it was developed by old survey data in the 1970's and should be updated. In addition, the original SYNTH program should be used only in small communities with few external economic and geographic factors that may affect the distribution of external trips.

Appendix E outlines a modification to the SYNTH approach that requires the analyst to estimate the percent of through trips for the entire region based on a relationship between the total ADT at the external stations and the land use within the planning area. Once regional through trips are estimated they can be allocated to each external station based on the characteristics of the roadway. To create O-D trip pairs between the external stations, the regression equations used by SYNTH are a suitable approach with manual modifications if appropriate.

In the Phase II of this research project a new through trip model will be developed for both small and medium urban areas (population < 200,000). Therefore, this model will cover Phase I and Phase II. The new through trip model will be developed with new external station survey data while accounting for economic and geographic factors. Appendix G presents the background, literature review, data collection and methodology of the proposed new SYNTH model.

Trip Generation Rates

The literature review for this research (Chapter 2) concluded that small urban areas need planning techniques that are less data intense, less expensive, and less time consuming to implement when compared to traditional transportation modeling methods. The widely used National Cooperative Highway Research Program (NCHRP) Report 365 provides a set of U.S. average trip rates for cities with population greater than 50,000. The usefulness of the NCHRP 365 quick response techniques and parameters is questionable, however, for small communities with population between 5,000 and 50,000.

Appendix H explores the feasibility of using trip generation rates for North Carolina versus national average rates for small communities. The appendix also evaluates the travel behavior of small fringe towns, the effects of different trip rates on traffic operation, and simplifies the trip generation procedure by using fewer trip purposes.

The major findings and recommendations from the Appendix H study of trip generation rate are:

- The households in small fringe towns behave very much like those in the urban center. Therefore, the planners in fringe towns can defensibly use data tools and national averages based on the nearby urban center.
- Different trip rates (e.g. national default, NC average and local rates) produce very similar VMT and VHT, so they do not significantly impact the traffic volumes and operations for small communities.
- Although local generation rates are always desired for travel demand modeling, it is feasible to use borrowed national default rates or adjusted NC average values for small urban areas where local rates are not available.

- For small urban areas, using two trip purposes (HBW and NHBW) or a single trip purpose based solely on the zonal aggregated number of households and employment is a legitimate method to simplify the trip generation process.

Trip Distribution

The usual approach for trip distribution is the gravity model and iterative procedures to calibrate friction factors. This research assumes that small communities do not need such a calibrated trip distribution model when a TDM approach is used. Rather, it is assumed that trips distribute according the travel time, a common assumption. The approach uses mean travel time from the zone to zone minimum path matrix to estimate initial frication factors (Appendix I).

Based on case study analysis of Wendell (Appendix E) and Fuquay-Varina, NC (to be documented for Phase II), it appears that the simplified trip distribution sub-model works well for a small urban area with a population between 5,000 and 10,000 and a medium urban area with population less than 30,000.

Mode Choice

The mode choice sub-model (Appendix J) derives from Transit Cooperative Research Program (TCRP) project B-3 "Demand Forecasting for Rural Passenger Transportation". Using socioeconomic data available from the census, a spreadsheet available from the McTrans Center estimates the latent demand for demand responsive rural transportation. Such transit is the usual mode for small communities and the surrounding area. Phase II of this research considers the demand for fixed-route transit in larger communities.

Network Assignment

The research evaluated the following network assignment algorithms for travel demand modeling in small urban areas: All-or-nothing (AON), capacity restraint, equilibrium assignment, and stochastic assignment (Appendix E).

While an all-or-nothing (AON) assignment is the most common algorithm applied for small urban areas, extreme caution should be used when selecting this technique because it can over estimate the traffic demand for new, higher speed facilities in the future year analysis. Another drawback to an AON assignment is that there are no parameter adjustments during the assignment process. In order to change the results of an assignment for better calibration the user would need to adjust link attributes which can be difficult to defend and which may bias the base year model and make it less predictive to changes in future travel demand.

The recommended TDM approach for small community networks is a stochastic assignment with a small diversion parameter, or an iterative capacity restraint using a 40-30-20-10 division of the trip table. To achieve better calibration using the stochastic assignment, values of Θ can be adjusted to change the proportions of trips that are allocated to the equally efficient paths. In the iterative capacity restraint, the portions of the trip table can be adjusted to achieve better link assignments. It is critical to note that the assignment technique and associated parameters applied for base year calibration must also be applied for future year analysis.

Special guidelines of performance and reasonableness checks for trip assignment in small communities are addressed in the sub-model.

Summary

Given the guidelines to select TDM modeling approaches based on community size and needs, simplified sub-models can be applied effectively and efficiently for communities between 5,000 and 10,000 population. Sub-models are critical components of the travel demand model. While the traditional travel demand modeling approaches were designed for large cities and are data intensive, simplified sub-models require less data, rely on national averages rather than survey data, and require less effort to apply. They include: trend line traffic forecasting methods, manual travel allocation, synthetic through trip estimation, average trip rates, reduced trip purposed, trip distribution based on mean travel time, mode choice for special populations, and stochastic or all-or-nothing traffic assignment. Regardless of the model simplicity or complexity, careful model performance and reasonableness checks are necessary as the TDM develops. Appendices give detailed examples.

CHAPTER 5: FINDINGS AND RECOMMENDATIONS

Small Communities with Less Than 5,000 Population

For small communities several planning approaches are appropriate depending on the context of community, environment and transportation needs. These are discussed below.

Context Sensitive Solutions (CSS) Approach

The key advantage of the CSS approach is its comprehensiveness. It helps ensure that transportation projects are safe and efficient and they are also in harmony with the natural, social, economic, and cultural environment. However, these advantages of the CSS approach require quantitative and qualitative analysis data. In addition, the CSS approach requires an early and continuous commitment to public involvement, flexibility in exploring new solutions, and openness to new ideas.

Pilot Mountain, NC, demonstrates the CSS approach. This case study involves three critical issues:

- Integration of land use and transportation planning;
- Addressing environmental and community concerns;
- Supporting the use of alternative transportation modes, e.g. walking and biking.

The proposed CSS approach balances safety, mobility, community, and environmental goals when planning for transportation improvement projects. The proposed model has an interesting feature that predicts walking trips based on distance to destinations. This feature can be used to assess the demand for walking in other small communities.

Overall, the CSS approach can assist small urban and rural communities in improving the planning process through the use of narrative or graphic analysis to identify both local and regional problems, and the involvement of a broad range of stakeholders.

GIS Approach

For small communities, the GIS approach helps to develop a land use inventory that is easy to visualize. It quantifies developable land and with added model features can calculate housing capacity, or conversely excess capacity for development. With assumptions about housing density in future years, the GIS approach can generate housing capacity in various traffic analysis zone. Results of land capacity analysis can also be useful in the validation of trend line forecasting analysis. The GIS approach combines land use, environmental, and transportation planning. For example, the locations of suitable sites for new developments provide insights on future travel demand. In addition, identifying the locations of wetlands can be useful for preserving them. The GIS approach obviously links very well with the CSS approach. The Pilot Mountain case demonstrates the approach.

Trend Line Analysis Approach

For most small towns and rural areas, highway networks are usually simple and traffic volumes are not as heavy as those in the metropolitan areas. Therefore, major highways are of greatest interest in small towns and rural areas. In these cases, corridor or project level forecasts can be made by extrapolating current trends. The trend line analysis is especially appropriate for rural areas without a regional travel demand model, since the trend line travel forecasting is easy to use and the required dataset is not too intensive.

The Pilot Mountain case demonstrates the trend line forecasting approach. The case study indicates that the trend line analysis leads to reasonable forecasting results for a critical arterial in Pilot Mountain with minor errors (within 10%) compared to ground counts. It also seems that the trend line model may work better than the manual allocation model for critical arterials in small communities. In general, the trend line forecasting method can only be applied on critical arterials or corridors in a small urban area where good historical traffic data is available, since the efforts of collecting traffic data only happen in those places.

Manual Travel Allocation Approach

Manual travel allocation models are useful for small urban areas meeting the following criteria:

- Population < 5,000
- Anticipated growth within the planning area
- Anticipated new transportation facilities

The development of a travel allocation model can provide the analyst build an appreciation for existing and future travel patterns and flows. This knowledge leads to better decisions with respect to location decisions, design requirements, and the evaluation of user benefits for proposed improvements.

By employing the manual travel allocation model, transportation planners are able to manually accomplish trip generation and trip distribution. The traffic assignment procedure can be handled by either manual allocation or a computer-based traffic assignment process depending on the complexity of the highway network in the planning area. Because the manual travel allocation model can produce estimates of future travel patterns in a fast, low cost, and easy to apply manner, the benefits should be increased product output and reduced costs. Secondary benefits should be staff development leading to a greater understanding of the concepts of transportation planning and transportation modeling.

A spreadsheet developed during this research project implements the manual travel allocation model. It is designed for any small urban area with up to 10 internal zones, 12 external stations and population less than 5,000. It facilitates travel forecasting in small communities.

Small Communities of 5,000 -10, 000 Population

Communities with population from 5,000 to 10,000 typically require computer-based travel demand models, at least in North Carolina. However, a quick response method (QRM) with model parameters determined by state or national averages will likely suffice. Among the short cuts in a quick response method are the following approaches to avoid costly surveys: national or state average trip generation rates, synthetic external trip distribution, mean travel time for distribution, and all-or-nothing or stochastic trip assignment.

TransCAD QRM Approach

§ Trip Generation

The benefits of applying the TransCAD QRM approach are clearly the ease of use and application. The weakness of this approach is that in the existing format it can be applied to internal trips only and requires the user to apply a different approach to IE/EI trips or assume that all external trips are through trips.

Due to its greater applicability and user control it is recommended that the cross-classification approach to trip generation be applied with North Carolina average rates for areas between 5,000 and 10,000 population. In Phase II of this project, this approach will also be tested on small MPO models and a TransCAD tool will be developed to facilitate its application.

§ External Station Analysis

The NCDOT SYNTH program is an effective procedure for estimating through trips for communities that fall within the urban area population range of 4,000 to 50,000, under which the original model was specified. However, even when applied for a community falling within this range, caution should be applied to the through trip percentages estimated as they may not reflect the character of the community being studied, especially so since SYNTH is based on 1970's data.

Another approach outlined in the Wendell Case Study (Appendix E) requires that the analyst estimate the percent of through trips for the entire region based on a relationship between the total ADT at the external stations and the land use within the planning area. Once regional through trips are estimated they can be allocated to each external station based on the characteristics of the roadway. To create O-D trip pairs between the external stations, the regression equations applied in SYNTH are a suitable approach with manual modifications if appropriate.

§ Trip Distribution

The mean travel time from the zone to zone minimum path matrix shows promise as a robust approach to estimating initial friction factors for a small urban area with a population between 5,000 and 10,000. The approach assumes that trip distribute according the travel time, a common simplification. The approach uses mean travel times from the zone to zone minimum path matrix to estimate initial frication factors (Appendix I).

§ Mode Choice

Mode choice is an optional sub-model for small communities. Almost no small community has a fixed-route system because transit demand is so low compared to automobile travel. However, many communities have demand responsive dial-a-ride transit for transportation disadvantaged groups. The TCRP B-3 approach outlines in Appendix J may be used to estimate the latent demand or actual demand for demand responsive transportation. Phase II of this research considers the demand for fixed-route transit in larger communities.

§ Traffic Assignment

The all-or-nothing assignment algorithm does not allow the user to adjust assignment parameters to achieve assignment results that better reflect traffic count measurements, assuming that parameters for all previous sub-models have been adjusted. Instead the user must modify link attributes directly in order to change a link assignment. There is an inherent risk in making link level adjustments as the adjustments may be masking a system relationship problem or error that may bias the future year forecast.

An equilibrium assignment is not recommended for a 24-hour trip table because a daily capacity is not a true measure of capacity. A better approach for an equilibrium assignment is to use hourly trip tables or peak period trip tables with an hourly capacity. This will result in a more theoretically appropriate application of the volume-delay function. However, for a community with a population between 5,000 and 10,000 the use of an hourly trip table can be burdensome to the analyst unless automated procedures are developed for the assignment step.

The stochastic assignment is fairly straight forward to apply and comes closer to replicating "real world" path finding where several optimum paths may exist between a given origin and a given destination. The value of Θ can be adjusted to reflect a more conservative assignment where fewer optimum paths are allowed versus an assignment where many optimum paths are utilized.

For the reasons outlined above it is recommended that a stochastic assignment be used for a community with a population between 5,000 and 10,000. The value of Θ should initially be set to five which will favor paths most like the original minimum path. This value can be adjusted as needed to improve link level assignments once all other model parameters have been tested.

Further Research

At this point in the research engineers and planner should give the TDM guidelines for small communities a "test drive" and add to the library of applications presented in the appendices of this report. As more experience is gained with the guidelines, they should be revised as necessary. Of particular interest will be the impacts of the simplified and quick response methods on community acceptance of transportation plan recommendations, on travel forecast accuracy, and on transportation planner productivity.

Products and Implementation and Technology Transfer Plan – Phase 1

<u>Primary Products</u>

Guidelines for best practice for travel demand modeling in small communities. Summary travel demand model guidelines for small communities are presented by an extensive matrix and a multi-level decision tree. They can help transportation planners and engineers apply appropriate methods, data sources and sub-models to simplify their efforts. The authors also believe that the guidelines will help make models compatible with community and environmental issues, as well as transportation needs.

Small community models, sub-models, and tools. There are many planning tools in the "toolbox" that can be applied to the variety of communities based on size and needs. The tools include trend line, travel forecasting spreadsheets, manual travel allocation spreadsheets, a new model for synthetic through trip estimation, special calibrated and validated trip generation rates for small communities in isolation or near larger cities, trip distribution model simplifications, mode choice models for low density rural areas, and implementations for network assignment. All models are described and demonstrated with a case study.

Executive Summary. The Executive Summary presents the guidelines for best practice, decision tree, and suggestions for model use and data sources.

Case Studies. The guidelines, models and tools are demonstrated by case study applications. Complete data. Spreadsheets and TransCAD input files are available.

Training Sessions. Two training sessions demonstrated the use of the guidelines and the manual allocation method.

Technical Documentation. A technical report presents the background for the research, literature review, and justification for using the various guidelines, tools, and methods.

<u>Secondary Products</u>

Input Data and Default. Baseline values, project data and parameters are given for the case studies.

Recommendations. Suggestions for implementing the guidelines for small community travel demand modeling at NCDOT and for future research are presented.

Implementation and Technology Transfer Plan

The implementation and technology transfer of the products of this research have already begun.

During the first phase of the implementation, the NCSU-UNC project team held two workshops for NCDOT personnel who will use the guidelines and methods. During the first workshop the team discussed the guidelines, tools and methods. During the second workshop the team presented the manual allocation spreadsheet and discussed other methods. Additional workshops outside the scope of this project may be necessary for other personnel and for complete demonstration of all the tools and small community cases. For example, the NCDOT Transportation Planning Branch has a tradition of in-house training sessions for which the results of this research can be applied.

NCDOT should distribute the final technical report for Phase 1 guidelines and examples for small community travel demand models to project engineers and planners in North Carolina and other states.

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APPENDIX A: CSS APPROACH – PILOT MOUNTAIN

Discussion and Guidelines

Context Sensitive Solutions (CSS) is a nationwide movement with objectives rooted in safety, mobility, environment, community, and an innovative planning approach that takes the whole picture of a transportation improvement into consideration. CSS considers a comprehensive view of the total context within which transportation planning takes place and transportation projects are implemented. FHWA promotes CSS as “thinking beyond the pavement” and defines it as:

> *A collaborative, interdisciplinary approach that involves all stakeholders to develop a transportation facility that fits its physical setting and preserves scenic, aesthetic, historic, and environmental resources, while maintaining safety and mobility.*
> Source: http://www.contextsensitivesolutions.org/content/reading/css-definition

The recommended CSS approach in small communities is based upon:
1) A CSS narrative and graphic scenario for the base year including demographic and spatial structure, current transportation/land use related factors, features and issues, transportation planning process, economic development, environmental and safety concerns, and community values and issues;
2) Anticipated growth of the planning area reflecting current zonal traffic trends determined by a travel allocation model; and
3) Estimated land capacity for future development and redevelopment in each planning zone as indicated by GIS land supply analysis.

A comprehensive view of these three categories provides a sound basis for the CSS approach to specific transportation projects. The approach requires considering the impacts of those specific transportation improvements on growth trends, environment, economy, safety, and community needs. After collecting, describing, and visualizing the transportation planning context, CSS improves the planning process by:
1) More detailed impact analysis for transportation improvements (e.g., simple vision models that consider alternative modes) including specific topics such as land use/transportation integration, alternative transportation modes, and environmental and community concerns.
2) Greater public involvement through the planning process. The use of Internet and relevant information technologies ensures an open, early, easy, and continuous communication with all members in the community.

To illustrate the CSS approach and how it can improve the planning process, this appendix uses a case study of Pilot Mountain, NC. The case study contains the following topics:

Section I: Background

Collect background information and create narrative and graphic scenarios for the community based on demographics, economic growth, spatial structure, regional corridors, the history of local transportation plans, and the current planning process.

Section II: Context Sensitive Design

Based on the collected information, assess the impacts of specific transportation improvements on growth trends, the environment, local economy, traffic safety, and community needs. Three main planning topics are focused on in this case study, including land use/transportation integration, environmental and community concerns, and alternative transportation modes.

Section III: Summary

Pilot Mountain Case Study

Section I: Background

Settled on the eastern edge of Surry County, North Carolina, Pilot Mountain is a small town of 1,274 named after its distinctive landmark above. Traditionally a textiles and manufacturing area, all major employers have left Pilot Mountain in the wake of NAFTA. Many residents now commute to neighboring towns and near-by Winton-Salem for work. Population growth has been extremely slow, as many residents have left the county to move to Winston-Salem and Greensboro. NCDOT plans to extend I-77 along US 52, and significant impacts will occur. Winston-Salem is just twenty-four miles south along this route, and future development of this corridor will bolster economic growth for Pilot Mountain and the surrounding areas.

- Demographics

In 1963, Pilot Mountain had a population of 1,310. Over forty years later, the town currently has an estimated 1,274 residents. This decrease in population can be largely attributed to stagnant economic growth and the demise of the textiles industry in the region. Most residents live along two main arteries through the town: NC 268 (Key Street) and Main Street, which run north to south and east to west, respectively. The majority of non-white people live close to downtown. Fifty-five percent of the population is female, and forty-five percent is male.

The 2000 census reports the median resident age is forty and median household income is $33,529. The median house value was $103,800. The population is fairly homogenous with whites making up 87.5

percent, blacks 9.3 percent, and Latinos 1.2 percent. The remaining 3.1 percent are Native American or mixed race. Figure A-1 gives year 2000 population density in Pilot Mountain.

Education levels in Pilot Mountain are moderate. While 75 percent of residents have graduated from high school, only 17.8 percent have gone to college and 6.9 percent have a graduate degree or higher. The unemployment rate is 4.5 percent.

- Economic Growth

Pilot Mountain and the surrounding areas have traditionally been supported by textile and manufacturing industries. Three local textile firms (hosiery, knitted fabric, dye and finishing) once comprised the largest industries. The area's failure to diversify its industries resulted in economic hardship for the past ten years since NAFTA passed. Armtex and Intex were the last two major employers to close their Pilot Mountain facilities in 1997 and 2004, respectively. So far, manufacturing jobs have largely been replaced with lower-end customer service jobs. Replacing lost jobs remains the number one priority for the region. Figure A-2 shows the employment distribution by industry in Surry County.

The town's economic future will likely rely on heritage, recreation, tourism, and proximity to Winston-Salem. Near-by Mount Airy is known for being the inspiration behind the town of Mayberry on "The Andy Griffith Show". Pilot Mountain State Park draws thousands of annual visitors. Surry County is a wine-growing region. Pilot Mountain's close proximity to Winston-Salem also makes the town a good candidate to become a "bedroom community" for the city. This will of course depend on the economic growth and development of Winston-Salem.

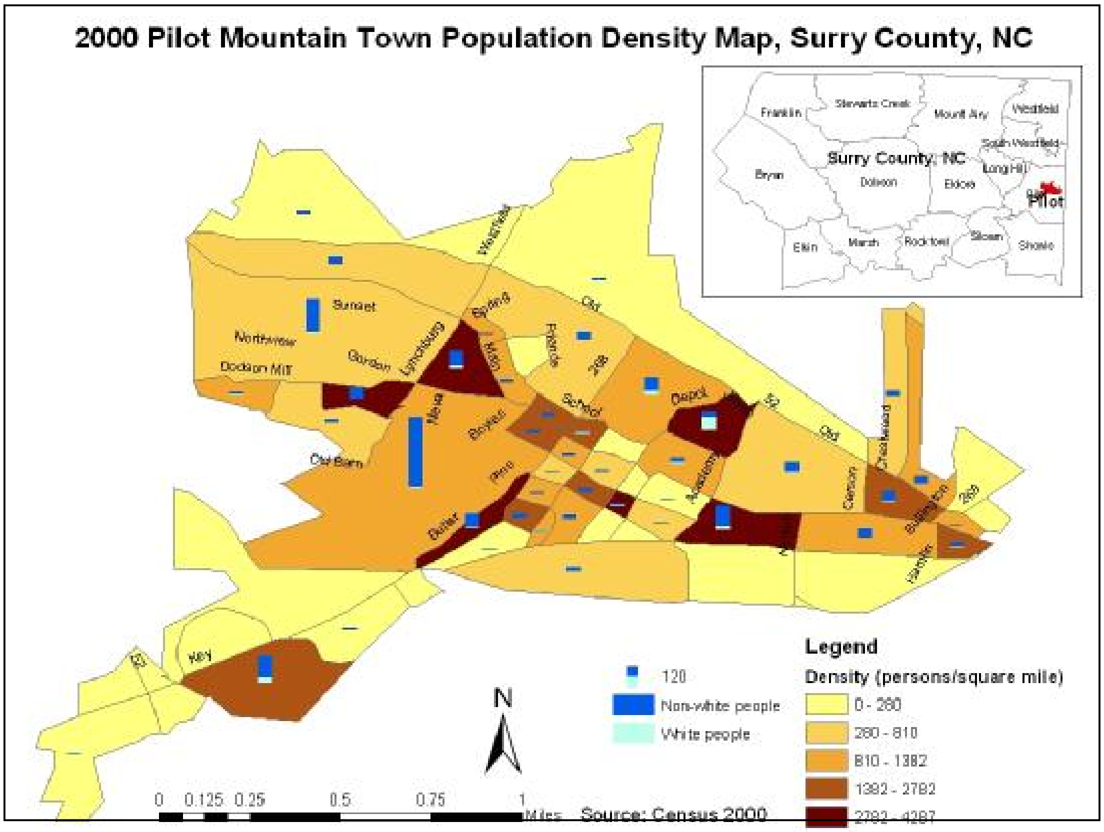
- Spatial Structure

Pilot Mountain is situated approximately 24 miles north of Winston-Salem, with a driving time of 30 minutes. The town is 130 miles from Raleigh and 101 miles from Charlotte. The town's elevation is 1,152 feet and has a land area of 1.7 miles. (Figure A-3 shows the regional location and main corridors in the town.) Like many small towns, the developed land in Pilot Mountain and the fringe area are mostly residential. Most of the commercial activity is located within the CBD along the western segment of US 52 and segments of Main Street. Moderate to heavy industry is outside the town limits.

US 52 is the main highway that serves Pilot Mountain (Figure A-4). This highway provides access to Winston-Salem to the south and Mount Airy to the north. It is currently four lanes wide, and there are plans to widen it to five and six lanes in some areas. The highway has mostly through-traffic with minimal local Pilot Mountain traffic.

NC 268 (Key Street) is the main arterial through the town, and intersects US 52 about three quarters of a mile southwest of the CBD. NC 268 is showing some deficiencies and much of the town's development is happening along this route. Two other major roads, Carson Road and Main Street, run parallel through the town's center and merge with US 52 on the northwest end of Pilot Mountain. Downtown Main Street is a major route and, therefore, serves mixed traffic. I-77 is approximately a 25-minute drive away, and I-40 is a 30-minute drive. The Norfolk/Southern Railroad serves the town.

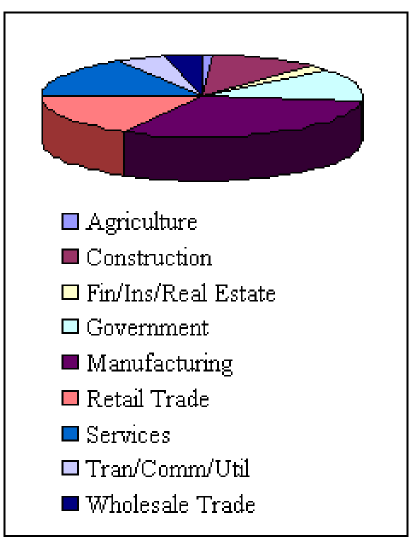
Figure A-1. 2000 Pilot Mountain Town Population Density Map



Source: 2000 Census CD, American Fact Finder

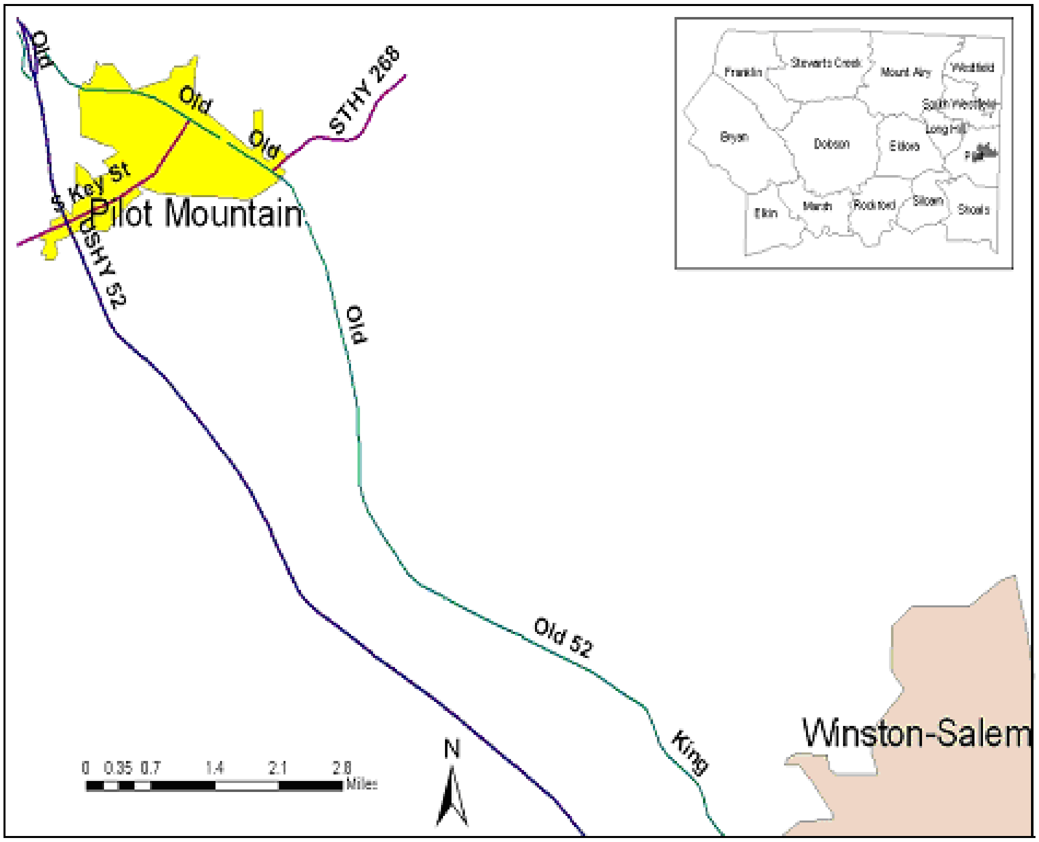
(Key demographic data for small communities can be obtained through American Factfinder (http://factfinder.census.gov/home/saff/main.html?_lang=en)

Figure A-2. Surry County Employment by Industry, 2000



Source: Census Bureau Economic Programs

Figure A-3. Regional Location and Corridors of Pilot Mountain



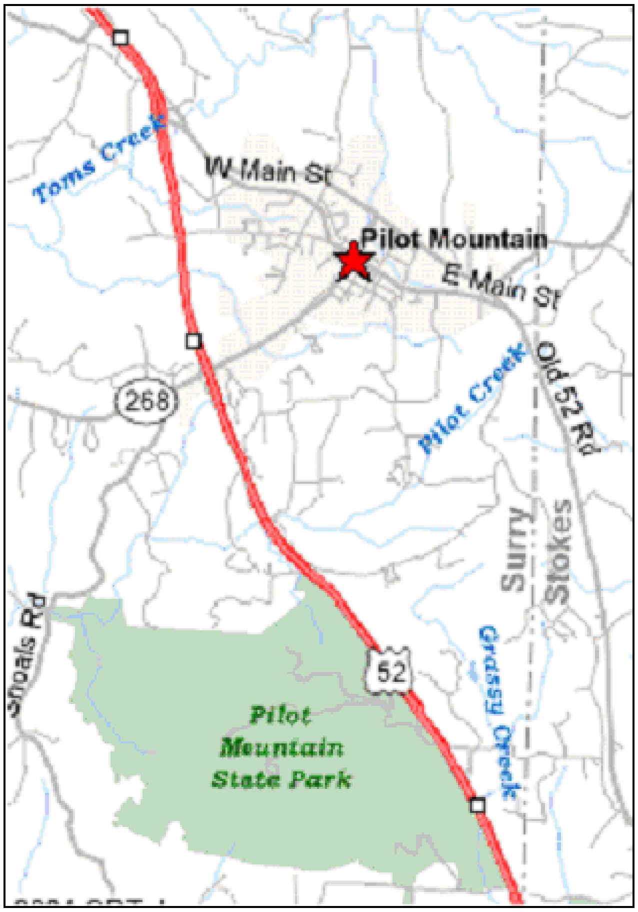
(Key spatial data for small communities can be obtained through ESRI http://www.esri.com/)

- Regional Corridors

US 52 connects Pilot Mountain to Winston-Salem (Figure A-4). The highway skirts the eastern portion of Pilot Mountain State Park and continues along the western edge of the town. The current four-lane highway is constructed near the mountain and expansion could potentially be an environmental threat to the area. The area surrounding the State Park is most prone to development, and environmental groups have been working to prevent impacts on the natural areas. The Park Service has already put restrictions on cellular towers in the park area

A proposed expansion of I-74 will likely enhance economic opportunities in Surry County by attracting industries. I-74 will run northwest to Winston-Salem partially along a new road and partially along existing US 311. It will then bypass Winston-Salem on a proposed beltway and head north on a “Future 74 Corridor” toward Mount Airy. The proposal locates I-74 along US 52 past Pilot Mountain and then northwest along I-77 into Virginia. NCDOT recommends that the four-lane section be widened to six lanes by 2020 (*Pilot Mountain Thoroughfare Plan*, 1998). In 1998 this route carried approximately 20,000 vehicles per day (vpd), and it will carry 48,000-61,500 vpd by the design year. Expansion of roads through the State Park area could be met with challenges from environmental interest groups.

Figure A-4. US Highway 52



- History of Local Transportation Plans

The 1998 *Thoroughfare Plan Study of Pilot Mountain* (NCDOT) made a series of transportation planning recommendations for the area. The study was as an update to the 1983 *Pilot Mountain Thoroughfare Plan*. In addition to the 1983 plan, two earlier plans were adopted for the town in 1963 and in 1971. The purpose of the most recent study was to examine present and future transportation needs of the area through 2020. Three principal measures were established to estimate the benefits derived from each proposed transportation improvement: road user costs savings; the potential for increased economic development; and the positive and negative environmental impacts. The two major proposals are related to alleviating traffic along NC 268 (Key Street), which serves as the main arterial through the town. Much of the following information comes from this report.

The first proposal is the widening of NC 268 (Key Street) to a five-lane road with curb and gutter. Local officials feel that improving the traffic capacity of NC 268 would attract new businesses along that route. As the Thoroughfare Plan reported:

> *Transportation Improvement Program (TIP) project R-3605 proposes to widen NC 268 to a five-lane section from Shoals Road (SR 2048) to the existing four-lane section. TIP project R-3423 is planned to upgrade NC 268 and provide turn lanes from Elkin, NC east to Shoals Road in Pilot Mountain. Due to the high volume of projected traffic along NC*

268, it is recommended to widen to three lanes from the western planning area boundary to Shoals Road (projected traffic volumes of 8,400- 10,500 vpd) and from Denny Street to Main Street (projected traffic volumes of 13,000 vpd). In addition, NC 268 is recommended to be widened to five lanes from Shoals Road to Denny Street, where the projected traffic ranges from 16,000 – 29,600 vpd. (p.11)

The second plan is for a NC 268 east-west bypass to circle the south side of the town to connect NC 268 (Key Street) and NC 268 (East) leaving the Pilot Mountain area. This by-pass would be a two-lane thoroughfare. This proposal was previously made in the 1983 report and has been included in the Transportation Improvement Program (TIP) since that time. Since the 1998 report was issued, commercial development along NC 268 has blocked the proposed connection points for the by-pass. If and when the project is approved, these connection points will need to be altered. Funding has not yet been earmarked for either of these projects.

The 1998 Thoroughfare Plan also reported on population, land use and the economy as factors in determining future travel patterns.

Population: A survey of housing and employment information was conducted to determine the 1995 socio-economic data required for travel analysis. The planning area population was determined by applying an occupancy factor to the actual number of dwelling units (see page 35 and Figure 9 of the Thoroughfare Report).

Land Use: The planning area consists of four types of land use: residential, commercial, industrial and public. Commercial development dominates the downtown area and the NC 268 corridor. The rest of town is mostly residential and industrial. Outlying areas are primarily residential with some industrial and commercial development.

Economy: Employment was used as an indicator for economic activity. Employment is projected to increase 30 percent between 1995 and 2020 (2,214 to 3,213 jobs).

- Current Planning Process

The Northwest Piedmont Rural Planning Organization (NWPRPO) is the transportation planning organization for Surry County. North Carolina's Rural Planning Organizations (RPOs) grew out of the 1998 Federal Transportation Equity Act for the 21st Century, which encouraged local officials of small towns and rural areas and the public to participate in the transportation planning process. In 1997-1998, the North Carolina General Assembly mandated that the state Board of Transportation, Transportation Secretary and Department of Transportation establish RPOs as a counterpart to the existing Metropolitan Planning Organizations (MPOs).

In July 2000, the General Assembly charged the RPOs with four primary duties:

- Develop long-range local and regional multi-modal transportation plans in cooperation with the area MPO and the N.C. Department of Transportation.
- Provide a forum for public participation in the rural transportation planning process.
- Develop and prioritize suggestions for transportation projects to be included in the state Transportation Improvement Program (TIP).
- Provide transportation-related information to local governments and other interested organizations and persons.

Building relationships with local residents and officials has been identified as a vital component to planning in rural communities. Residents typically prefer to deal with people they know, and some expect to have had a large impact upon civic projects. NWPRPO has developed a scoring system to prioritize projects, improve objectivity and mitigate biases. They have found that this system improves the facilitation of public engagement. The project proposal steps are outlined as follows:

Step 1: NWPRPO holds a public meeting in each county for elected officials, staff and community to give input/vision for future development.
Step 2: Projects are then prioritized based on that input, and the final vote goes to local elected officials.
Step 3: The approved list of priorities goes to the RPO committee, which uses a scoring system to rank the projects.
Step 4: The list is then submitted to the Statewide Transportation Improvement Program (TIP) - the document that lists all major construction projects to be undertaken by the DOT for the next several years.

In terms of travel forecasting, NWPRPO still primarily relies on the NCDOT or a third party for the data. Traffic analysis zones organized by census blocks are not available in rural areas such as Pilot Mountain. GIS is frequently used to look at traffic patterns, average daily traffic and projections. County and local maps provide detailed spatial data and NCDOT maps give traffic data. New traffic counts usually supplement historical traffic data.

Section II: Context Sensitive Design

A CSS case study like this one for Pilot Mountain should include three main planning topics: land use/transportation integration, environmental and community concerns, and alternative transportation modes.

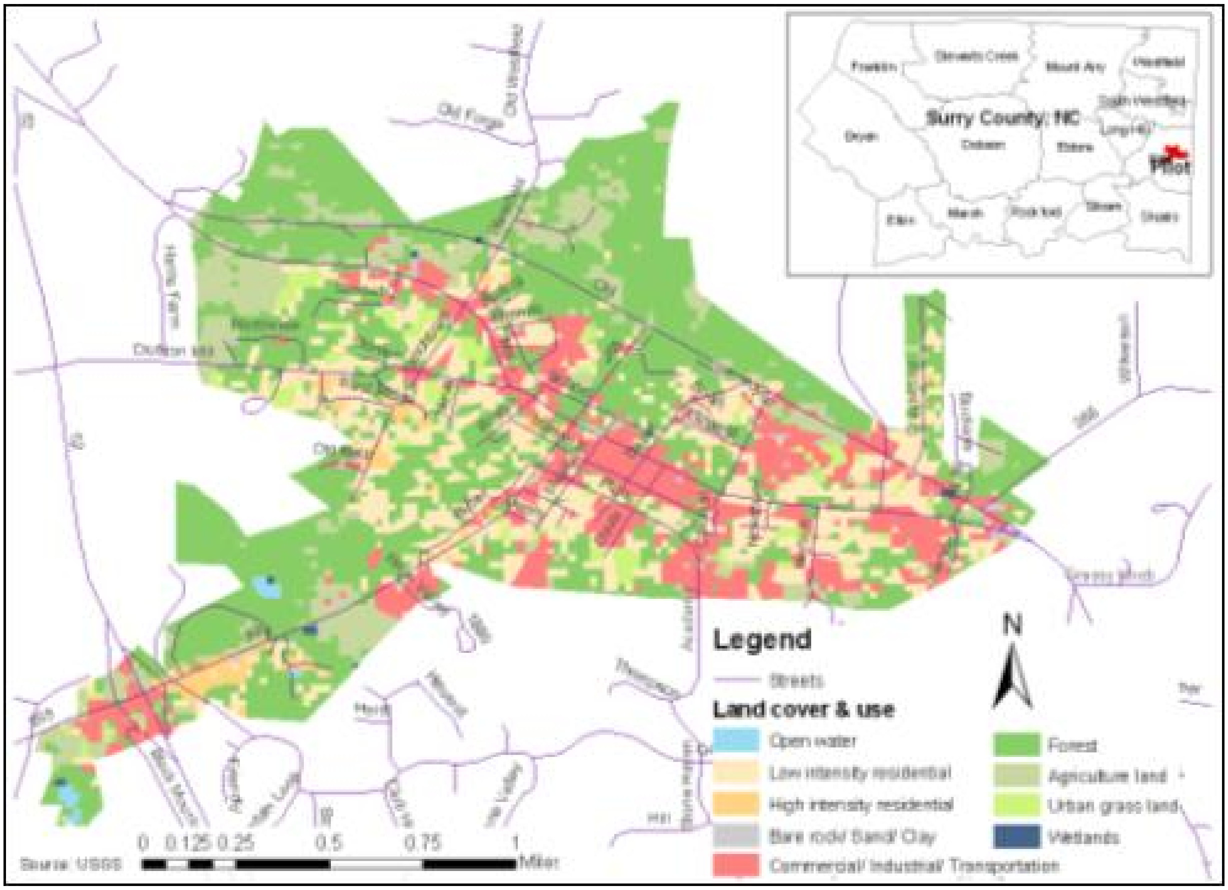
- Land use/transportation integration

In Pilot Mountain, the total area is 1,103 acres of which 413 acres are developed. Developed residential land use covers about 245 acres, and industrial/commercial and transportation land use account for 168 acres.

Figure A-5 shows that most undeveloped land includes forests and farms that are scattered around the edge of Pilot Mountain Township. Commercial developments are mainly confined to the Main Street corridor. Residential land use is primarily concentrated on the periphery of commercial developments. The highway junction of NC 268 and US 52 make a small commercial area in addition to the downtown business district along Main Street. Corridors along and intersections of major routes often create opportunities for development. The east side of the town is more developed than the others. This is understandable given that the eastside of the town is closer to the regional center – Winston-Salem and people on the east side of the town are able to access Winston-Salem without going through the downtown. Following this rationale, the south part of the town will have better locations for new developments due to US 52 improvements which will shorten the trip from Pilot Mountain to Winston-Salem.

The applied GIS Approach (Appendix B) not only can provide a detailed land use inventory including the amount of different land uses in each census block, but it can also quantify and locate the suitable land area for new land development (Figure A-6). The results of land supply analysis show that most developable land is located on the northern and the western side of the town. However, those locations are not the ideal areas for new development given their relatively low accessibility to Winston-Salem. Since

Figure A-5. Pilot Mountain Township Land Coverage Map, Surry County, NC



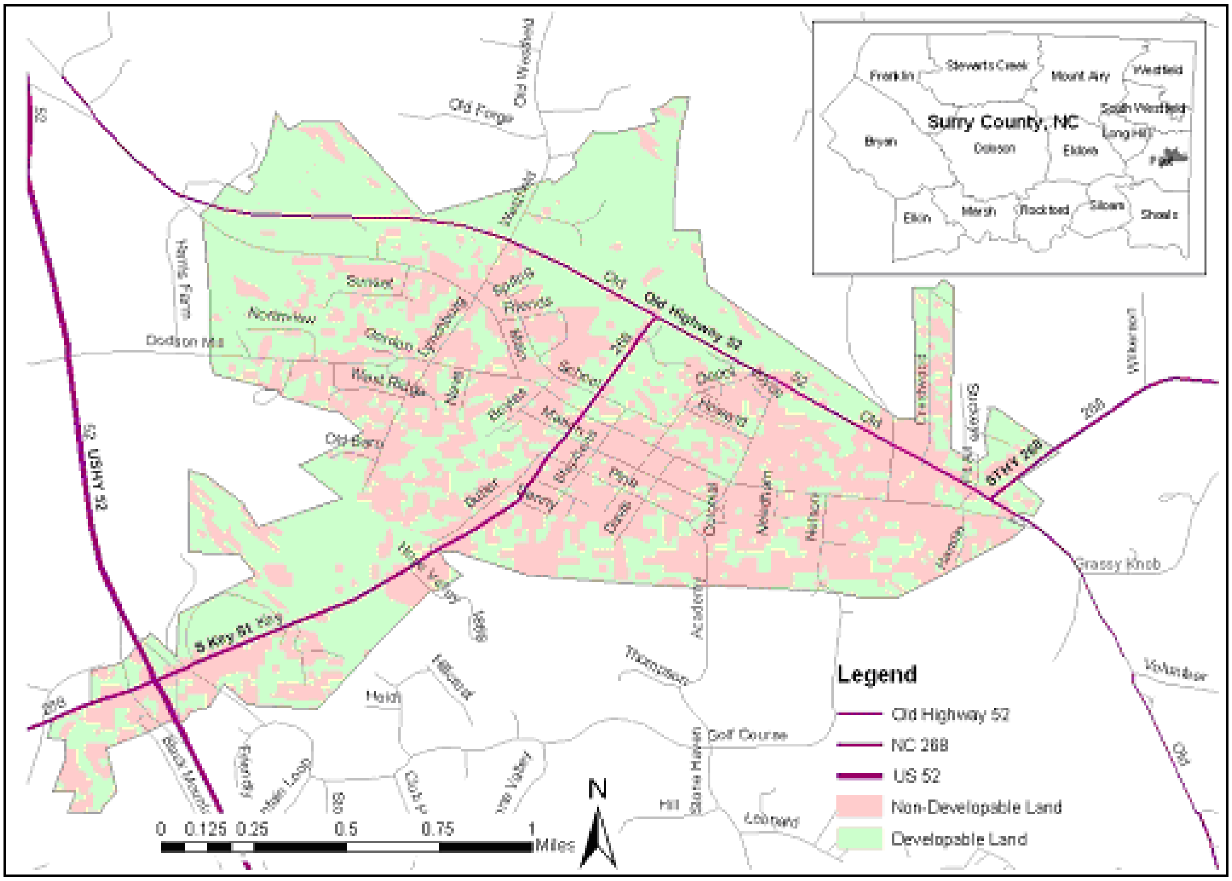
the prevailing land development policy in North Carolina has practically no limits on growth (no urban growth boundaries), the southern side of the town is more likely to be the future growth area, and new development will likely cross the current township boundary.

- Environmental and Community Concerns

The primary environmental concerns are wetlands on the north side of the Pilot Mountain area. The 1998 Thoroughfare Plan reported that the recommended improvements would cause minimal impact to this area. The mapping was an approximation of the wetlands location based on aerial photography rather than field data. Further investigation will be required before moving forward on designs. Further mapping from the North Carolina Department of Environment, Health, and Natural Resources showed that no threatened or endangered species are within the planning area. Mapping and GIS analysis indicate that that no historic structures or archeological sites are located within the planning area. Further investigation is needed.

A common community concern is transportation safety. Crash data can be obtained from state records maintained by the Department of Motor Vehicles (DMV). Figure A-7 shows the locations of high accident rate intersections in Pilot Mountain. Intersections on NC 268 (Key Street) have the highest accident rates: four intersections have 5-11 accidents over two years from 2003 to 2005. Several intersections on Main Street and Old US 52 also have moderately high accident rates: 2-4 accidents over two years. Thus analysis can be done to identify safety “hot spots.”

Figure A-6. Calculated Suitable Land for Development, Pilot Mountain, NC



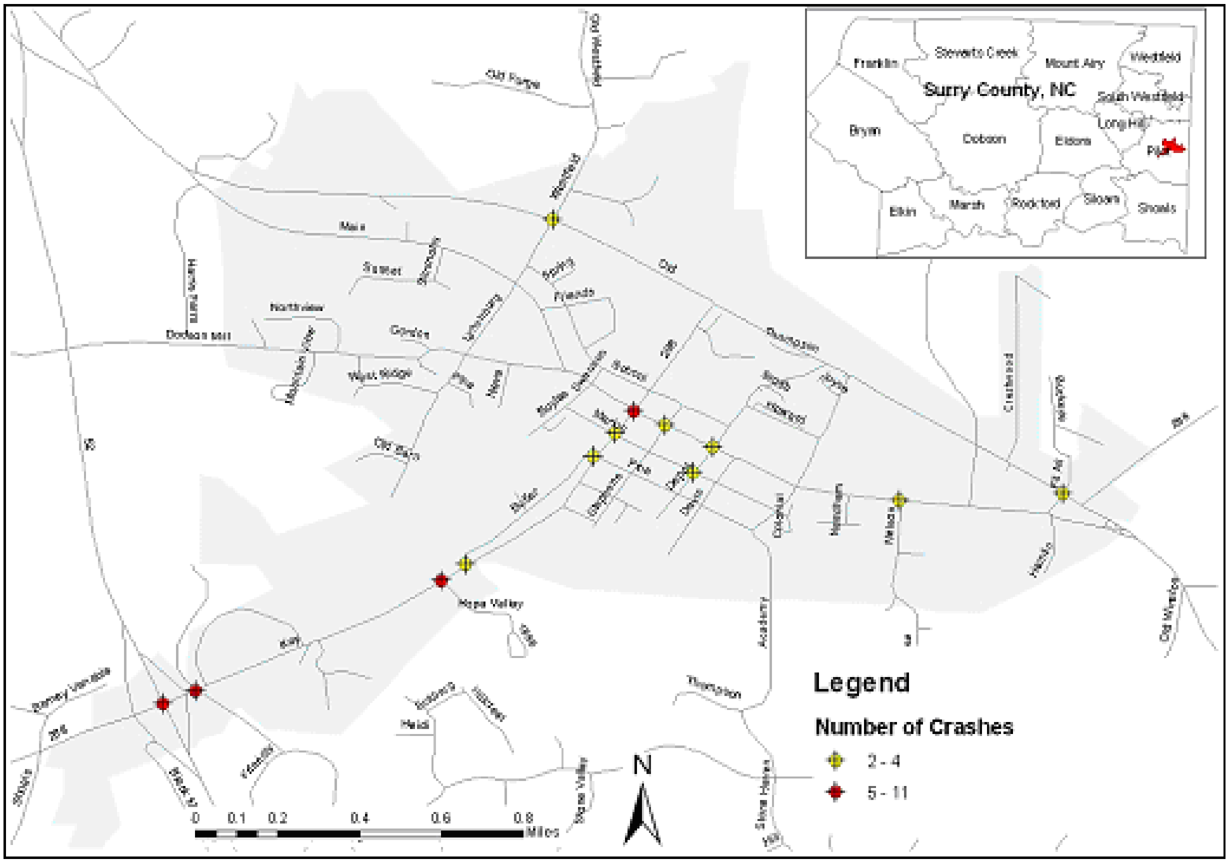
Source: seamless.usgs.gov

Due to the traffic safety concerns, the 1998 Plan maintains that the transportation proposals will have a positive impact on the town's neighborhoods by relieving traffic on residential streets. A proposed widening of Main Street is predicted to improve access and safety for Surry High School. Two proposals were provided to improve the traffic conditions on NC 268 (Key Street). One is to widen NC 268 (Key Street) to a five-lane road with curb and gutter. Another plan is to build a NC 268 east-west bypass to skirt the south side of the town connecting NC 268 (Key Street) and NC 268 (East) as it leaves the Pilot Mountain area. Proper highway design and safety countermeasures will address traffic safety issues.

- Alternative transportation modes – transit, walking and biking

The objectives and principles of CSS encourage planners and engineers to consider modes of transportation that are alternatives to the automobile. Further, state and federal regulations require assessment of alternative modes. Sidewalks, parking, bicycle paths, transit, and ride sharing are related to safety, enhancement of the natural environment, and preservation of community values, as well as mobility. For example, providing a walkable environment will improve pedestrian safety, increase physical activity, and strengthen the social fabric of the community. A wide range of individual user, household, and environmental factors shape travel behavior and create needs for different transportation modes. Considering alternative transportation needs and modes and incorporating appropriate proposals are necessary in a good transportation plan that follows CSS principles.

Figure A-7. High Accident Intersections, Pilot Mountain, NC (01/01/2003 – 01/01/2005)



Source: TEAAS v5.2, http://dmvcrashweb.dot.state.nc.us/TEAAS/index.htm

One approach to considering alternative modes is to obtain satellite photographs and observe physical features like roads, neighborhoods, and commercial areas. However, the satellite photos of Pilot Mountain that could be obtained from public sources only display local streets and highways. Due to the relatively low resolution of satellite photos in the Pilot Mountain area (Figure A-8 obtained from www.google.com), the non-auto network in Pilot Mountain including sidewalks, parking, and accessibility to shops and services could not be studied. However, in the near future, high quality and resolution satellite photos will be available for small and remote communities such as Pilot Mountain.

In addition to obtaining physical data for the transportation network and land use, planners and engineers need to forecast the demand for alternative modes. Demand-responsive van transportation or ridesharing is the most likely alternative mode in a small community such as Pilot Mountain, and indeed, the Northwest Piedmont Rural Planning Organization operates such a service. Appendix J describes a typical method to assess the demand for rural ridesharing.

Walking and biking are other options; however, traditionally they are excluded from transportation forecasts for a small community because the impact on highway transportation is relatively small and the forecasting methods not well known. To illustrate how to assess non-motorized transportation for a small community, this case will consider an example for a self contained traditional neighborhood development

Figure A-8. Satellite Photo of Pilot Mountain Town, NC

Source: http://earth.google.com/

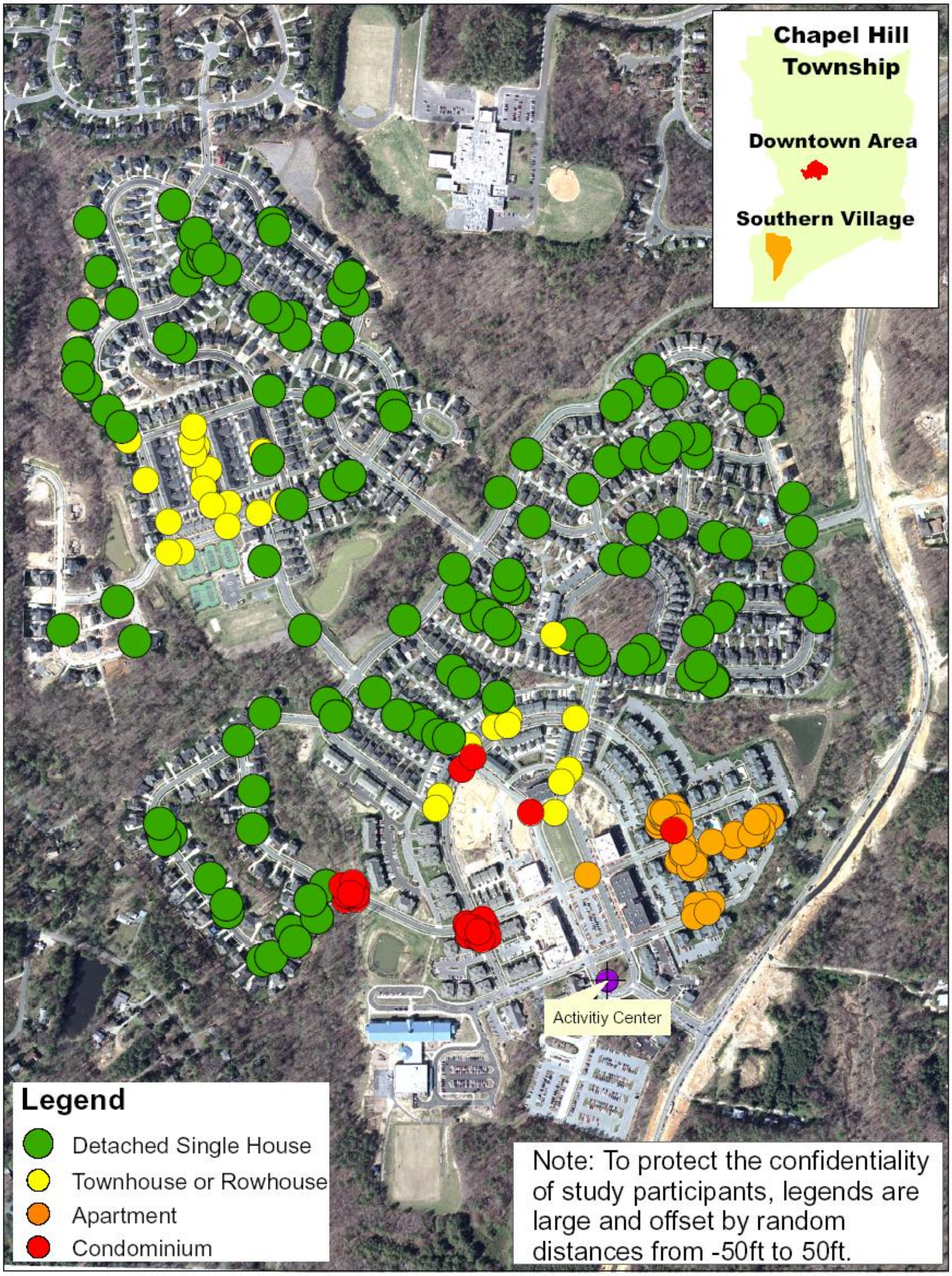
or TND. It can serve as a proxy for a small town like Pilot Mountain for the purpose of estimating walking and bike trips.

This section will use the Southern Village (Chapel Hill, NC) travel behavior study (Khattak, Stone, et al. 2004 and Shay et al. 2006) to indicate the importance of alternative transportation modes during the development of travel demand models and during the whole planning process. The Southern Village TND is located in Chapel Hill, NC. It is mixed use and pedestrian/bicycle friendly. It is relatively high-density, so it can represent small towns with similar features.

Southern Village is a neo-traditional community that is higher-density (relative to conventional developments), mixed land use (has a commercial core) and is pedestrian/transit friendly. In the analysis that follows, we will treat Southern Village as a proxy for a small town, despite its location in an urban area. Compared to Pilot Mountain the resolution of satellite photos obtained from GIS sources is very high in Southern Village (Figure A-9). Sidewalks, cars, parcels, commercial sites, and parking lots can be clearly identified.

The Southern Village development is located on US 15/NC 501 several miles from downtown Chapel Hill and the campus of the University of North Carolina. Construction of Southern Village began in the late 1990s. At the time of the 2003 data collection, several dozen businesses with 432 employees operated in approximately 200,000 ft^2 of commercial space. At the same time, over 750 residences were complete, including 250 condominiums and apartments in or adjacent to the commercial core, and 514 single-family homes in the areas spreading out from the center. Since the first residential units became available, Southern Village has enjoyed rapid growth in both residential population and activity in the commercial core, which includes restaurants, retail stores (including a popular community grocery), and a well-attended movie theatre. A bank, financial services office, spa and clinic also operate in the commercial center, along with a church, daycare, and public elementary school. Office space fills several buildings in

Figure A-9. Satellite Photo of South Village, Chapel Hill, NC



Source: Seamless.usgs.gov

the center, and occupies floors above ground-level retail in others. The commercial center attracts trips from both outside and within the neighborhood. Two Chapel Hill transit routes serve the neighborhood, including one route that runs through the residential area. A park-and-ride lot adjacent to the commercial center has space for over 400 cars. Other features of the development (e.g., pool and recreation facilities) are located away from the center for use primarily by residents.

The analysis of walking behavior in Southern Village includes 348 people in the sample representing 215 households. Those homes include 122 single-family detached houses, 56 condos and town houses (including one duplex), and 37 apartments. During the two-day travel diary period, those 348 Southern Village residents made 1,765 total trips including 125 (7%) internal trips (both origin and destination are within Southern Village) and 1,640 (93%) external trips . Of those 1,765 total trips, 326 (19%) are walking trips and 1,338 (81%) are driving trips. Of those 125 internal trips, 70 (56%) are walking trips and 55 (44%) are driving trips. The mean number of internal trips per person is 0.36, including 0.20 walk trips and 0.16 drive trips. Table A-1 gives the summary statistics for the trip survey.

Table A-1. Descriptive Statistics of Southern Village Trip Survey

Southern Village Trip Survey	Sum	Minimum	Maximum	Mean	Std. Dev.
Number of total trips	1,765	1	13	5.07	2.412
Number of total walking trips	326	0	9	0.94	1.447
Number of total driving trips	1,338	0	13	3.84	2.287
Number of total internal trips	125	0	4	.36	.696
Number of total internal walking trips	70	0	4	.20	.547
Number of total internal driving trips	55	0	3	.16	.459

The study focuses on the generation of utilitarian trips within the neo-traditional neighborhood, and compares total trip generation with mode-specific (i.e., walk and drive) trip generation. Ordinary Least Squares (OLS) regression is used to estimate how walking trips, driving trips, and total trips are respectively related to a set of independent variables including household characteristics and distance from residences to the commercial center. See the Table A-2 and Figure A-10 for detailed modeling information and estimation results.

Results show that walk trip generation rates are sensitive to distance to destinations within the neighborhood with a significantly negative relationship. However, the distance factor is positively associated to driving trips. This suggests that one kilometer decrease in the distance between residence and destinations may result in 0.266 increase in walking trips and 0.161 decrease in drive trips. Although number of children (below the age of 16) has significantly positive effects on both drive and walking trips, those effects have different magnitudes. One additional child leads to 0.105 more drive trips but 0.062 more walking trips. Thus it can be seen that walking substitutes for auto travel, if the destination is proximate. Small towns are more likely to have proximate destinations and that is why the analysis provided here is useful in estimating travel demand.

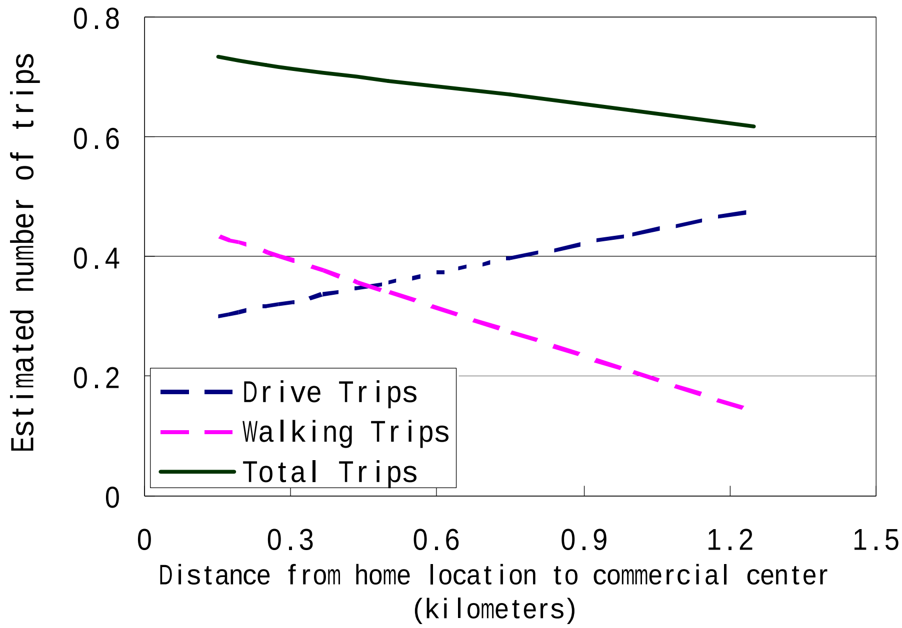
The results can be used to forecast the demand for alternative modes in small towns. For instance, total auto and walk trips depend on how far the destination is (e.g., distance between home and main street), and how many household trips may be forecast. The forecasts can be aggregated to the get a sense of the trips that people will make by walking and passenger cars.

Table A-2. Modeling Results

	Walking trip model			Drive trip model			Total trip model		
	Coef.	Std. Err.	P	Coef.	Std. Err.	P	Coef.	Std. Err.	P
Distance*	**-0.266**	**-0.266**	**0.012**	**0.161**	**0.086**	**0.063**	-0.123	0.132	0.354
# of cars	-0.014	-0.014	0.769	-0.038	0.039	0.327	-0.045	0.059	0.444
# of children	**0.062**	**0.062**	**0.055**	**0.105**	**0.026**	**0.000**	**0.176**	**0.040**	**0.000**
Constant	0.348	0.348	0.000	0.066	0.078	0.399	0.403	0.119	0.001
# of cases	348			348			348		
R-Square	0.0252			0.0677			0.0534		
F-test	0.0322			0.000			0.0003		

* Distance from home location to commercial center, unit: kilometers

Figure A-10. Estimated Number of Daily Trips by Distance



<u>Section III: Summary of the CSS Approach</u>

The development of new highways near Pilot Mountain offers an opportunity to apply the principles of CSS. Findings and recommendations for this case follow.

- This case gave a limited demonstration of CSS concepts and analysis. More effort is needed to understand fully the landscape, the community, and valued resources (before designing and implementing projects). In particular, stakeholder involvement and community feedback is needed.
- Involving citizens, local officials and NWPRPO is important. Besides community meetings and small group meetings, the Internet and relevant information technologies can facilitate open, early, easy, and continuous communication with key stakeholders.
- The expansion of US 52 in the vicinity should be harmonized with the community, preserving the environmental, scenic, aesthetic, historic, and natural resource values of the area residents. In particular, the area surrounding the State Park, facing substantial development pressure, should be

developed in accordance with the values of the community and by considering a range of alternatives.

- The proposed projects can satisfy the purpose and needs of the full range of stakeholders. For instance, local officials feel that improving the traffic capacity of NC 268 would attract new business along that route. However, it will be prudent to involve the larger community in the project. Wider involvement can address commercial development along NC 268, the development that has blocked the proposed connections points for a proposed by-pass, and additional impacts and benefits of the proposed by-pass.
- There is potential to use a full range of tools for communication about project alternatives and analysis of those alternatives. These would include GIS (e.g., analysis to relate population and land use or comparing vehicle, bike and walk trips), visualization, data (e.g., AADT and socioeconomic), application of analysis methods (e.g., simple models that consider alternative modes) and use of information technology (e.g., to involve the community).

Overall, Pilot Mountain demonstrates how to improve the planning process of a small community through the use of CSS and related analysis methods. Subsequent sections of this report will demonstrate the relative ease of use and accuracy of other methods including GIS analysis, manual forecasting and travel assignment methods, quick response travel models. It is recognized that community involvement is also necessary in the process to elicit values and preferences and gather feedback on interim results of the analyses.

References:

Websites:

a) American Factfinder, Maps and Geography: http://factfinder.census.gov/jsp/saff/SAFFInfo.jsp?_pageId=gn7_maps
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c) Surry County Government: http://www.co.surry.nc.us/
d) Northwest Piedmont RPO: http://www.nwprpo.org/
e) North Carolina Department of Transportation: http://www.ncdot.org/planning/development/TIP/i73and74.htm
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1. Tammy Johnson, Community Development Coordinator for Pilot Mountain. October 19, 2004.
2. Chris Knopf, Director of Surry County Planning and Development. October 20, 2004.
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5. Wayne Davis, November 1, 2004.
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2. Shay E., Y. Fan, D. Rodriguez and A. Khattak, *Drive or Walk? Utilitarian Trips within A Neo-Traditional Neighborhood*, Forthcoming in Transportation Research Record: Journal of the Transportation Research Board, National Academies, Washington, D.C., (presented at the TRB Annual Meeting), 2006.

APPENDIX B: GIS APPROACH – PILOT MOUNTAIN

Discussion and Guidelines

The GIS approach documents the land use inventory, quantifies developable lands, and estimates housing capacity. The analysis involves four steps:

1) Collect land use and coverage information including wetlands, flood plains, public lands, critical slopes, historic locations, farmland, parks, and so on.
2) Calculate developable land and tabulate the area of developable lands by analysis zones.
3) Make assumptions about housing density in future years, and then calculate the housing capacity for analysis zones. (The assumptions should account for land use trends and forecasts.)
4) Adjust the results of the typically used trend analysis by using the housing capacity as a constraint, and come to the final growth prediction in the future year.

Pilot Mountain Case Study

This section introduces the land supply analysis process for the test case of Pilot Mountain, NC. Pilot Mountain is a small town of approximately 1,300 named after its distinctive landmark. It is located on the eastern edge of Surry County, North Carolina.

<u>Section I: Data and Information Collection</u>

To identify the potential developable land, land use and cover information, Geographic Information System (GIS) is used to identify and characterize potential development sites. Detailed digital maps and data can be obtained from many sources, including the U.S. Geological Survey, the National Atlas, the American FactFinder, the National Wetlands Inventory, and Census Bureau. See Table B-1 for a list of public geographical sources. Given developable land, undevelopable sites can be identified and quantified, and categorized as land under public ownership, underwater lands, and lands with a slope of 15 percent or more.

For developers, sites should not only be physically developable, but also be economically feasible. Thus, wetlands, lands too far from existing infrastructure, and Q3 flood zones are excluded from suitable sites for land development. GIS data sources mentioned above provide enough information to obtain the feasibility of land development.

<u>Section II: Calculation and Tabulation of Developable Land</u>

ArcGIS is an important tool at this stage for compiling a land use inventory. First, calculate the total potentially developable land, which excludes already developed sites and undevelopable sites. Already developed sites include sites developed for commercial, industrial, public, and residential uses. Undevelopable sites include land under pubic ownership, underwater lands, and lands with a slope of 15 percent or more.

Within the potentially developable sites, identify developable and accessible sites excluding wetlands, Q3 flood zones, unique farmlands, and natural lands. Accessible sites are typically within 10 kilometers (6.2 miles) of a major roadway (Interstate highways, four-lane freeways, and/or major federal or state highways) or within 10 kilometers of an existing urban development. The final land amount obtained from such analysis is the total land supply for suitable commercial and residential developments.

Table B-1. List of Main Public Geographical Sources

Main Sources	Download website	Data content	Data format	Usefulness	Comments
USGS Seamless Data Distribution System	seamless.usgs.gov	Elevation, Land Cover, Orthoimagery, Hydrograph	*.Tif (Raster)	The resolution of orthoimagery in some areas is high enough to see parking lots and sidewalks. Land cover data can be converted to shapefiles to make calculations about land use ratio.	Orthoimagery is up to date. The coverage of 2001 land cover data is not nationwide.
		Transportation, Boundaries	*.shp (vector)		
CENSUS CD	UNC Davis Library, or purchase from www.census.gov	Boundaries, Transportation, Socio-economic, Demographic, Travel behavior	*.shp (vector) *.dbf (table)	Block Short Form data is extremely useful for small towns since its data is at block level. Census tract level and block group level are not so useful due to the limited geographic variation of small towns.	Need to use specific software to export data from the Census CD.
American FactFinder	factfinder.census.gov	Same as census CD	*.xls (table) *.txt (table)	Data at census tract level, block group level, and block level.	.xls and .txt can be imported into ArcGIS and joined or related to *.shp.
Keyhole	www.keyhole.com	Names, locations, and categories of existing businesses Satellite photos	.jpg (image)	Can be used to identify activity center since it can zoom down to detail showing individual buildings, search for existing businesses by name or category. However, keyhole can only export image instead of GIS data. For small areas, we can consider geocoding.	Shapefiles can be brought into Keyhole with Keyhole's add on module called data importer. However, keyhole cannot output into an ArcGIS file. This data importer module is $299 per year and can only be added on Keyhole Pro which is $599 per year.
National Atlas	www.nationalatlas.gov	Environments, places, and people	*.shp (vector)	Including information about Agriculture, Environment, People, Biology, Geology, Transportation, Boundaries, History, Water, Climate	Can build map online
Federal Emergency Management Agency	www.fema.gov	Flood Hazard Mapping	*.shp (vector)	100yr Flooding, 100yr Shallow Flooding, 100yr Flood way, 500yr Flooding	

* All of those sources use data from multiple agencies. The accuracy and reliability will not be a problem.

With ArcGIS functions and GIS information sources listed in Table B-2, the land amount of various categories can be obtained. A table is created to document the developable, accessible, and suitable land. See Table B-3 as a sample table for illustration. The calculation procedure includes deciding which datasets are needed as inputs, creating new information through data manipulation, reclassifying each dataset to a common scale, and combining datasets to find suitable locations. The input datasets include land use/cover, elevation, road networks, and flood hazards. Using those original datasets, calculate slope and find distance. The calculated slope and distance will be reclassified as >=15% or <15%, and inaccessible or accessible. Finally, reclassified datasets are combined based on a suitability model to identify suitable sites. See Table B-4 for detailed land use inventory of Pilot Mountain, obtained using this method. In Pilot Mountain, the total amount of land is 1103 acres; the total already developed land is 413 acres; and the final calculated developable land is 644 acres. Among the already developed land, developed residential land use is about 245 acres and developed industrial & commercial & transportation land use is about 168 acres. The undevelopable land includes 2 acres of wetlands, 41 acres of lands with a slope of 15% or more, and 4 acres of underwater land. To have a better general view of data collected, Figure B-1 through Figure B-4 list GIS maps that visualize the original datasets and reclassified datasets.

Table B-2. Information Needed for Land Supply Analysis

Variables Needed	Data Source	Agency	Data Type	Website Address
Block ID	Census CD Block Short Form	American FactFinder	Vector Polygon	Factfinder.census.gov
Raw Land	National Land Cover Dataset (NLCD)	U.S. Geological Survey	Raster Grid	landcover.usgs.gov
Already Developed Land	National Land Cover Dataset (NLCD)	U.S. Geological Survey	Raster Grid	landcover.usgs.gov
Public Land	Public Land Survey System (PLSS)	National Atlas	Raster Grid	www.nationalatlas.gov/atlasftp.html#plss00p
Land with a slope of 15% or more	National Elevation Dataset (NED)	U.S. Geological Survey	Raster Grid	ned.usgs.gov
Underwater Land	National Land Cover Dataset (NLCD)	U.S. Geological Survey	Raster Grid	landcover.usgs.gov
Inaccessible Land	Census Bureau TIGER Files	ESRI	Vector Polyline	www.census.gov/geo/www/tiger/index.html
Floodzone	North Carolina Floodplain Mapping Information System	Federal Emergency Management Agency	Shapefile Polygon	www.ncfloodmaps.com
Wetlands	National Land Cover Dataset (NLCD)	U.S. Geological Survey	Raster Grid	landcover.usgs.gov

Table B-3. Sample Table for the Calculation of Final Developable Land

Planning Zone ID	Raw land	Already developed land	Public land	Lands with a slop of 15% or more	Underwater land	Inaccessible land	Flood zone	Wetlands	Final developable land
1									
2									
…									

Table B-4. Pilot Mountain Land Use Supply Analysis

Zone ID	Census Block ID	Raw land	Already developed land (ADL)	ADL1: Residential use	ADL2: Commercial, Industrial, transportation	Public land	Lands with a slope of 15% or more	Underwater land	Inaccessible land	Flood zone	Wetlands	Final developable land	*Acres
1	1003	70962	33052	31121	1931	0	3206	0	0	0	0	34704	9
2	1004	54027	19976	17725	2251	0	2019	0	0	0	94	31938	8
3	1005	54220	2641	0	2641	0	9986	0	0	0	0	41593	10
4	1007	43234	34006	19428	14577	0	992	0	0	0	1442	6794	2
5	1008	180942	123980	49245	74735	0	8204	0	0	0	0	48758	12
6	1009	471668	14339	6731	7607	0	20409	492	0	0	0	436428	108
7	1010	238499	0	0	0	0	12792	0	0	0	768	224938	56
8	1016	186178	27571	12284	15287	0	2601	0	0	0	768	155238	38
9	1017	398137	102286	77090	25196	0	12210	0	0	0	0	283641	70
10	1018	56778	33427	17999	15428	0	1146	0	0	0	0	22206	5
11	1019	12568	8915	5333	3582	0	0	0	0	0	0	3653	1
12	1020	179420	62936	31004	31932	0	3850	0	0	0	0	112634	28
13	1021	20369	15831	9576	6255	0	0	0	0	0	0	4538	1
14	1022	26446	18546	6561	11985	0	0	0	0	0	0	7900	2
15	1023	13908	5837	727	5110	0	0	0	0	0	0	8071	2
16	1024	13816	5626	2835	2792	0	0	0	0	0	0	8190	2
17	1025	126567	26235	23307	2928	0	2863	0	0	0	0	97469	24
18	1026	52692	41121	38405	2716	0	60	0	0	0	0	11511	3
19	1027	53081	26476	18894	7582	0	2112	0	0	0	0	24493	6
20	1028	15523	10815	3198	7617	0	0	0	0	0	0	4707	1
21	1029	20606	15728	10220	5508	0	0	0	0	0	0	4878	1
22	1030	474550	193144	174878	18266	0	13292	0	0	0	0	268114	66
23	1031	31414	24891	16834	8057	0	422	0	0	0	0	6101	2
24	1032	76139	54462	54462	0	0	0	0	0	0	0	21677	5
25	1033	34994	22574	18376	4198	0	0	0	0	0	0	12420	3
26	1035	31405	9591	9591	0	0	426	0	0	0	0	21388	5
27	1040	213816	10662	6540	4121	0	23158	6650	0	0	1080	172266	43
28	1041	62002	4944	4243	700	0	565	0	0	0	0	56493	14
29	1043	15106	4050	3281	769	0	0	0	0	0	0	11056	3
30	1044	11573	5254	620	4634	0	62	0	0	0	0	6257	2
31	1045	14148	2517	1072	1445	0	0	0	0	0	23	11608	3
32	2001	18894	12644	8209	4435	0	2331	0	0	0	0	3919	1

33	2002	83344	70048	30425	39622	0	0	0	0	0	0	13296	3
34	2003	63574	51775	29721	22053	0	0	0	0	0	0	11799	3
35	2004	29019	22141	361	21780	0	31	0	0	0	0	6847	2
36	2005	9039	9039	0	9039	0	0	0	0	0	0	0	0
37	2006	21287	20975	1	20974	0	589	0	0	0	0	-277	0
38	2007	11464	9475	2126	7349	0	25	0	0	0	0	1963	0
39	2008	14016	10161	2538	7623	0	21	0	0	0	1225	2610	1
40	2009	14395	11522	4978	6544	0	16	0	0	0	311	2546	1
41	2010	7951	5854	1804	4049	0	0	0	0	0	0	2097	1
42	2011	24457	17254	11508	5747	0	0	0	0	0	0	7203	2
43	2012	10196	5306	2376	2929	0	0	0	0	0	0	4890	1
44	2013	15005	14635	514	14121	0	0	0	0	0	0	370	0
45	2014	29667	24790	16917	7873	0	0	0	0	0	0	4878	1
46	2015	14295	13494	5945	7549	0	0	0	0	0	0	801	0
47	2016	15529	13774	10497	3277	0	0	0	0	0	0	1755	0
48	2017	8448	7378	6539	840	0	0	0	0	0	0	1070	0
49	2018	33691	20463	16577	3885	0	53	0	0	0	0	13176	3
50	2019	175189	89723	37305	52418	0	2983	0	0	0	0	82483	20
51	2020	98741	65051	27870	37181	0	299	0	0	0	0	33390	8
52	2021	116103	64884	31626	33258	0	1464	0	0	0	0	49755	12
53	2022	1844	336	0	336	0	0	0	0	0	0	1509	0
54	2027	16002	11935	1659	10277	0	0	0	0	0	0	4067	1
55	2028	62588	15283	739	14544	0	0	0	0	0	0	47305	12
56	2029	136442	52533	52466	68	0	0	1537	0	0	0	82372	20
57	2030	27176	14668	9429	5239	0	13502	0	0	0	0	-993	0
58	3005	34110	12793	2388	10405	0	510	0	0	0	0	20807	5
59	3009	119883	42183	5403	36779	0	23121	6915	0	0	1260	46404	11
Total Acres		1103	413	245	168	0	41	4	0	0	2	644	644

* "Acres" means final developable land in acres. The unit of land area in this table is square meter except of the last column – "Acres".

Figure B-1. 2000 Pilot Mountain Town Population Density Map

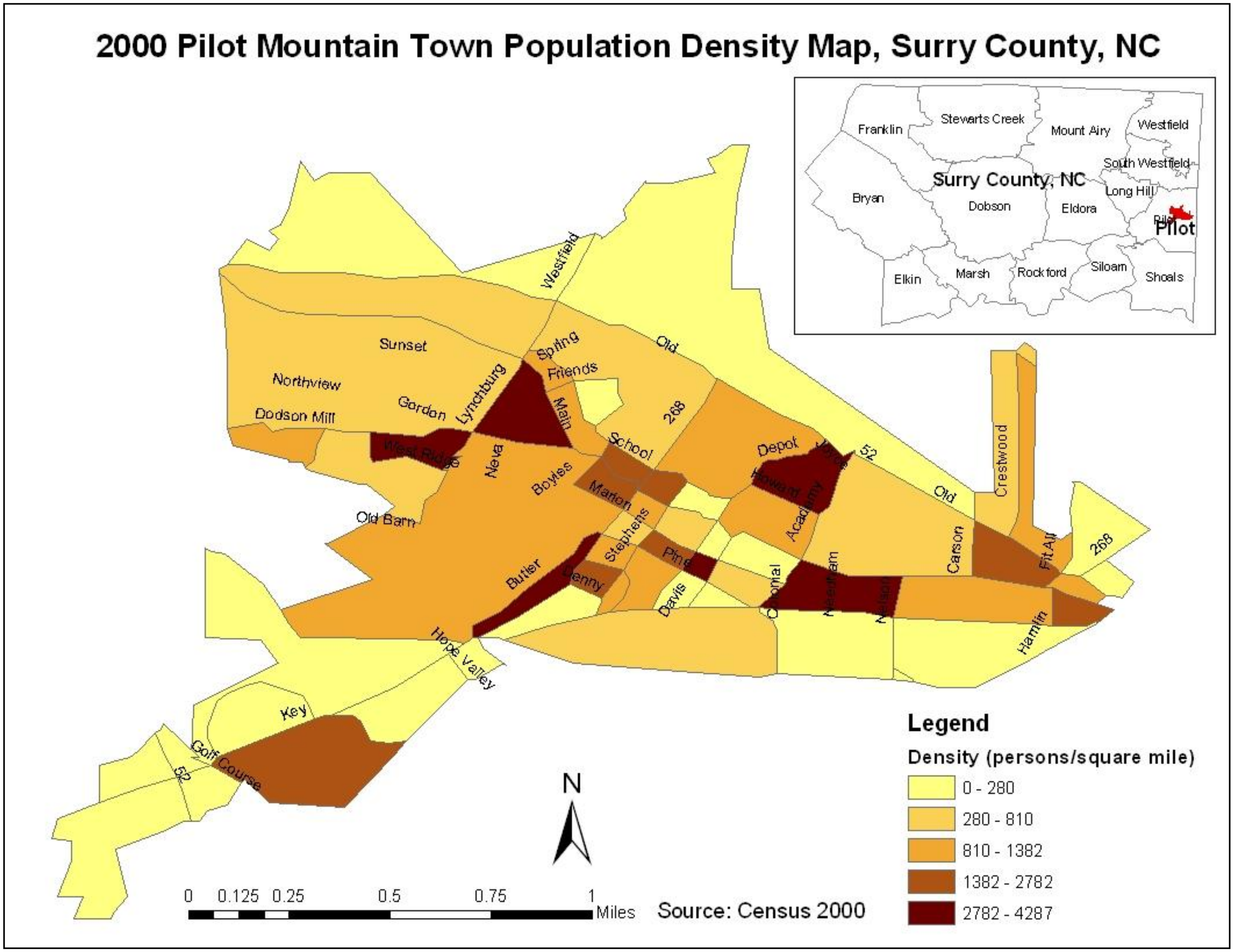


Figure B-2. Pilot Mountain Town Land Cover Map

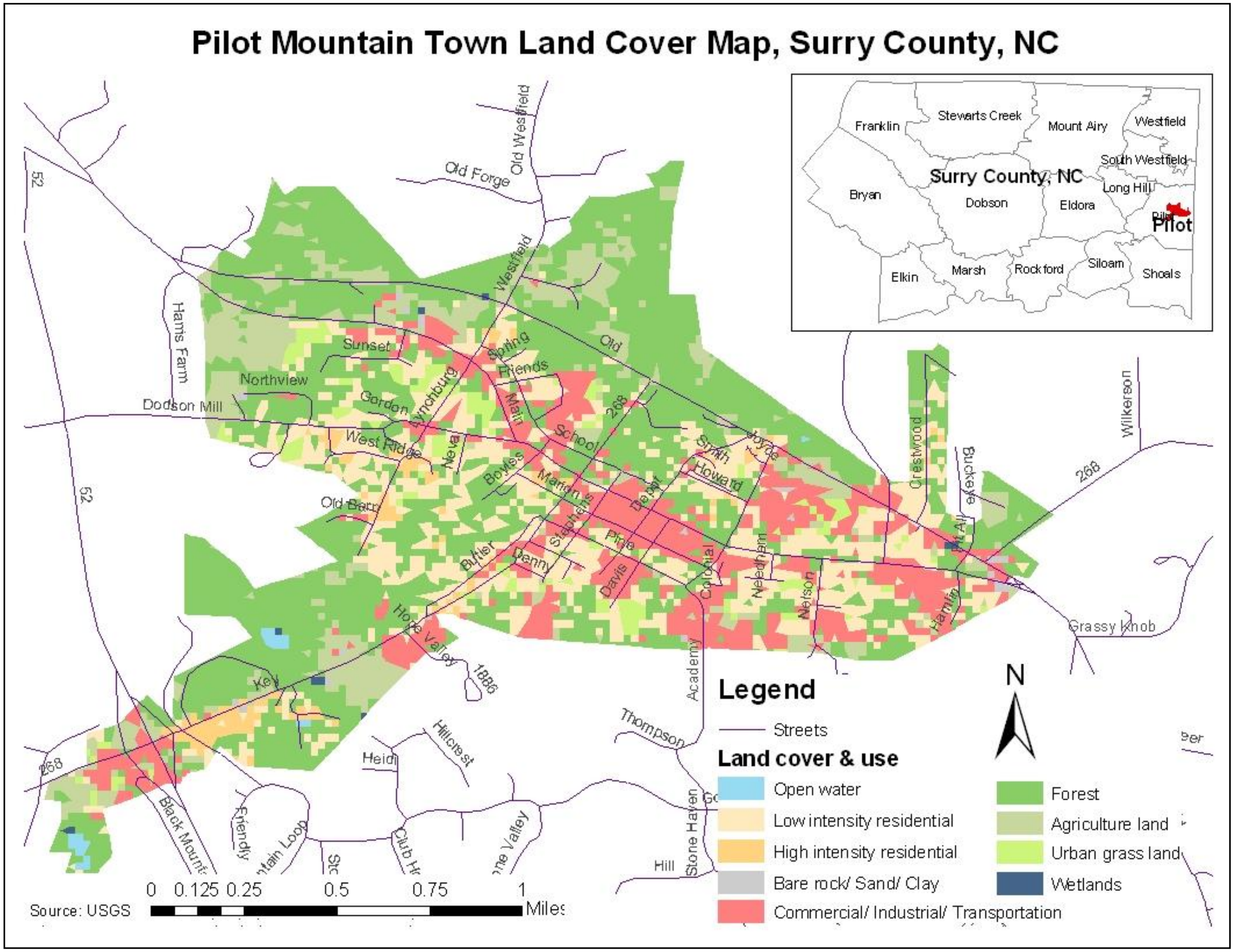


Figure B-3. Pilot Mountain Town Reclassified Slope Map

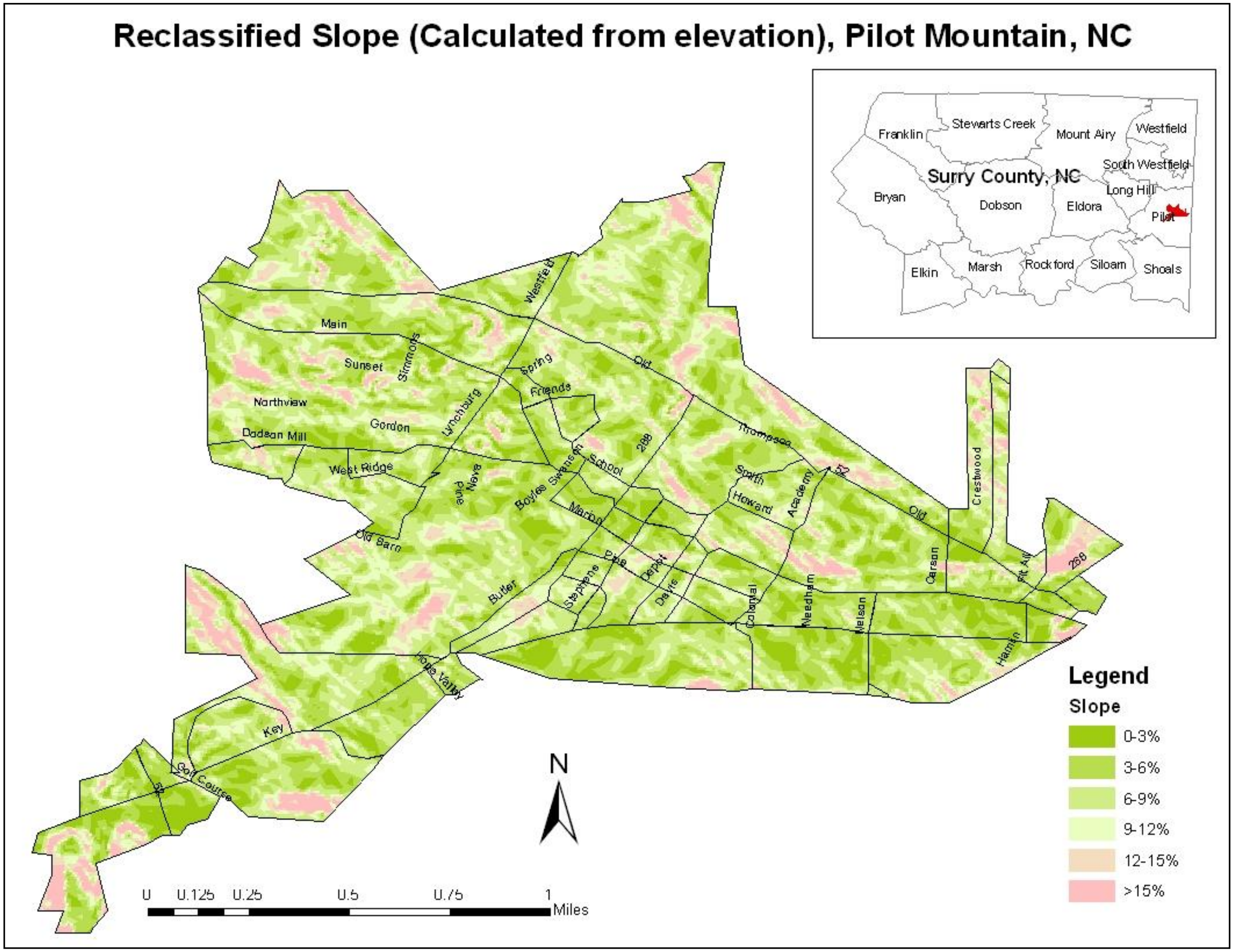
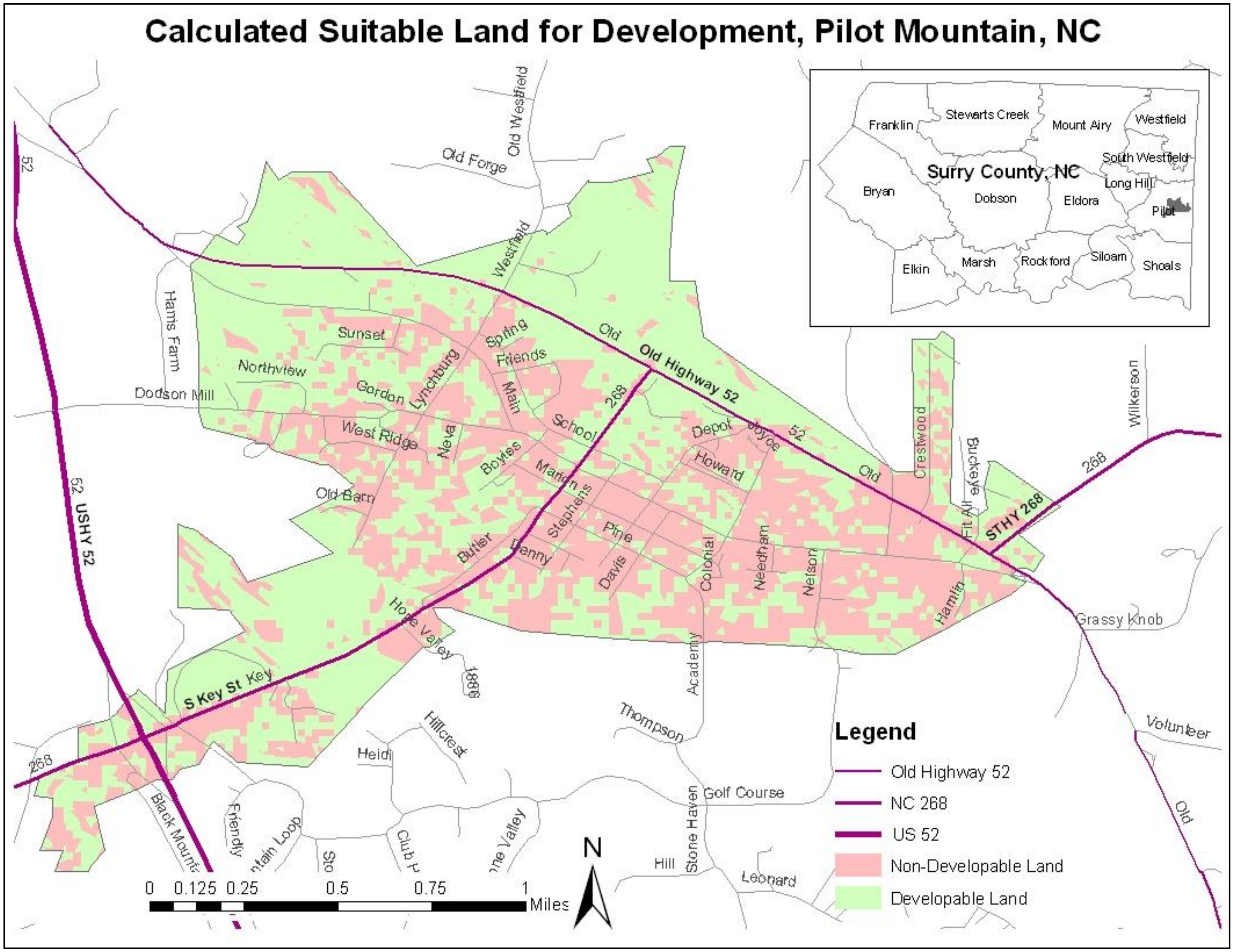


Figure B-4. Pilot Mountain Town Calculated Suitable Land for Development



Section III: Calculate Housing Capacity

To calculate housing capacity, two housing capacity scenarios (based on assumptions about population density) can be analyzed.

1) "Status Quo" development scenario: In this scenario the current structure of population, housing, and land use are used for forecasting future development patterns.

- American Factfinder provides population and housing data for the year 2000. For Pilot Mountain these numbers are:

Total population	1,281
Total households	585
Average household size	2.19 persons
Total housing units	660
Housing vacancy rate	9.2%

- Pilot Mountain Land Use Supply Analysis (Table B-4) provides land use structure of already developed and developable land.

Total Land developed	413 acres
Residential use	245 acres
Non-residential use	168 acres
(Commercial, Industrial, transportation)	
Final developable land	644 acres

- Calculate housing capacity

Developable land for residential use

$$= \text{Final developable land} * \frac{\text{Land developed for residential use}}{\text{Total land developed}}$$

= 644 * (245/413) = 382 acres

Developable land for non-residential use

$$= \text{Final developable land} * \frac{\text{Land developed for non-residential use}}{\text{Total land developed}}$$

= 644 * (168/413) = 262 acres

Developable dwelling units

$$= \text{Developable land for residential use} * \frac{\text{Total housing units}}{\text{Land developed for residential use}}$$

= 382 * (660/245) = 1029 dwelling units

Total housing capacity

= *Developable dwelling units* * *(1 - Housing vacancy rate)*

= 1029 * (100-9.2%) = 934 dwelling units

Population accommodated in developable lands

= *Total housing capacity* * *Average household size*

= 934 * 2.19 = 2,046

Population accommodated in Pilot Mountain

= *Total current population + Population accommodated in developable lands*

= 1,281 + 2,046 = 3,327

2) "Compact" land use scenario:
   - Use current average household size for prediction.
   - Assume an average residential density of 3 dwelling units per acre (> 660/245 = 2.69, current density in already developed residential lands)
   - Calculate housing capacity

Developable dwelling units

= *Developable land for residential* * *Assumed residential density*

= 382 * 3 = 1146 dwelling units

Total housing capacity

= *Developable dwelling units * (1-Housing vacancy rate)*

= 1146 * (1-9.2%) = 1041 dwelling units

Population accommodated in developable lands

= *Total housing capacity* * *Average household size*

= 1041 * 2.19 = 2,280

Population accommodated in Pilot Mountain

= *Total current population + Population accommodated in developable lands*

= 1,281 + 2280 = 3,561

Table B-5 summarizes the estimated housing capacities under the two scenarios.

Table B-5. Summary of results in calculating housing capacity

Results	"Status quo" development pattern	"Compact" development pattern	Diff
Total Housing capacity	934	1,041	107
Population accommodated in developable land	2,046	2,280	234
Population accommodated in Pilot Mountain (total)	3,327	3,561	234

Results show that the total housing capacity is 934 dwelling units using the status quo development pattern. Assuming a compact development pattern will enlarge the housing capacity to 1,041 dwelling units giving 107 units more units than the status quo development pattern. Compact development can accommodate a total population of 3,561 in Pilot Mountain while status quo development can accommodate 234 fewer people.

Note that this is land use capacity which will not change over time under the assumptions of the analysis in particular the assumption about the total size of Pilot Mountain. Clearly size can be increased by annexing county land. Similar analyses can be accomplished for "suburban rings" around Pilot Mountain or corridors along US 52, NC 268 and the proposed corridor for I-74.

Section IV: Adjust the Projected Growth Trend Analysis

The Travel Allocation Model anticipated growth within the urban areas in Pilot Mountain (Appendix D). In 2020, population within the planning area is estimated to be 3,619 (for year 2020) rather than 3,561 estimated by the land supply analysis. These independent results are within 2% of each other and confirm the procedures and estimates.

Summary Conclusions and Recommendations

The land supply analysis using GIS methods represents a powerful tool to determine the growth scenarios for a community. First, GIS methods help planners and stakeholders visualize and quantify natural and man-made features which determine opportunities for and constraints on community growth and development. Second, the land supply analysis allows planners to develop alternative scenarios for development and growth consistent with community standards for density, residential versus commercial development, preservation of open space, and other important values.

Land supply analysis should be an important precursor step to travel demand model development. It can help confirm the ability of the study area to accommodate assumed development patterns and the resulting population growth and future traffic.

APPENDIX C: TREND LINE TRAVEL FORECASTING – PILOT MOUNTAIN

Discussion and Guidelines

There are three different approaches to travel forecasting that are of interest to planners in state DOTs: statewide (regional), corridor and project. For most small towns and rural areas, the highway networks are usually simple and traffic volumes are not as heavy as those in the metropolitan areas. Therefore, the major highways are of greatest interests in small towns and rural areas. In these cases, corridor/project level forecasts can be made by extrapolating current traffic trends. Since trend line travel forecasting is easy to use and the required dataset is not too intensive, it is a good tool to predict travel on critical arterials or major highways for small towns, especially for rural areas without a regional travel demand model. (See the CD that documents this research for NCDOT trend line spreadsheets.)

National and state guidelines standardize roadway and intersection design [1], pavement design [2] and traffic controls [3]. To estimate the future traffic for such designs trend line analysis is an efficient approach. It can determine the fundamental traffic characteristics for the roadway design, such as ADT, peak hour traffic, turning movements and truck volumes. A variety of national [4] and state guidelines [5, 6] document the application of the trend line analysis to travel forecasting.

Trend line travel forecasting includes four steps:

1) Collection of historical traffic data and related demographic and economic information. For traffic data, the common sources include:
    - Bureau of Transportation Statistics;
    - Highway Performance Monitoring System (HPMS);
    - Vehicle Travel Information System (VTRIS);
    - Commodity Flow Survey (CFS);
    - State DOT traffic survey unit, etc.

    For demographic/economic data, the common sources include:
    - U.S. Census Bureau;
    - Bureau of Labor Statistics;
    - Census Transportation Planning Package (CTPP), etc.
2) Develop the trend line models, including growth factor, linear regression, moving average, Box-Jenkins methods, etc.
3) Validate and calibrate the developed trend line models by traffic counts and professional judgment.
4) Apply the validated model for travel forecasting.

Pilot Mountain Case

Background

Pilot Mountain is a small town with about 1,300 residents in the eastern Surry County, North Carolina. The population in the planning area is 2,912, and it has an extremely slow population growth rate. Pilot Mountain is situated 25 miles north of Winston-Salem, 130 miles from Raleigh, and 101 miles from Charlotte. Figure C-1 shows the location of study area in North Carolina. US 52 is the main highway that serves this small town. NC 268 is the main artery through the town, and intersects US 52 about three quarters of a mile southwest of the CBD. NCDOT's plans for extending I-77 along US 52 will have a significant impact on the town. Figure C-2 shows the major routes throughout the study area. In this case study the trend line forecasting models will be employed to predict travel on US 52 in the Pilot Mountain planning area.

Figure C-1. Study Area – Pilot Mountain

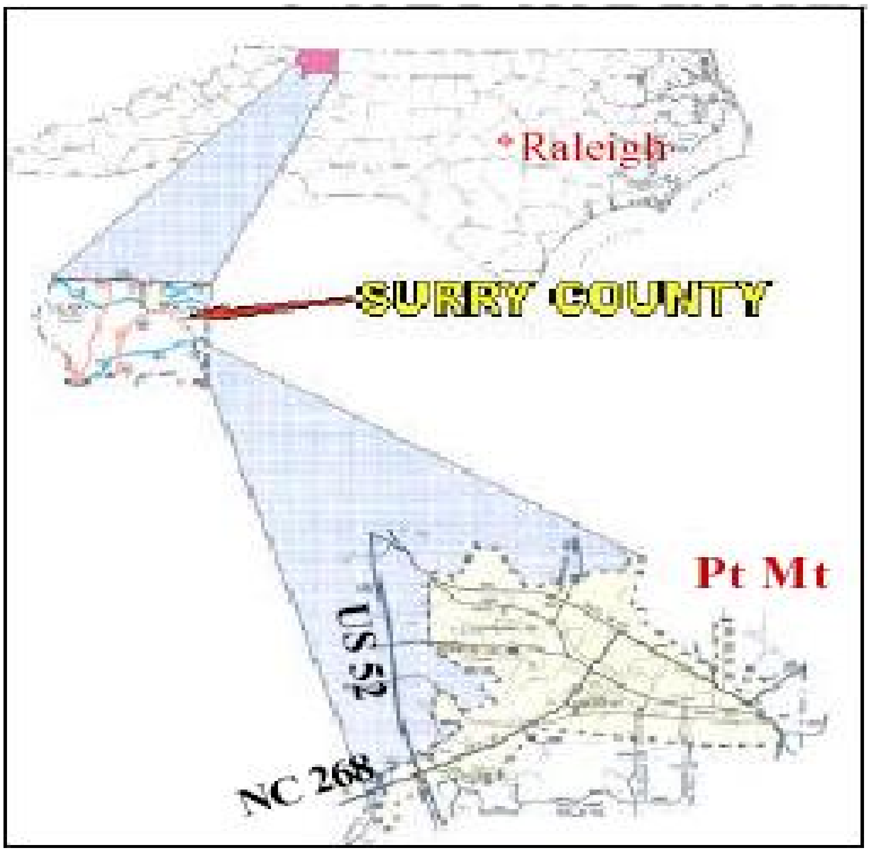
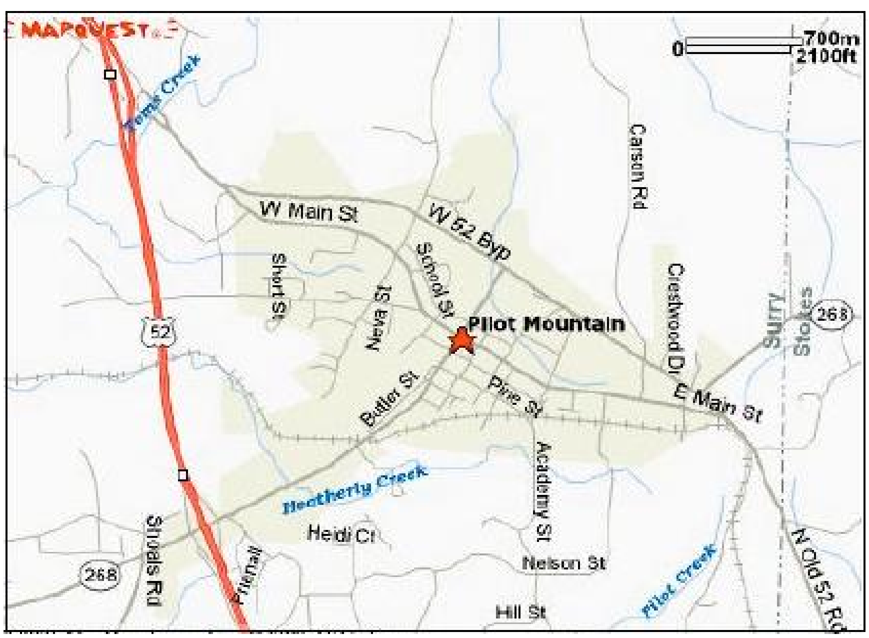


Figure C-2. Major Routes in Pilot Mountain



Data Sources

The historical ADT counts for US 52 in Pilot Mountain were obtained from NCDOT Traffic Survey Unit. Limited data was available from the traffic record station 258 for specific years of 1992 to 1996. Table C-1 shows the historical ADT counts. In an actual forecast current counts would supplement Table C-1.

Table C-1. ADT Counts for US 52, Pilot Mountain

Station	Route	County	Year	ADT
258	US 52	SURRY	1992	21000
258	US 52	SURRY	1993	21800
258	US 52	SURRY	1994	21100
258	US 52	SURRY	1995	20400
258	US 52	SURRY	1996	22700

Source: NCDOT Traffic Survey Unit

Demographic and economic factors usually play important roles in travel forecasting. In this case study possible causal indicators to be considered are the following:

- Population
- Employment
- Total income (in thousand)
- Auto registration

Because the historical data for these factors for Pilot Mountain are not available, Surry County's information will be used. In addition, two more factors will be analyzed for the purpose of this case study. They are:

- Population in North Carolina
- US GDP (in billion)

Table C-2 shows the demographic and economic data from 1992 to 2003 [7, 8].

Table C-2. Demographic and Economic Data

Year	PopSurry	PopNC	Employment	Income (thousand)	AutoRegs	GDP (billions)
1992	63239	6892673	43141	1102526	53600	6337.7
1993	64053	7036927	44175	1160764	55594	6657.4
1994	65122	7180525	45101	1228763	57813	7072.2
1995	66103	7336228	46240	1262057	58373	7397.7
1996	66831	7490812	46668	1336956	59008	7816.9
1997	68168	7645512	47495	1442547	59833	8304.3
1998	69564	7797501	46830	1553578	62125	8747.0
1999	70489	7938062	46771	1618263	63703	9268.4
2000	71216	8046813	46314	1674340	64961	9817.0
2001	71530	8198173	44961	1717198	65291	10100.8
2002	71838	8311778	43309	1709642	65488	10480.8
2003	71965	8421050	42600	1738828	65549	10983.9

Source: Log Into North Carolina, http://linc.state.nc.us/
U.S. Department of Commerce, Bureau of Economic Analysis, http://www.bea.gov/bea/ARTICLES/2004/02February/0204GDP&Other.pdf

Trend Line Travel Forecasting Approach

In this case study two trend line analysis approaches - the growth factor model and the multiple linear regression model - will be employed for the travel forecasting on US 52, Pilot Mountain.

- Growth Factor Model

The growth factor model is a popular way of forecasting trends in variables that have been increasing in time. Time series transportation data can sometimes be accurately modeled by growth factors. Growth factors work best when the variable to be forecasted is heavily influenced by other variables that inherently grow proportionally [4]. Many transportation variables are heavily influenced by the overall size of the economy, which has grown steadily over time. Furthermore, the growth factor method is efficient because a growth factor is easily computed for any data series.

Based on average daily traffic (ADT) counts, the annual growth factor (GF) and the average annual growth factor (AGF) can be calculated by the following formulas:

$$GF = \frac{ADT_t - ADT_{t-1}}{ADT_{t-1}}$$

(1)

$$AGF = \frac{\sum GF}{N}$$

(2)

Where,

ADT = average daily traffic;
GF = annual growth factor of ADT;
AGF = average annual growth factor of ADT;
t = year;
t-1 = previous year;
N = the number of ADT years.

For US 52 in Pilot Mountain, the annual growth factor (GF) and average annual growth factor (AGF) can be calculated following formulas (1) and (2). Table C-3 shows the results.

Table C-3. GF and AGF for US 52, Pilot Mountain

Year	ADT	GF	AGF
1992	21000		
1993	21800	0.038	
1994	21100	-0.032	
1995	20400	-0.033	
1996	22700	0.113	0.021

After the annual growth factor of ADT is calculated, the future ADT can be forecasted by using the formula below:

$$ADT_{fy} = ADT_{by}(1 + AGF)^{(fy-by)}$$
(3)

Where,

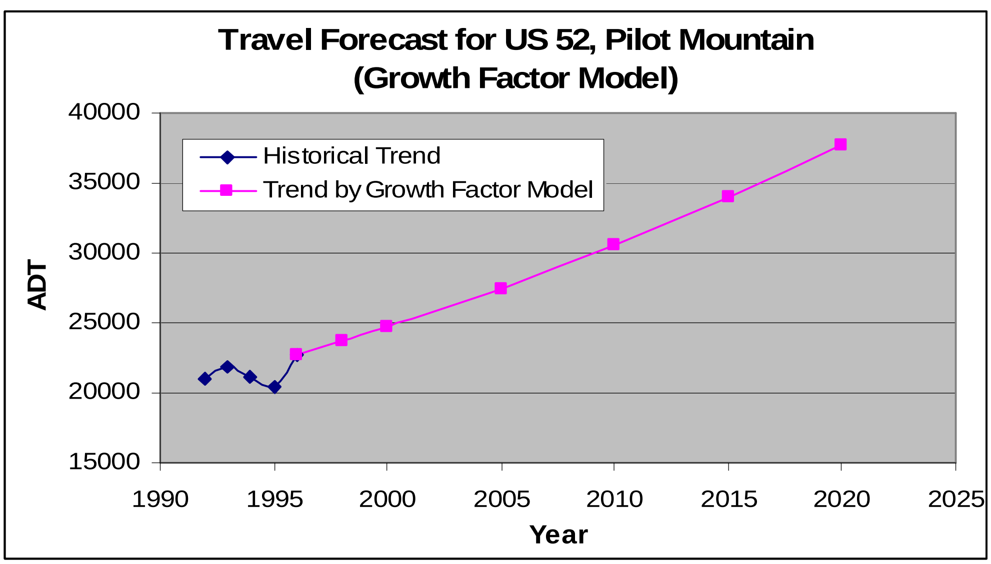
ADT = average daily traffic;
fy = future year;
by = base year;
AGF = average annual growth factor of ADT.

The future ADT of US 52 in Pilot Mountain can be forecasted according to formula (3). Table C-4 and Figure C-3 show the forecasting results.

Table C-4. Travel Forecast for US 52, Pilot Mountain (Growth Factor Model)

	Year	ADT
Counts	1992	21000
	1993	21800
	1994	21100
	1995	20400
	1996	22700
Forecasts	1998	23681
	2000	24705
	2005	27463
	2010	30528
	2015	33936
	2020	37723

Figure C-3. Travel Forecast for US 52, Pilot Mountain (Growth Factor Model)



- Multiple Linear Regression Model

Regression analysis is the most widely used statistical technique for investigating and modeling the relationship between variables [9]. The basic idea of regression analysis is to use data on a quantitative independent variable to predict or explain variation in a quantitative dependent variable [10].

In most applications, such as the case with Pilot Mountain and US 52, there will be more than one independent variable that helps to explain the dependent variable. The multiple regression model is used in such situations. It is shown below:

$$y = b_0 + b_1 x_1 + b_2 x_2 + \mathbf{L} + b_n x_n + e$$

where y is the natural dependent variable (e.g. ADT), and x_1, x_2, …, x_n are the independent variables (e.g. demographic and economic indicators). The resulting analysis is termed multiple linear regression analysis.

Perhaps the most critical decision in constructing a multiple linear regression model is the initial selection of independent variables [10]. The final selected independent variables should be those which have significant effects on the dependent variable and have low co-linearity between each other. For the purpose of this study, the stepwise selection method is employed to identify the causal variables. The detailed SAS output of the stepwise selection is provided at the end of this appendix. Table C-5 shows the summary of the stepwise selection.

Table C-5. Summary of Stepwise Selection

Step	Variable Entered	Variable Removed	Partial R-Square	Model R-Square	Adjusted R-Square	F-value	Pr > F
1	Income	None	0.1678	0.1678	-0.1096	0.6	0.4934
2	PopSurry	None	0.5810	0.7488	0.4976	4.63	0.1644
3	PopNC	None	0.2510	0.9998	0.9991	1169.85	0.0186

Note: SLENTRY=0.5, SLSTAY=0.5

Three independent variables, Income, PopSurry and PopNC, are determined as the causal indicators included in the regression model based on the stepwise selection procedure. Note that PopSurry and PopNC are selected in step 2 and 3, respectively. Although PopSurry and PopNC are both population indicators, it is wise to keep the variable of PopNC in the model because it largely improves the model's fitness and prediction power by increasing R^2 and adjusted R^2.

A multiple linear regression model can be fit by using the selected causal factors of Income, PopSurry and PopNC. Table C-6 shows the summary of the model parameters.

Table C-6. Summary of the Model Parameters

Parameter	Estimate	Standard Error	t-value	Pr > | t |	95% Confidence Limits
Intercept	203862.5871	3143.754693	64.85	0.0098	[163917.3963, 243807.7778]
Income	0.0294	0.001371	21.44	0.0297	[0.0120, 0.0468]
PopSurry	-7.1203	0.126378	-56.34	0.0113	[-8.7260, -5.5145]
PopNC	0.0341	0.000997	34.20	0.0186	[0.0214, 0.0468]

The resulting regression model is shown as below:

ADT = 203862.5871 + 0.0294*Income – 7.1203*PopSurry + 0.0341*PopNC

(R^2=0.9998)

Where,

ADT = average daily traffic;
Income = total personal income of Surry County (in thousand);
PopSurry = population of Surry County;
PopNC = population of North Carolina.

In order to use the regression model for travel forecasting, the values of Income, PopSurry and PopNC for future years must be known. Using the information provided by Table C-2, three simple regression models are developed to forecast the values of Income, PopSurry and PopNC, respectively. The set of models are shown below. Table C-7 shows the forecasted values of the variables from 2005 to 2020.

Income = -126871219 + 64247*Year (R^2 = 0.9655)
PopSurry = -1669635 + 870.1*Year (R^2 = 0.9665)
PopNC = -274864159 + 141455*Year (R^2 = 0.9976)

Where,

Income = total personal income of Surry County (in thousand);
PopSurry = population of Surry County;
PopNC = population of North Carolina;
Year = ADT year.

Instead of developing new forecasting equations for Income, PopSurry and PopNC, official NC forecasts are usually available from NC Link or similar sources.

Table C-7. Forecasted Values of Income, PopSurry and PopNC for Fugure Year

Year	Income	PopSurry	PopNC
2005	1944016	74916	8753116
2010	2265251	79266	9460391
2015	2586486	83617	10167666
2020	2907721	87967	10874941

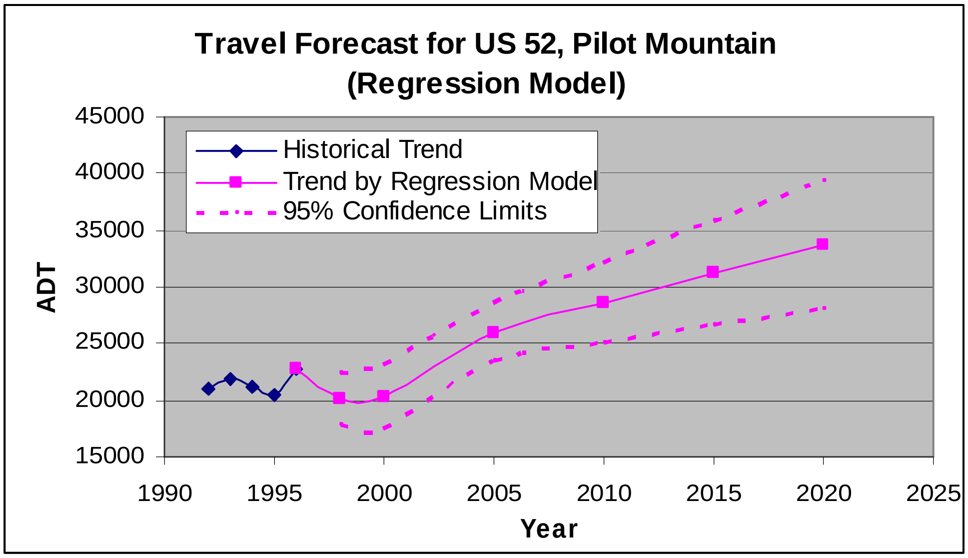
Table C-8 and Figure C-4 show the predicated ADT for US 52, Pilot Mountain in future years.

Table C-8. Travel Forecast for US 52, Pilot Mountain (Regression Model)

	Year	ADT	95% Confidence Lower Limits	95% Confidence Upper Limits
Counts	1992	21000		
	1993	21800		
	1994	21100		
	1995	20400		
	1996	22700		
Forecasts	1998	20057	17739	22374
	2000	20344	17501	23185
	2005	26006	23444	28568
	2010	28590	25011	32168
	2015	31166	26567	35766
	2020	33749	28128	39371

Note: Actual values of Income, PopSurry and PopNC are used for year 1998 and 2000.

Figure C-4. Travel Forecasts for US 52, Pilot Mountain (Regression Model)



- Model Comparison

In this case study, both the growth factor model and multiple regression model were employed for travel forecasting. The two different trend line models and the travel allocation model (See Appendix D) can be evaluated by checking the predicted ADT against the traffic counts. Table C-9 and Figure C-5 show the results of model comparison.

By comparing with the traffic counts for the base year (1998), the growth factor model forecasts more traffic (7.64% error) while the regression model forecasts fewer traffic (8.83% error). Both of the models yield good estimation (error < 10%) and are better than the result of the manual allocation model (13.18% error). For the future year 2020, all three models indicate that the predicated ADT will be more than the highway capacity. Therefore, improvements of US 52 should be conducted to meet increasing traffic.

<u>Findings and Recommendations</u>

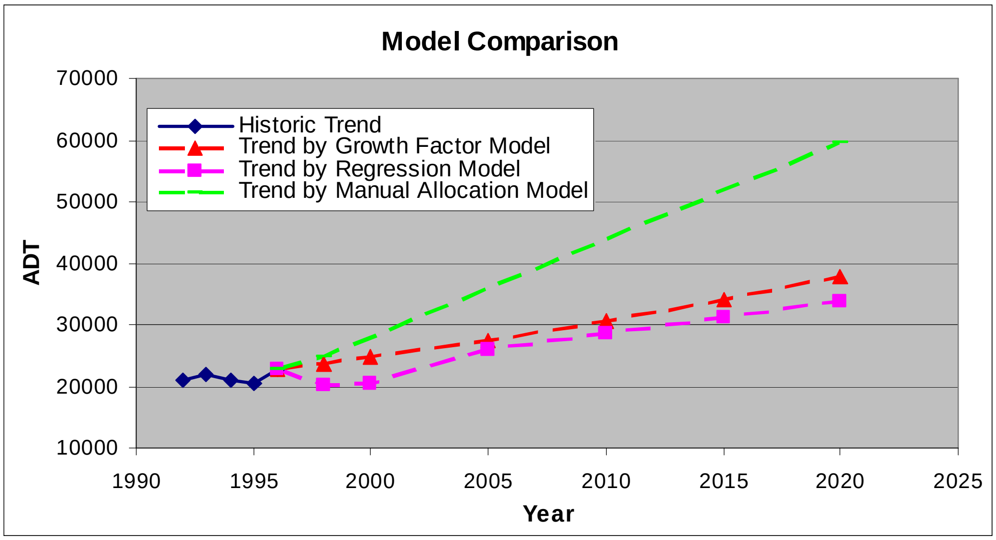
In this case study the growth factor model and regression model predicted traffic on the critical arterial (US 52) in the Pilot Mountain planning area.

The analysis results indicate that both the growth factor model and regression model lead to reliable travel forecasts for US 52 with errors within 10%. It also seems that the trend line model works better than the manual allocation model for critical arterials. Since the trend line model is easier to use and the required data is not intensive, the trend line model should be the primary tool for the travel forecasting on critical arterials or corridors in a small community. It should be noted, however, that good historical data is needed to apply the approach. Current year traffic counts are desirable, also. The trend line approach is not feasible on minor roads where traffic counts are not taken and the trends may change dramatically from a local development, rather than for population or other causal factors.

Table C-9. Model Comparison

Method	Base Year 1998			Future Year 2020	
	Forecasts	Counts	Error%	Forecasts	Capacity
Growth Factor Model	23681	22000	7.64%	37723	27000
Regression Model	20057	22000	-8.83%	33749	27000
Travel Allocation Model	24900	22000	13.18%	59700	27000

Figure C-5. Model Comparison



References:

1. *A Policy on Geometric Design of Highways and Streets*, American Association of State Highway and Transportation Officials, 2001.
2. *AASHTO Guide for Design of Pavement Structures*, American Association of State Highway and Transportation Officials, 1986.
3. *Manual on Uniform Traffic Control Devices*, USDOT Federal Highway Administration, 2001.
4. *Guidebook on Statewide Travel Forecasting*, U.S. Department of Transportation, Federal Highway Administration, 1999
5. John R. Stone. Guidelines for NCDOT Project-Level Traffic Forecasting Procedures, prepared for North Carolina Department of Transportation, 2002.
6. Project Traffic Forecasting, Florida Department of Transportation, 2000.
7. Log Into North Carolina, http://linc.state.nc.us/
8. U.S. Department of Commerce, Bureau of Economic Analysis, http://www.bea.gov/bea/ARTICLES/2004/02February/0204GDP&Other.pdf
9. D.C. Montgomery and E.A. Peck. *Introduction to Linear Regression Analysis*, WILEY, Second Edition, 1992.
10. R.Lyman Ott and Michael Longnecker. *An Introduction to Statistical Methods and Data Analysis*, Duxbury, Fifth Edition, 2001.

SAS Output of Stepwise Selection

Stepwise Selection of the Independent Variables for US 52, Pilot Mountain

The REG Procedure
Model: MODEL1
Dependent Variable: ADT

Number of Observations Read	5
Number of Observations Used	5

Stepwise Selection: Step 1

Variable Income Entered: R-Square = 0.1678 and C(p) = .

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	520151	520151	0.60	0.4934
Error	3	2579849	859950		
Corrected Total	4	3100000			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	16550	6249.80173	6030315	7.01	0.0771
Income	0.00398	0.00512	520151	0.60	0.4934

Bounds on condition number: 1, 1

Stepwise Selection: Step 2

Variable PopSurry Entered: R-Square = 0.7488 and C(p) = .

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	2321354	1160677	2.98	0.2512
Error	2	778646	389323		
Corrected Total	4	3100000			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	173028	72870	2195031	5.64	0.1408
PopSurry	-3.43350	1.59628	1801203	4.63	0.1644
Income	0.05893	0.02578	2034679	5.23	0.1496

Bounds on condition number: 56.011, 224.04

Stepwise Selection: Step 3

Variable PopNC Entered: R-Square = 0.9998 and C(p) = .

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F

Model	3	3099335	1033112	1553.49	0.0186
Error	1	665.02541	665.02541		
Corrected Total	4	3100000			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	203863	3143.75498	2796507	4205.11	0.0098
PopSurry	-7.12026	0.12638	2110999	3174.31	0.0113
PopNC	0.03409	0.00099676	777981	1169.85	0.0186
Income	0.02940	0.00137	305644	459.60	0.0297

Bounds on condition number: 334.3, 1897.9

All variables left in the model are significant at the 0.5000 level.

No other variable met the 0.5000 significance level for entry into the model.

Summary of Stepwise Selection

Step	Variable Entered	Variable Removed	Label	Number Vars In	Partial R-Square	Model R-Square	F Value	Pr > F
1	Income		Income	1	0.1678	0.1678	0.60	0.4934
2	PopSurry		PopSurry	2	0.5810	0.7488	4.63	0.1644
3	PopNC		PopNC	3	0.2510	0.9998	1169.85	0.0186

APPENDIX D: MANUAL TRAVEL ALLOCATION – PILOT MOUNTAIN

It is desirable that existing and projected traffic be defined for urban areas for a number of reasons. These include the need to determine the adequacy of the existing major street system, to provide guidance in the development of an adequate thoroughfare system to serve future travel needs, to determine design requirements for thoroughfare improvements, and to evaluate the user benefits of planned improvements.

For medium and large size urban areas, the traditional 4-step travel forecast model has proven to be an accepted and efficient method for accomplishing these objectives. For small communities with a population less than 5,000, where new growth and new thoroughfares are anticipated, a less automated, more manual travel allocation model is useful. The development of a travel allocation model can provide the analyst with "hands-on" knowledge of existing and future travel patterns and flows. This knowledge leads to better decisions with respect to location decisions, design requirements and the evaluation of user benefits for proposed improvements.

A travel allocation model is the standard analysis methodology for small urban areas meeting the following criteria:

- Population < 5,000;
- Anticipated growth within the urban area; and
- Anticipated new transportation facilities.

A spreadsheet model has been developed based on NCDOT Technical Report #11 *Allocation Type Approach to Estimation of Travel for Small Urban Areas*. This model is suitable for small urban area with up to 10 internal TAZs, 12 external stations and population less than 5,000. This report will take Pilot Mountain (Surry County, North Carolina) as an example to demonstrate the spreadsheet model and the procedure of a travel allocation model. The results will be estimates of existing and future travel patterns, and they will be determined systematically in a fast and easy-to-apply manner. Appendix F gives the details for the development of the spreadsheet.

Input Worksheet

All information needed by the spreadsheet model goes into the "Input" worksheet. Cells needed to be filled are marked by grey coloring. (Please see the spreadsheet provided with the CD documenting Phase I research.) There are five types of information which are required by the spreadsheet model:

- General Information about Planning Area
- Population
- Housing and Employment
- External and Through Trips
- Parameter

For "General Information about Planning Area" and "Population", all marked cells must be filled with appropriate information.

For "Housing and Employment" and "External and Through Trips", not all marked cells must be filled. It will depend on the number of internal TAZs and external stations. For example, if the internal TAZs and external stations are less than 10 and 12, respectively, only those cells corresponding to existing TAZs or external stations need to be filled.

Through trip tables will be developed by Synth rather than this spreadsheet model, thus through trip tables should be input in this worksheet as given information.

“Parameter” lists necessary ones which will be used by the spreadsheet model.

Output Worksheet

This “Output” worksheet provides the outputs of the spreadsheet model: PA matrices and OD matrices.

A PA matrix provides movements that are between production-ends and attraction-ends. Movements in a PA matrix are not in the correct direction because the home-end is always a production-end. Therefore, before traffic assignment occurs, the PA matrix needs to be converted to an OD matrix which represents actual trips between TAZs. In the spreadsheet model, “matrix folding” is used to convert the PA matrix to the OD matrix.

The developed OD matrices can be imported into selected software packages (e.g. TransCAD) and directly used for traffic assignment.

Step 1: Define Planning Area and Traffic Zones

As in larger urban areas, the planning area should include all the area anticipated to be urbanized. The planning area should additionally include, to the extent possible, all anticipated thoroughfares. The number of traffic zones should be less than 10.

In the spreadsheet model zone numbers 1 through 10 indicate internal TAZs. Internal TAZs must be coded beginning from number 1.

<u>Example</u>

In the case study, five internal TAZs and a simplified road network for the Pilot Mountain planning area are developed, as shown in Figure D-1.

<u>Issues</u>

The *Thoroughfare Plan Study Report for The Town of Pilot Mountain* (called below “Thoroughfare Plan Report” for convenience) developed by NCDOT in 1998 defined a planning area for the Town of Pilot Mountain. It encompasses all of the town limits and the surrounding area that is anticipated to become urban by the 2020 design year. However, the planning area is divided into 36 internal TAZs which is fine for a computer-based model, but so many zones violates the guidelines for a travel allocation model because too many TAZs will significantly increase the effort and possibly cause inaccurate results. Therefore, five TAZs and their corresponding housing and employment information are developed by aggregating these 36 TAZs for this case study.

Table D-1, Table D-2, Figure D-2 and Figure D-3 show the housing and employment information in the base year (1995), and the projected design year (2020).

Figure D-1. TAZs and Road Network for Pilot Mountain

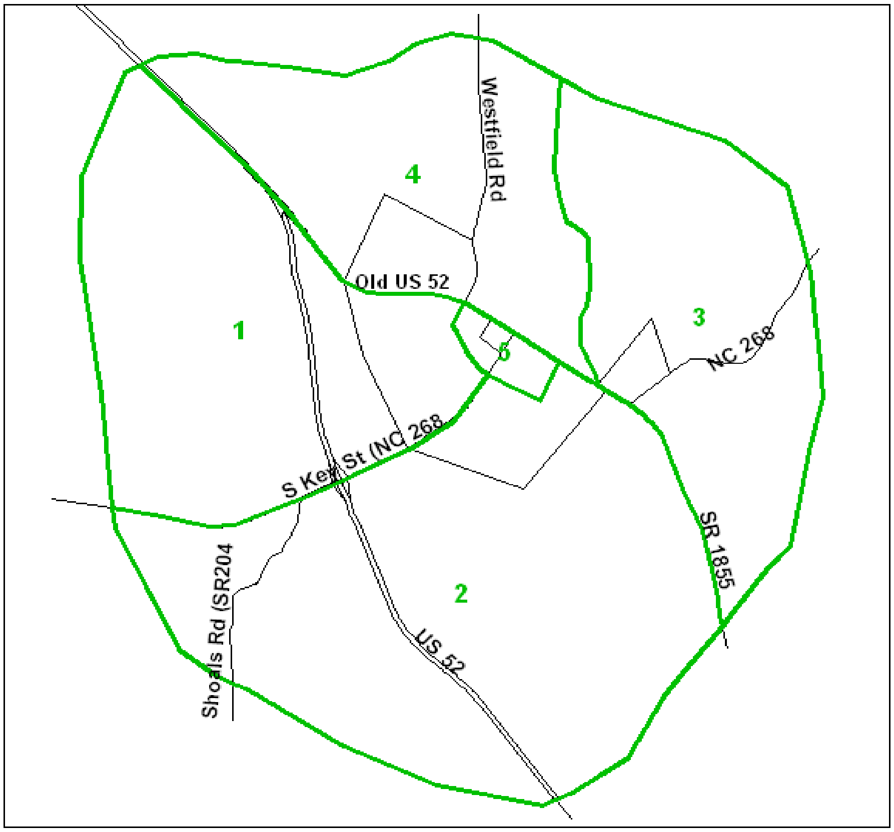
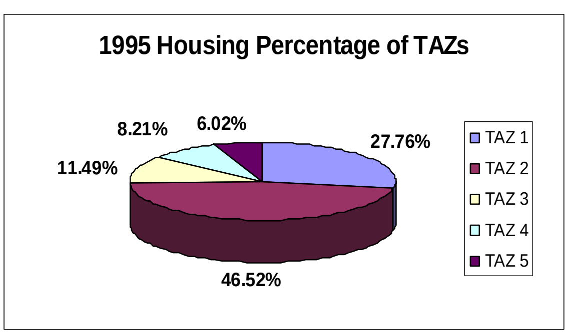


Table D-1. Zone-level Housing and Employment Data in 1995

Zone	Housing	Employment
1	355	342
2	595	1375
3	147	54
4	105	261
5	77	182

Figure D-2. Zone-level Housing and Employment Percentage in 1995



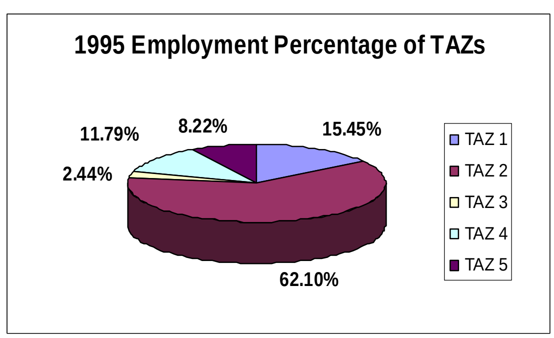
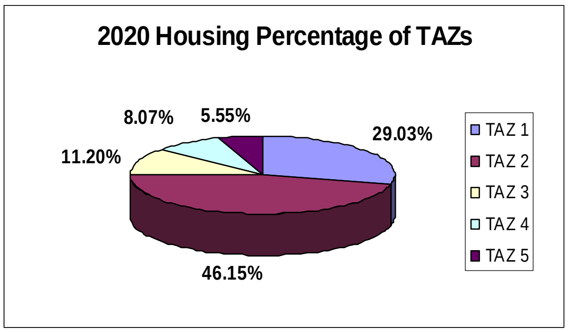
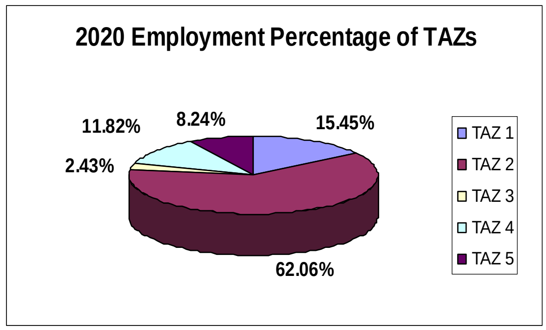


Table D-2. Zone-level Housing and Employment Data in 2020

Zone	Housing	Employment
1	565	497
2	898	1996
3	218	78
4	157	380
5	108	265

Figure D-3. Zone-level Housing and Employment Percentage in 2020





Step 2: Estimate Existing and Future Population

In a travel allocation model, it is suggested that a step-down approach be used to estimate existing and future population starting with the county, then the township, and subsequently the planning area. The reason why this procedure is adopted is that boundaries of both the counties and townships rarely ever change.

The US Census Bureau and the NC Office of State Budget and Management (OSBM) prepare and maintain current and future estimates of population (projections) for all North Carolina counties. These are official estimates and should be used for the model development.

The township population is generally estimated by looking at the historical trend of the township population as a percentage of the county population. The population of the planning area is subsequently estimated as a percentage of the township population or as a percentage of several townships if there is more than one involved with the planning area.

<u>Example</u>

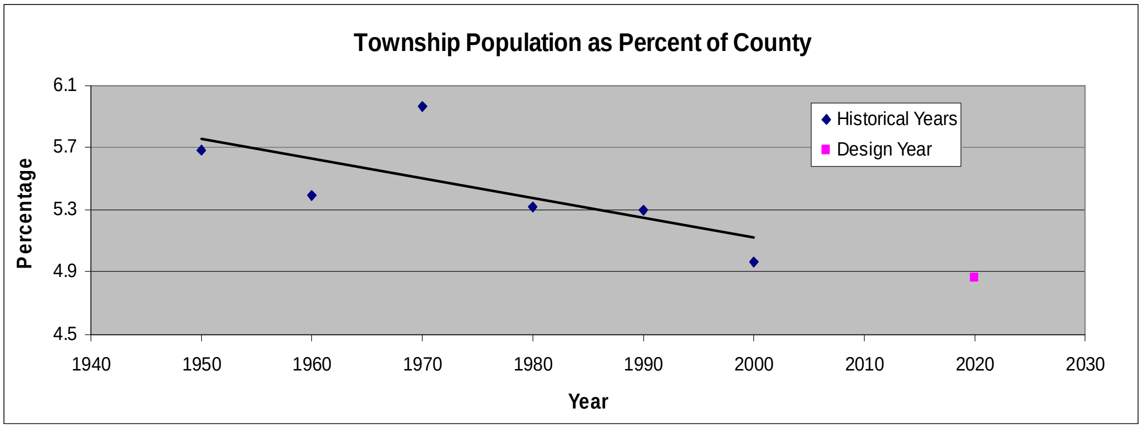
The populations of Surry County and Pilot Mountain Township over time are collected, as shown in Table D-3.

Table D-3. Populations of Surry County and Pilot Mountain Township

Year	1950	1960	1970	1980	1990	2000	1995	2020
Pilot Township	2,590	2,601	3,069	3,166	3,273	3,537	3,426	4,258
Surry County	45,593	48,205	51,415	59,499	61,704	71,219	66,103	87,576
Township as Percentage of County	5.6807	5.3957	5.9691	5.3211	5.3044	4.9664	5.1828	4.8618

Based on data in Table D-3, the trend of township population as a percentage of county population can be developed as shown by Figure D-4.

Figure D-4. Pilot Mountain Township Population as a Percentage of County Population



The linear regression equation of the trend line is:

$$\text{Percent} = 30.7965887 - 0.012839 * \text{Year} \qquad (1)$$

Therefore, the township population as a percentage of county population is calculated as below:

Percent (1995) = 30.7965887 – 0.012839*1995 = 5.1828
Percent (2020) = 30.7965887 – 0.012839*2020 = 4.8618

The population of the township for the base year (1995) and the design year (2020) can be calculated as below:

Population of township (1995) = 66103*5.1828% = 3426
Population of township (2020) = 87576*4.8618% = 4258

Assuming that the percentage of the township population in the planning area is 85%, the population of the planning area can be calculated as Table D-4 shows.

Table D-4. Population of the Planning Area

Year	Township	Percent of Township in Planning Area	Planning Area
1995	3426	85%	2912
2020	4258		3619

<u>Issues</u>

1. US Census Bureau and OSBM provide population information for Surry County for a long term from 1970 to 2030. They also provide the population at the township level for recent years.

2. In the Pilot Mountain Thoroughfare Plan Report, the population in the planning area is estimated by applying an occupancy factor to the actual number of dwelling units counted, which is different from the method used in this case study. While applying a travel allocation model, it is difficult to assume

the percentage of township population in the planning area with high confidence. This percentage value is usually determined by knowledge of the planning area. In this study, the percentage of township population in the planning area is taken as 85% and assumed to remain constant over time.

3. According to Thoroughfare Plan Report, the estimated population in the planning area is 2,900 in the 1995 base year, and 4,200 in the 2020 design year. Its estimation for the 1995 base year estimate is close to the Table D-4 value using NC OSBM data, while the estimation for the future year 2020 is fairly different that in Table D-4.

Step 3: Estimate External and Through Trips for External Stations

External stations are the points where the roads on the network cross the study area boundary. Two types of trips cross the boundary at the external stations: through trips, external to internal (E-I) trips, and internal to external (I-E) trips. (The I-E and E-I trips are sometimes called IX trips together). Through trips travel through the planning area without stopping, while external trips (IX trips) cross into or out of the planning area. That is,

$$IX_{trips} = ADT - THROUGH \tag{2}$$

where,

$$IX_{trips} = IE_{trips} + EI_{trips} \tag{3}$$

External cordon O-D surveys should be conducted to obtain information about ADT and through trips for the base year, which is thereafter used as a guide to estimate external and through travel. In general, external and through trip projections for the future year are projected from base year data using past growth rates along with knowledge of the planning area's development patterns. The procedure is shown below:

$$GF = \frac{T_t - T_{t-1}}{T_{t-1}} \tag{4}$$

$$AGF = \frac{\sum GF}{N} \tag{5}$$

$$T_{fy} = T_{by}(1 + AGF)^{(fy-by)} \tag{6}$$

where:

T = traffic;
fy = future year, by = base year;
GF = annual growth factor;
AGF = average annual growth factor;
t = year, t-1 = previous year;
N = the number of annual growth factors.

According to the spreadsheet model, zones 11 through 22 indicate external stations. External stations must be coded beginning from number 11.

Example

There are 10 external stations surrounding the planning area. The external cordon O-D survey of Pilot Mountain for the base year, 1995, is shown below in Table D-5. External and through trip projections for the 2020 design year were projected from the 1995 base year traffic using a linear projection of past growth rates and knowledge of the area's development patterns.

Table D-5. External Cordon O-D Survey of Pilot Mountain

Station Location	1995 BASE YEAR			2020 DESIGN YEAR		
	Total ADT	Through Trip-Ends	IX Trips	Total ADT	Through Trip-Ends	IX Trips
Key Street (SR 1901)	2000	278	1722	6800	946	5854
Old Hwy 52 (SR 2012)	700	100	600	1900	273	1627
Shoals Road (SR 2048)	2500	272	2228	3600	393	3207
NC 268 (West)	4100	1146	2954	9700	2722	6978
US 52 (North)	22200	18614	3586	51000	43228	7772
Westfield Road (SR 1809)	3700	570	3130	6900	1064	5836
Carson Street (SR 1837)	420	58	362	1100	152	948
NC 268 (East)	3200	858	2342	6000	1620	4380
Old Hwy 52 (SR 1855)	900	146	754	2000	325	1675
US 52 (South)	23670	19378	4292	56000	45491	10509
Total	63390	41420	21970	145000	96214	48786

In order to simplify the road network in the planning area, stations SR 1901, SR 2012 and SR1837 are ignored because less traffic passes through these stations. Traffic volumes on SR 1901 and SR 2012 are added to US 52 (North), while traffic on SR 1837 is added to SR 1809. The aggregated trip table is shown in Table D-6 below.

A summary of travel in the planning area is presented in Table D-7.

Table D-6. Aggregate Trip Table

Station Number	Station Location	1995 BASE YEAR			2020 DESIGN YEAR		
		Total ADT	Through Trip-Ends	IX Trips	Total ADT	Through Trip-Ends	IX Trips
# 11	US 52 (North)	24900	18992	5908	59700	44447	15253
# 12	Westfield Road (SR 1809)	4120	628	3492	8000	1216	6784
# 13	NC 268 (East)	3200	858	2342	6000	1620	4380
# 14	Old Hwy 52 (SR 1855)	900	146	754	2000	325	1675
# 15	US 52 (South)	23670	19378	4292	56000	45491	10509
# 16	Shoals Road (SR 2048)	2500	272	2228	3600	393	3207
# 17	NC 268 (West)	4100	1146	2954	9700	2722	6978
Total		63390	41420	21970	145000	96214	48786

Table D-7. Planning Area Travel Summary

Summary		
Year	1995 Base Year	2020 Design Year
ADT	63390	145000
Through Trips	20710	48107
IX Trips	21970	48786

<u>Issues</u>

1. The Thoroughfare Plan Report only displays the base year traffic data and not traffic data in past years; therefore, the growth factor cannot be calculated. As the Thorough Plan Report explains, however, it does use past traffic growth rates to estimate trips in the future year.

2. Compared to with nearby route US 52 (North) that has 22,200 ADT, SR 1901 and SR 2012 have small ADT volumes with 2000 and 700, respectively. Similarly, SR 1837 with ADT 420 has a small volume compared to SR 1809 with ADT 3700. Therefore, traffic volumes on SR 1901 and SR 2012 are added to US 52 (North), and traffic on SR 1837 is added to SR 1809 and the low volume roads are dropped from the network for simplicity.

3. According to the O-D table, the through trips should be half of the through trip ends.

4. The spreadsheet model uses the projected external and through trips as given information; therefore, the forecasts of external and through trips in the design year should be completed in advance and input into "Input" worksheet.

Step 4: Estimate Trips Generated by Population and Development

This step estimates trips generated by population and development in the planning area. This is done by multiplying the dwelling units (DU) by an assumed appropriate trip generation rate, and adding trips assumed generated by commercial autos and trucks (CV) by assuming commercial vehicle trips as a percent of dwelling unit trips (usually 12.5%). In order to obtain the number of dwelling units in the planning area, two approaches may work:

- Converting population to dwelling units by using occupancy rates
- Available housing survey data

For the two approaches, the DU trips can be calculated using the following two formulas respectively (the spreadsheet model employs the first approach):

$$DU\ Trips = (Population)/(Occupancy\ \ Rate)\times(Trip\ \ Rate) \quad (7)$$

$$DU\ Trips = DU\times(Trip\ \ Rate) \quad (8)$$

Commercial vehicle trips and total trips are estimated using the following formulas:

$$CV\ \ Trips = (Percent\ \ Commercial\ Vehicles)\times(DU\ Trips) \quad (9)$$

$$Total\ Trips = DU\ Trips + CV\ \ Trips \quad (10)$$

<u>Example</u>

Using the estimated Step 2 population in the planning area for 1995 and 2020, trips generated in Pilot Mountain planning area can be estimated.

For the base year (1995):

DU trips = (2912 / 2.25) * 7.56 = 9785
CV trips = 9785 * 12.5% = 1223
Total = 9785 + 1223 = 11008

For the design year (2020):

DU trips = (3619 / 2.18) * 7.80 = 12949
CV trips = 12949 * 12.5% = 1619
Total = 12949 + 1619 = 14568

The planning area trip calculation summary is shown in Table D-8.

Table D-8. Planning Area Trip Calculation Summary

Year	Population	Persons/DU	DU Trip Generation Rate	DU Trips	Percentage of CV Trips	CV Trips	Total (DU+CV)
1995	2912	2.25	7.56	9785	12.50%	1223	11008
2020	3619	2.18	7.80	12949	12.50%	1619	14568

Issues

1. The house occupancy rates should be determined by population and households in the planning area. If known. In this study, this parameter is assumed to be 2.25 in 1995 and 2.18 in 2020, respectively, which are the same values in the Thoroughfare Plan Report.

2. Trip generation rates for the study area are important parameters in the trip generation procedure. NCHRP Report 365 provides a person trip generation rate of 9.2 person trips/day/DU for an urbanized area with a population of 50,000 to 200,000. According to Thoroughfare Plan Report, the average trip generation rate (vehicle trip rate) for households in the planning area in 1995 was 7.56 vehicle trips per household, and the predicted vehicle trip rate is 7.80 vehicle trips per household. These averages fall within the State's average which is 7 to 8 vehicle trips per household. In order to be consistent with Thoroughfare Plan Report, these two values are used in this case study. In order to improve the analysis, updated trip generation rates for small/medium urban areas in North Carolina should be checked.

3. The parameter commercial vehicles as a percentage of dwelling unit trips is another value which is difficult to determine with confidence. Knowledge of the traffic patterns in the study area is needed.. A typical value is 0.125 as suggested in the Thoroughfare Plan Report.

Recommendation

NCHRP Report 365 does not provide a trip generation rates for small urban areas with population less than 5,000, indeed 50,000 is the lowest category. No other references suggest transferable trip rates for small urban areas either. However, during this Phase I research a statistical analysis has been done to show that fringe town trip rates appear to be similar with that of the nearby metropolitan (Appendix H). Also, a sensitivity analysis of trip rates in small communities indicates that the US default rate for urban areas with population 50,000 to 200,000 is qualified for usage when local trip rates are not available. Therefore, based on NCHRP Report 365, the vehicle trip rate in small urban areas should be about 8, but can be adjusted between 7 and 8 depending to knowledge of the planning area.

Step 5: Account for Trips Made by Residents Leaving The Area

Internal to internal (I-I) trips are those trips that originate in the study area and remain inside the study area. The percentage of I-I trips for an area is generally 80%-90% of all trips made by residents who live within the study area. A study area that has numerous attractions (such as Charlotte) would have a higher percentage of I-I trips, while a bedroom community like Pilot Mountain has fewer attractions and would have a lower percentage of I-I trips.

Use the following formula to determine I-I trips:

$$II\ Trips = (DU\ Trips + CV\ Trips) \times (Percent\ of\ \ II\ Trips) \qquad (11)$$

Internal to external (I-E) trips are those trips that originate in the study area and then leave the study area. Use the following formula to determine the I-E trips:

$$IE\ Trips = (DU\ Trips + CV\ Trips) - (II\ Trips) \qquad (12)$$

Example

Based on the calculations completed by step 4, the I-I trips and I-E trips for the Pilot Mountain planning area can be estimated.

For the base year (1995):
I-I trips = 11008 * 80% = 8806
I-E trips = 11008 – 8806 = 2202

For the design year (2020):
I-I trips = 14568 *80% = 11654
I-E trips= 14568 – 11654 = 2914

The summary of the I-I trips and the I-E trips is shown in Table D-9.

Table D-9. I-I Trips and I-E Trips for 1996 and 2020

Year	DU trips + CV trips	Percentage of I-I Trips	I-I Trips	I-E Trips
1995	11008	80%	8806	2202
2020	14568	80%	11654	2914

Issues

In this study, the percentage of I-I trips is taken as 80% based on the knowledge of trip patterns in the planning area, which also keep consistent with Thoroughfare Plan Report.

Step 6: Account for Non-home Based Trips Made by Non-residents

External to internal (E-I) trips are those trips that originate outside of the study area and end inside the study area. Use the following formula to determine the E-I trips:

$$EI\ Trips = (AADT - Through\ Trips) - (IE\ Trips) \qquad (13)$$

In general, the E-I trip will result in secondary internal to internal (I-I) trips in the planning area. The secondary I-I trips are usually estimated by assuming a percentage of the E-I trips. Use the following formula to determine the secondary I-I trips:

$$Secondary\ II\ Trips = (EI\ Trips) \times (Percent\ of\ \ Secondary\ Trips) \qquad (14)$$

The total internal to internal trips is the sum of I-I trips calculated in Step 5 and the secondary I-I trips, as the following formula shows:

$$Total\ \ II\ Trips = (II\ Trips) + (Secondary\ \ II\ Trips) \qquad (15)$$

Example

In step 2 and step 5, the IX trips and I-E trips were calculated, respectively. Therefore, for the base year (1995)

E-I Trips = 21970 – 2202 = 19768

and for the design year (2020):

E-I Trips = 48786 – 2914 = 45872

By assuming I-E trips produce 20% secondary I-I trips, we can calculate the total internal trips as below.

For the base year (1995):

Secondary I-I Trips = 19768 * 20% = 3954
Total I-I Trips = 8806 + 3954 = 12760

For the design year (2020):

Secondary I-I Trips = 45872 * 20% = 9174
Total I-I Trips = 11654 + 9174 = 20829

The E-I trips, secondary I-I trips and total I-I trip values are shown in Table D-10.

Table D-10. E-I Trips, Secondary I-I Trips and Total I-I Trips Values

Year	I-I Trips	E-I Trips	Percent of Secondary Trips	Secondary Trips	Total Internal Trips
1995	8806	19768	20%	3954	12760
2020	11654	45872	20%	9174	20829

Issues

1. The percentage of secondary I-I trips is an estimated value, which is determined based on the knowledge of the traffic patterns in the study area. The value of 20% is used in this study.

2. The secondary I-I trips are produced by the E-I trips rather than both the I-E and E-I trips (IX trips). Therefore, a problem exists in Technical Report 11, where the secondary I-I trips were calculated by the IX trips.

Step 7A: Develop Through Trip Table

Through trips are produced outside the planning area and pass through in route to a destination which is also outside the planning area. The through trip table for this study was developed using SYNTH, a computer program developed by James T. McDonnell, of the Thoroughfare Planning Branch. This program was based upon ***Technical Report #3, Synthesized Through Trip Table for Small Urban Areas***, by David G. Modlin. This method of developing through trips is based on the Fratar balancing method which balances the trip interchanges at the external stations.

The SYNTH program output was used in conjunction with engineering judgment and knowledge to derive the number of trip-ends passing through each external station. These through trip percentages vary depending on the function of the road.

The spreadsheet model will directly use the through trip tables as given information to develop the PA matrix. Therefore, through trip tables should be run by Synth in advance and input in “Input” worksheet.

Example

Truck percentage and roadway classification of each link in the network are shown in Table D-11.

Table D-11. Truck Percentage and Roadway Classification of Links

Station Number	Station Location	Roadway Classification	Truck Percent
# 11	US 52 (North)	P	20%
# 12	Westfield Road (SR 1809)	J	0
# 13	NC 268 (East)	M	5%
# 14	Old Hwy 52 (SR 1855)	J	0
# 15	US 52 (South)	P	20%
# 16	Shoals Road (SR 2048)	L	0
# 17	NC 268 (West)	M	5%

SYNTH uses the following, the functional classifications of roadways:

I = Interstate;
P = Principle Arterial;
M = Minor Arterial;
J = Major Connector;
L = Minor Connector / Local Road.

Using SYNTH, through trip tables for the planning area in the base year (1995) and the design year (2020) can be developed, as shown in Table D-12 and Table D-13.

Issues

The Thoroughfare Plan Report provides a recent O-D survey. The through trip percentages may be taken directly from the OD survey and used to develop through trip tables by SYNTH rather than the through trip percentage estimated by SYNTH.

Table D-12. 1995 Through Trip Table

1995 Through Trip Table								
To / From	**# 11**	**# 12**	**# 13**	**# 14**	**# 15**	**# 16**	**# 17**	**Total**
# 11	0	121	143	26	8882	60	264	9496
# 12	121	0	3	0	177	6	6	313
# 13	143	3	0	0	250	5	29	430
# 14	26	0	0	0	46	1	1	74
# 15	8882	177	250	46	0	59	267	9681
# 16	60	6	5	1	59	0	5	136
# 17	264	6	29	1	267	5	0	572
Total	9496	313	430	74	9681	136	572	20702

Table D-13. 2020 Through Trip Table

2020 Through Trip Table								
To / From	**# 11**	**# 12**	**# 13**	**# 14**	**# 15**	**# 16**	**# 17**	**Total**
# 11	0	224	253	54	20988	85	620	22224
# 12	224	0	4	1	356	12	12	609
# 13	253	4	0	0	494	7	52	810
# 14	54	1	0	0	105	1	1	162
# 15	20988	356	494	105	0	83	666	22692
# 16	85	12	7	1	83	0	8	196
# 17	620	12	52	1	666	8	0	1359
Total	22224	609	810	162	22692	196	1359	48052

Step 7B: Develop IX Trip Tables

IX trips have one end of the trip inside the planning area, with the other end located outside of the planning area. These trips are generated at the external station and as a component of the external station traffic count. These trips are made up of external to internal (E-I) trips and internal to external (I-E) trips.

<u>E-I Trip Table</u>

In Step 6, the total E-I trips attracted to the planning area are calculated. Then, the E-I trips from external stations to zones can be calculated by the formula below:

$$EI_{ij} = EI_{total} \times \frac{IX_i}{\sum_i IX_i} \times \frac{Employment_j}{\sum_j Employment_j} \tag{16}$$

Where,

EI_{ij} = E-I trips from external station i to zone j;

EI_{total} = total E-I trips attracted to the planning area, calculated by Step 6;

IX_i = IX trips at external station i;

$Employment_j$ = employment of zone j.

I-E Trip Table

In Step 5, the total I-E trips produced by the planning area are calculated. Then, the I-E trips from zones to external stations can be calculated by the formula below:

$$IE_{ij} = IE_{total} \times \frac{Household_i}{\sum_i Household_i} \times \frac{IX_j}{\sum_j IX_j} \tag{17}$$

where,

IE_{ij} = I-E trips from zone i to external station j;

IE_{total} = total I-E trips produced by the planning area, calculated by Step 5;

$Household_i$ = households of zone i;

IX_j = IX trips at external station j.

Example

Table D-14 provides the IX trips and percentages at each external station in the planning area, Pilot Mountain, in the base year (1995) and the design year (2020).

Table D-14. IX Trips and Percentages at External Stations for 1995 and 2020

Station Number	Station Location	1995 Base Year		2020 Design Year	
		IX Trips	Percent	IX Trips	Percent
# 11	US 52 (North)	5908	26.89%	15253	31.27%
# 12	Westfield Road (SR 1809)	3492	15.89%	6784	13.91%
# 13	NC 268 (East)	2342	10.66%	4380	8.98%
# 14	Old Hwy 52 (SR 1855)	754	3.43%	1675	3.43%
# 15	US 52 (South)	4292	19.54%	10509	21.54%
# 16	Shoals Road (SR 2048)	2228	10.14%	3207	6.57%
# 17	NC 268 (West)	2954	13.45%	6978	14.30%
Total		21970	100%	48786	100%

The total E-I trips attracted to the planning area are 19768 and 45872 in 1995 and 2020, respectively (See Step 6). And the employment percentages of each zone are shown in Table D-15.

Table D-15. Employment Percentages

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
1995 Empl Percent	15.45%	62.10%	2.44%	11.79%	8.22%
2020 Empl Percent	15.45%	62.06%	2.43%	11.82%	8.24%

Therefore, for example, the E-I trips from external station #17 to zone 1 in 1995 can be calculated as shown below:

$EI_{\#17\text{-}1}$ = 19768*13.45%*15.45% = 411

Similar calculations are conducted for other external stations and zones for both 1995 and 2020. Thus, the final E-I trip table is developed as shown by Table D-16.

Table D-16. E-I Trips in 1995 and 2020

E-I Trips Table for 1995 Base Year						
To / From	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**	**Zone 5**	**Total**
Station # 11	821	3301	130	627	437	5316
Station # 12	485	1951	77	370	258	3142
Station # 13	326	1309	51	248	173	2107
Station # 14	105	421	17	80	56	678
Station # 15	597	2398	94	455	317	3862
Station # 16	310	1245	49	236	165	2005
Station # 17	411	1651	65	313	218	2658
Total	3054	12277	482	2330	1625	19768
E-I Trips Table for 2020 Design Year						
To / From	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**	**Zone 5**	**Total**
Station # 11	2216	8901	348	1695	1182	14342
Station # 12	986	3959	155	754	526	6379
Station # 13	636	2556	100	487	339	4118
Station # 14	243	977	38	186	130	1575
Station # 15	1527	6133	240	1168	814	9881
Station # 16	466	1872	73	356	248	3015
Station # 17	1014	4072	159	775	541	6561
Total	7089	28471	1113	5420	3780	45872

The total I-E trips produced by the planning area are 2202 and 2914 in the base year (1995) and the design year (2020), respectively. The housing percentage of each zone is shown in Table D-17.

Table D-17. Housing Percentages

	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**Zone 5**
1995 Housing Percent	27.76%	46.52%	11.49%	8.21%	6.02%
2020 Housing Percent	29.03%	46.15%	11.20%	8.07%	5.55%

Therefore, for example, the I-E trips from zone 1 to external station #17 in 1995 can be calculated as below:

$IE_{1\text{-}\#17} = 2202 * 27.76\% * 13.45\% = 82$

Similar calculations are conducted for other zones and external stations for both 1995 and 2020. Thus, the final I-E trip table is developed as shown by Table D-18.

Table D-18. I-E Trips in 1995 and 2020

I-E Trips Table for 1995 Base Year								
To / From	Station #11	Station #12	Station #13	Station #14	Station #15	Station #16	Station #17	Total
Zone 1	164	97	65	21	119	62	82	611
Zone 2	275	163	109	35	200	104	138	1024
Zone 3	68	40	27	9	49	26	34	253
Zone 4	49	29	19	6	35	18	24	181
Zone 5	36	21	14	5	26	13	18	133
Total	592	350	235	76	430	223	296	2202
I-E Trips Table for 2020 Design Year								
To / From	Station #11	Station #12	Station #13	Station #14	Station #15	Station #16	Station #17	Total
Zone 1	264	118	76	29	182	56	121	846
Zone 2	420	187	121	46	290	88	192	1508
Zone 3	102	45	29	11	70	21	47	163
Zone 4	73	33	21	8	51	15	34	235
Zone 5	51	22	15	6	35	11	23	162
Total	911	405	262	100	628	192	417	2914

Issues

1. E-I trips should be allocated to internal zones based on the relative trip attractiveness as judged by knowledge of the land use in each zone. In this study, trip attractiveness is considered to be determined by employment of each zone in the planning area. In addition, the E-I trips are assigned to each external station approximately by external trip percentage at each external station.

2. I-E trips should be allocated to internal zones based on the relative trip production as judged by knowledge of the land use in each zone. In this study, trip production is considered to be determined by housing in each zone in the planning area. In addition, the I-E trips are assigned to each external station approximately by external trip percentage at each external station.

Step 7C: Develop I- I Trip Tables

Internal trips (I-I) have both their origin and destination inside the planning area. Internal trips should be allocated between zones (interzonal trips) based on relative attractiveness between zones and production of each zone. In this study, the total internal trips are calculated in Step 5, then they are allocated following the formula below:

$$II_{ij} = II_{total} \times \frac{Household_i}{\sum_i Household_i} \times \frac{Employment_j}{\sum_j Employment_j} \qquad (18)$$

Where,

II_{ij} = I-I trips from zone i to zone j;

II_{total} = total I-I trips in the planning area, calculated by Step 5;

$Household_i$ = households of zone i;

$Employment_j$ = employment of zone j.

Example

In step 5, the total internal trips are calculated as 12,760 and 20,829 for 1995 and 2020, respectively. Table D-19 and Table D-20 provide housing and employment percentages of each zone for both 1995 and 2020, respectively. Therefore, I-I trips from zone 1 to zone 2 in 1995 can be calculated as shown below:

$I\text{-}I_{1\text{-}2}$ = 12760*27.76%*62.24% = 2204
I-I trips within zone 1 in 1995 can be calculated as shown below:
$I\text{-}I_{1\text{-}1}$ = 12760*27.76%*15.45% = 547

Similar calculations are conducted for other zones for 1995 and 2020. Thus, the final I-I trip table is developed as shown by Table D-21.

Issues

I-I trips should be allocated between internal zones based on the relative trip attractiveness and production as judged by knowledge of the land use in each zone. In this study, trip attractiveness is considered to be determined by employment of each zone in the planning area, and production is considered to be determined by housing.

Table D-19. Zonal Housing Percentages

	1995 Housing Percent	2020 Housing Percent
Zone 1	27.76%	29.03%
Zone 2	46.52%	46.15%
Zone 3	11.49%	11.20%
Zone 4	8.21%	8.07%
Zone 5	6.02%	5.55%
Total	100%	100%

Table D-20. Zonal Employment Percentages

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Total
1995 Employment Percent	15.45%	62.10%	2.44%	11.79%	8.22%	100%
2020 Employment Percent	15.45%	62.06%	2.43%	11.82%	8.24%	100%

Table D-21. I-I Trips Table for 1995 and 2020

I-I Trips Table for 1995 Base Year						
To / From	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Total
Zone 1	547	2200	86	418	291	3542
Zone 2	917	3687	145	700	488	5936
Zone 3	227	911	36	173	121	1467
Zone 4	162	651	26	123	86	1048
Zone 5	119	477	19	91	63	768
Total	1971	7924	311	1504	1049	12760
I-I Trips Table for 2020 Design Year						
To / From	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Total
Zone 1	935	3753	147	715	498	6047
Zone 2	1485	5965	233	1136	792	9612
Zone 3	361	1448	57	276	192	2333
Zone 4	260	1043	41	199	138	1680
Zone 5	179	717	28	137	95	1156
Total	3219	12927	505	2461	1716	20829

Step 8: Assign Base Year Trips and Check against Ground Counts

The outputs of the spreadsheet model are a PA matrix and an OD matrix, which are produced by Step 1 through Step 7C. The developed OD matrix can be directly used for traffic assignment.

For small urban areas traffic assignment can be done by hand or by computer. For small urban areas which have up to four internal TAZs, up to five external stations and a very simple road network, it is probably easier and quicker to do a hand assignment. A hand assignment will also provide intuitive knowledge of travel movements which will be useful in subsequent benefits analysis. If the planning area has more internal TAZs, more external stations, or a more complicated road network, a computer-based traffic assignment will be preferred for efficiency and accuracy.

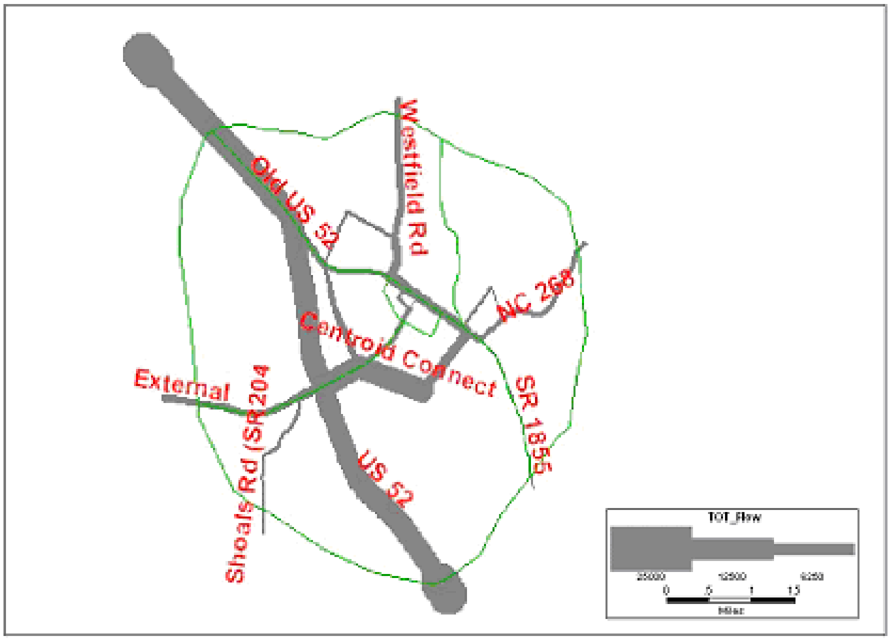
In this case study, TransCAD is used to do the computer traffic assignment. After importing the OD matrix into TransCAD, traffic assignment can be done by choosing the appropriate assignment method. Instructions for this procedure are in *Modeling 101, NCDOT*.

While checking the results of the loadings against ground counts, screenline analysis is recommended. A screenline is an imaginary line on a map, and it is composed of one or more straight line segments. In screenline analysis, all the links crossed by each screenline form a group for which the total directional ground traffic counts and the total directional assigned volumes are calculated. The ratio between the two sums is then used as an indicator for the accuracy for the assignment results at the screenline location.

<u>Example</u>

Figure D-1 in Step 1 shows the roadway network used in this case study. Only a few major routes are included in this network. User equilibrium method is taken in this case study to assign trips to the roadway network. The assignment results are shown in Figure D-5.

Figure D-5. 1995 Base Year Assignment (User Equilibrium)



In this case study, one screenline (cordon line) is built to evaluate the estimated traffic on major routes. Figure D-6 and Table D-22 show the screenline and the analysis results, respectively.

Figure D-6. Screenline

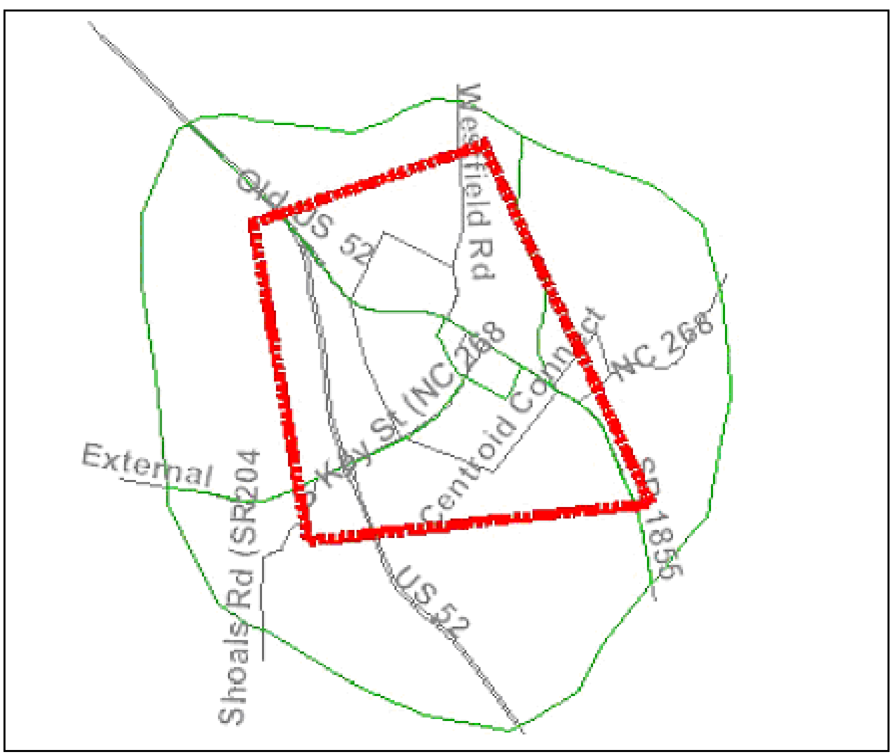


Table D-22. Screenline Analysis

Name	IN_FLOW	IN_COUNT	IN_RATIO	OUT_FLOW	OUT_COUNT	OUT_RATIO	TOT_FLOW	TOT_COUNT	TOT_RATIO
ScreenLine 1	39043	38135	1.02	39034	38135	1.02	78086	76270	1.02

Issues

1. There are several assignment methods available in TransCAD. In this case study, user equilibrium method is taken only as an example. All-or nothing assignment is often used for small cities but it can over estimate the demand for new high speed facilities. Some practitioners recommend stochastic assignment because it has an adjustment parameter. Others may use iterative capacity restraint (Appendix E).

2. All major routes, minor routes, centroid connectors and any combination of them can be checked by screenline analysis. This case study only shows one screenline to check assignment on major routes. The results of screenline analysis shows that, according to "in" and "out" directions as well as total volume, ratios of assigned flow to ground counts are all 1.02, which means the assigned trips to the network are very close to ground counts. Therefore, the travel allocation model is very consistent with ground counts.

Step 9: Assign Future Year Trips

Repeat Steps 3 through 8 using the estimated future year (2020) data. Assume that traffic will travel using the same routes used to complete the base year assignment. Make adjustment to these routes if any significant future development occurs in the planning area.

Example

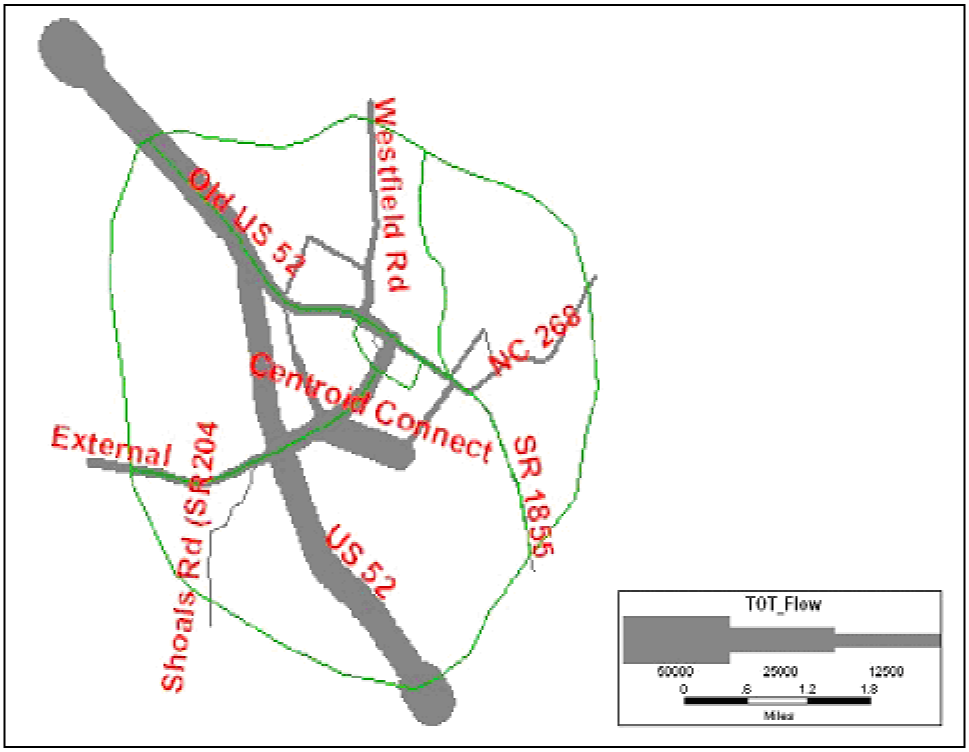
In this case study, traffic in 2020 is assumed to travel on the same roadway network which is used to complete the base year assignment. Similar to the base year, the future year trips are assigned by using user equilibrium in TransCAD, as shown in Figure D-7.

Issues

The "*1998 Thoroughfare Plan Study of Pilot Mountain*" (NCDOT) made a series of planning recommendations. The two major proposals alleviate traffic along US 268 (Key Street), which serves as the main artery through the town. The first suggestion is the widening of US 268 (Key Street) to a five-lane road with curb and gutter. Local officials feel that improving the traffic capacity of US 268 would attract new business along that route. The second recommends a NC 268 east-west bypass for the south side of the town to connect with the east end of Main Street. This by-pass would be a two-lane thoroughfare. However, in this case study, it is assumed that future traffic will still travel on the same roadway network as base year.

Step 10: Determine Any Existing or Future Roadway Deficiencies
Roadway deficiencies exist anywhere that the volume of traffic is close to or exceeds the practical capacity of the roadway. NCDOT staff typically use the capacity that corresponds to a level of service (LOS) D as the practical capacity for roadways within the study area.

Figure D-7. 2000 Design Year Assignment (User Equilibrium)



In this study, the following volume-to-capacity (V/C) ratios to indicate roadway deficiencies:

- Near Capacity – the V/C ratio is between 0.8 and 1.0; and
- Over Capacity – the V/C ratio is greater than 1.0

Example

After assigning base year and future year trips to the roadway network, we can find locations with V/C ratio over 0.8. Figure D-8 and D-9 show the V/C ratios on the roadway network in base year (1995) and design year (2020), respectively. In addition, Table D-23 lists the major routes and their V/C ratios.

Issues

In this study, any routes with V/C ratio over 0.8 will be considered to be deficient. According to TableD-23, only US 52 and Key Street are deficient in 1995; while almost all major routes except Shoals Road are deficient in 2020.

This study indicates that the V/C ratio of Key Street increase to 1.90 from 1.08 for the design year; therefore, improvement should be made to Key Street, which keeps consistent with the conclusion drawn from Thoroughfare Report.

This study also indicates that the V/C ratios significantly increase on US 52, Westfield Road and Old Hwy 52, with changes from 0.92 to 2.21, 0.53 to 0.97, and 0.63 to 1.77, respectively. Therefore, improvement should also be made to these routes to meet the future travel demand.

Figure D-8. V/C Ratios on 1995 Base Year Network

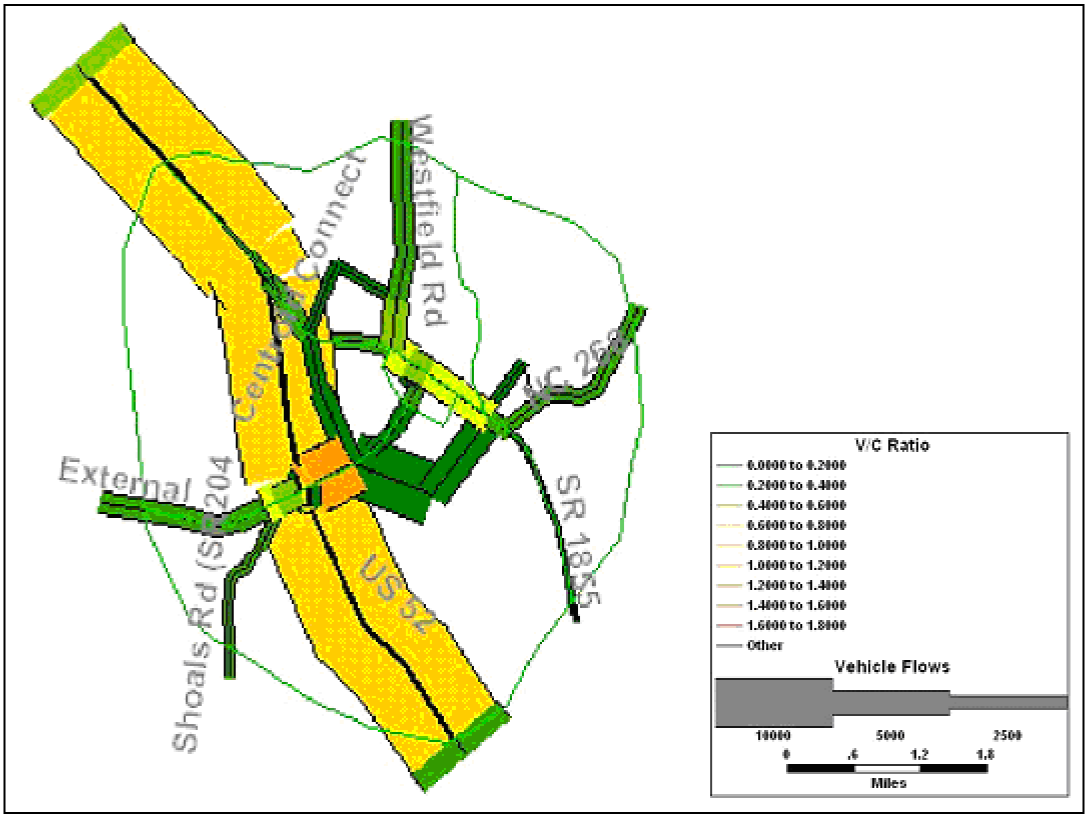


Figure D-9. V/C Ratios on 2020 Design Year Network

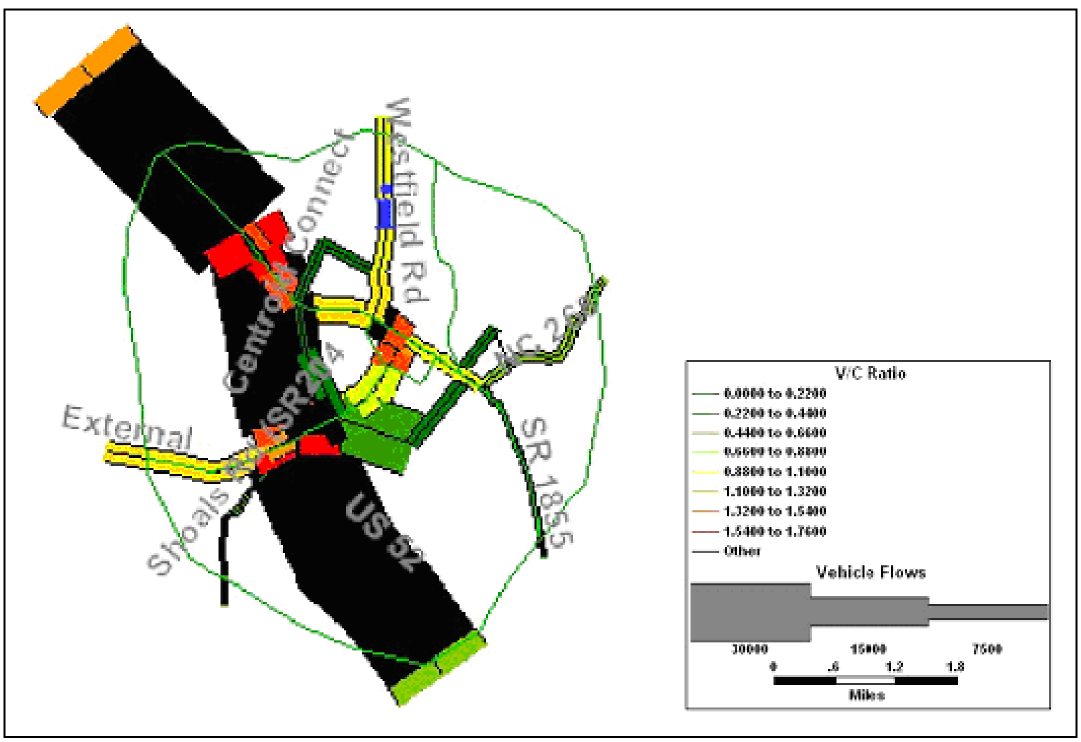


Table D-23. V/C Ratios and Deficiencies for Major Routes

Major Routes in Network	1995 Base Year		2020 Design Year	
	V/C Ratio	Deficiency	V/C Ratio	Deficiency
US 52	0.92	Yes	2.21	Yes
Westfield Road (SR 1809)	0.53	No	0.97	Yes
Key Street (NC 268)	1.08	Yes	1.90	Yes
Old Hwy 52 (SR 1855)	0.63	No	1.77	Yes
Shoals Road (SR 2048)	0.21	No	0.30	No

References:

1. Marion R. Poole, *Technical Report #11: Allocation Type Approach to Estimation of Travel for Small Urban Areas*, NCDOT Statewide Planning Branch, 1989.
2. Terry C. Arellano and Deborah Hutchings, *Thoroughfare Plan Study Report for The Town of Pilot Mountain*, NCDOT Thoroughfare Planning Branch, 1998.
3. http://census.state.nc.us/lookup
4. http://quickfacts.census.gov/qfd/states/37000lk.html
5. http://lilnc.state.nc.us/
6. David G. Modlin, *Synthesized Through Trip Table for Small Urban Areas*, NCDOT Thoroughfare Planning Branch, 1982.
7. William A. Martin and Nancy A. Mcguckin, *NCHRP Report 365: Travel Estimation Techniques for Urban Planning*, Transportation Research Board, National Academy Press, 1998.
8. Rhett Fussell, *Modeling 101: A Guide to Building A Travel Demand Model in TransCAD*, NCDOT Thoroughfare Planning Branch, 2002.
9. *TransCAD User's Guide*, Caliper Corporation, 2000.
10. *Travel Demand Modeling with TransCAD 4.5*, Caliper Corporation, 2000.

APPENDIX E: TRANSCAD QUICK RESPONSE - WENDELL

Overview

The North Carolina Department of Transportation (NCDOT) has a long history of travel demand forecasting, with planning analysis work dating back to the 1960s. Not only has NCDOT developed travel demand models for 17 urbanized areas across the state, but engineers have also conducted travel demand forecasting analysis and developed transportation plans for smaller incorporated municipalities. In the early years of travel modeling at NCDOT most of the modeling and analysis work was performed by a relatively small and knowledgeable staff that had an opportunity to do modeling on a regular basis. Over the years, the scope of responsibility for the Transportation Planning Branch at NCDOT has increased resulting in less time for modeling and analysis. This trend coupled with the loss of more experienced and knowledgeable staff has led to an erosion of modeling skills and institutional knowledge on modeling practices.

This document is intended to provide a set of guidelines for recommended practice in developing travel forecasting analysis tools for communities with population between 5,000 and 10,000. The guidelines are presented through a case study analysis of a small community in Wake County, North Carolina. Specifically, the following topics will be addressed:

- Transportation Data
- Basic Land Use Data for Modeling
- Trip Generation
- Trip Distribution
- Trip Assignment
- Model Validation and Reasonableness Checks

The format of each section is designed to provide the reader with general guidelines for developing a travel forecast model using a best practice approach. Best practice comes not only from applying the steps in the process in a conscientious manner, but also from performing reasonableness checks on the inputs and outputs and documenting this process for others. Recommendations for model validation and reasonableness checks are based on the TMIP manual on model validation and reasonableness checking prepared by Barton-Aschman Associates, Inc. and Cambridge Systematics, Inc., February 1997.

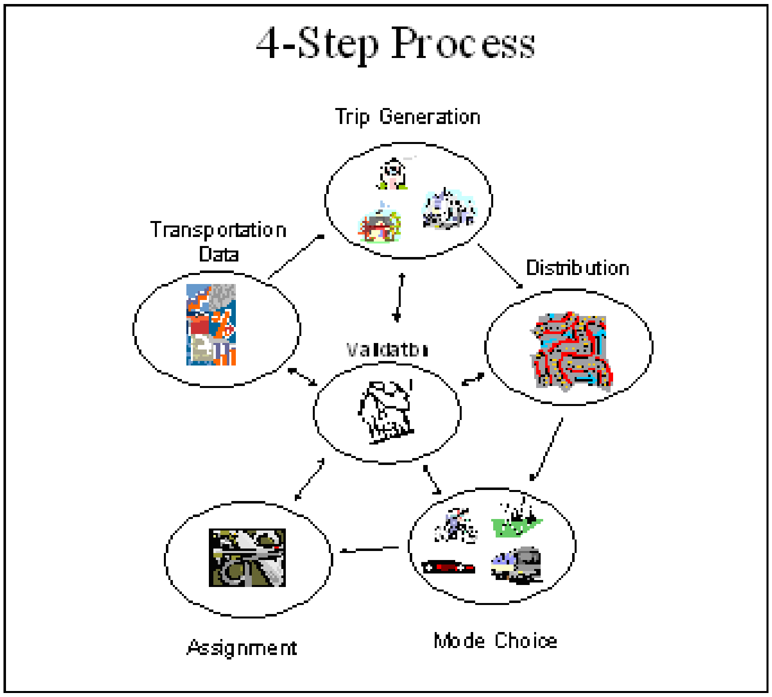
Approach

North Carolina uses the basic four-step process to develop transportation models for its urban areas. The four-step process includes trip generation, trip distribution, mode choice, and trip assignment. Other key elements of the process are transportation data and validation. The process flow is illustrated in Figure E-1. It can be seen from Figure E-1 that validation and/or reasonableness checking should be done during the development of each individual model component. Too often the process of calibration focuses only on the overall results of the travel model, typically a comparison of ground counts. The approach advocated for best practice performs reasonableness checks at each step. In addition to explaining what goes into the development of each model component, this appendix provides the user with guidelines for performing and documenting these reasonableness checks.

Transportation Data

The transportation data needed for the travel model is often the most expensive part of the model development process and it is also the most important. The data sets developed for the model are used not

Figure E-1. Four Step Process



only as model inputs, but also to estimate, calibrate, and validate the various individual model components. The basic data components in travel modeling are the street network and the socioeconomic or land use data aggregated into traffic analysis zones (TAZs). This section describes a best practice approach for selecting the roadway system to be analyzed, developing a zone structure that compliments the roadway system, and recommended roadway attribute data that should be coded. This section also covers recommend steps for checking each of these data elements.

<u>Determining the Study Area</u>

One of the first steps for any transportation planning study and travel demand model is determining the study area. The study area should be large enough so that nearly all (over 90%) of the trips will likely begin and end within the study area boundary through the planning horizon, typically 20 – 30 years. This can be accomplished by including all of the area that is anticipated to be urban within the planning horizon. The following guidelines should be followed when selecting this boundary:

- Identify the boundary such that major roadway crossings are minimized.
- Take into consideration political jurisdictions, census area boundaries, and natural boundaries.
- Include the major “commuter shed”, the area that provides most of the commuter trips.
- If using census data be sure that the boundary does not violate census block geography.

<u>Transportation Network</u>

The transportation network is a key input in the travel demand modeling process. The highway network provides the model with information relative to the time and cost of travel. Best practice modeling reflects a geographic relationship between the number of network links and the number of traffic analysis zones. A coarse network is supported by a coarse zone structure and a detailed network is supported by a detailed zone structure. Not all streets in the study area are included in the transportation network. The determination of which facilities to include is based on the level of analysis to be conducted.

Selecting the network

The minimum network for a travel model should typically be the system of functionally classified roadways, collectors and above. Additional facilities may be needed to provide a reasonable representation of actual travel patterns and to allow for connectivity. A useful guideline in assessing the adequacy of network coverage is that at least 85% of all interzonal travel should occur on the facilities represented in the network. The criteria below can be used as a guide for selecting network roadways.

1. Consider all functionally classified roadways, collector and above.
2. Consider locally classified roadways where they provide important network connectivity.
3. Consider links necessary to achieve a balance between zone and network compatibility.
4. Consider coding all roadways with signalized control at intersections.

TIP: The travel model should not be used to analyze traffic on the lowest classification of roadway in your model (typically collectors). Don't expect your model to closely replicate the ground counts on those lower level facilities. See Section on Traffic Assignment for recommended performance measures by facility type.

Attributes to code

Facility Type

Facility type defines the general operating characteristics of the facility and is useful in determining the capacity and free flow speed. For more advanced assignment techniques having accurate facility type coding can also assist in the selection of appropriate volume-delay curves. The facility type categories listed below are suggested categories to consider.

- Freeway (urban and rural)
- Multilane Highway (urban and rural)
- Two-lane Rural Highway (Class I or II)
- Urban Street (Arterial Classes I, II, III, and IV)
- Collectors and Locals
- Centroid connectors

Functional Classification

Unlike the facility type, the functional classification does not necessarily represent the operating characteristics of the roadway, but is based on the general framework outlined in the FHWA Functional Classification Guidelines (http://www.fhwa.dot.gov/planning/fctoc.htm). It is important to note that functional classification is bounded by mileage limitations for each State. These limitations can often lead to roadways being functionally classified into categories that are not well aligned with the operating characteristics represented by the facility type coded. The functional classification is needed to summarize the data required for air quality analysis. Functional classification is also needed to create assignment validation summaries. The functional classification for facilities in the planning area should be based on the official functional classification maps, as recommended by NCDOT and approved by FHWA.

Speed

Link speeds are a major input in the highway network because they are used to determine the minimum path between different areas of the planning region. In practice, it is easiest to code the posted speed limit and then use a formula or look-up table to calculate the free flow speed. The free flow speed will vary depending on prevailing traffic volume, posted speed, adjacent land use, access control, type of facility, intersection control, and spacing of intersections.

Capacity

Capacity can be defined as the reasonable maximum hourly rate of flow at a given point or segment during a given time period under prevailing conditions. When using a capacity restrained assignment, LOS E capacity should be coded for link capacity. The "policy LOS" or LOS D can also be coded to facilitate the evaluation of future alternatives for plan evaluation, but the LOS E capacity should be used for model analysis. The NCDOT has recently adopted a LOS software tool – NCLOS Analysis Software. This tool should be used to determine the capacity values for the facility types. All assumptions should be clearly documented.

Traffic Analysis Zones

Traffic analysis zones represent the unit of geography used for travel analysis in a travel demand model. These analysis zones enable the analyst to link information about activities and travel to the transportation system. Zones vary in size depending on the density and nature of the urban development. The smallest zones are typically located in the CBD and the larger zones are in the more undeveloped areas. The size of the traffic analysis zones should reflect the level of analysis desired.

If developing a model for an area that was previously modeled, the original zone structure should be adhered to as much as possible, unless there is reason to justify doing otherwise. Maintaining the original zone structure enables the tracking of changes from a previous study to the current one. However, there are times when new zones may need to be added due to an expansion of the study area, incompatibility of the zone structure with the highway network being evaluated, changes in the amount or type of development, or the adoption of census based zones. In defining zones, the following guidelines should be followed:

- The size of the zones should reflect the level of analysis desired.
- Zones should bound homogeneous activities as much as possible (residential, commercial, industrial, mixed use, etc.)
- Zones should consider natural boundaries and census designations.
- Zones should follow geographic boundaries where possible (roads, railroads, streams, etc.)
- The density of development across the zone should be relatively even.
- The number of trips generated by each zone should be relatively equal and the total trips generated by any one zone should be less than 10 – 15 thousand.
- The size of the traffic analysis zones should reflect the purpose of the intended analysis.
- IMPORTANT: It is important when establishing zones to consider their compatibilities with the transportation network to be used. Consideration should be given to how the zone will load to the network.
- GENERAL RULE: The network should form the boundaries of the zones.

Zone-Network Relationship

It is important to consider the relationship between the levels of detail represented by the roadway network in comparison to the level of detail for the zones. The key to this relationship is related to the number of intrazonal trips (trips whose origin and destination are within the same zone) present in the model. The larger the zone is, the higher the number of intrazonal trips. Therefore, a model with coarse zones and a fine network will result in an under assignment of trips because more trips stay within the zone and fewer trips are left to be assigned to the network. Conversely, a model with very small zones and a coarse network will result in an over assignment of trips as there are fewer intrazonal trips and fewer roadways to handle the trips assigned to the network. A proper balance between zones and network will lead to better assignment results.

Centroid Connectors

Travel is assigned to the street network from the centroid of each zone via a centroid connector. This centroid is a fictitious node from which all trips begin and end. This node typically represents the center of activity for the TAZ, not necessarily the geographic center. Determination of the center of activity is a judgment call based on street maps, aerial photography, and knowledge of the area.

Each centroid node is connected to the network by centroid connectors. These are fictitious links representing all local streets and access points to the network within the zone. The centroid connectors represent paths out of a zone and should not be linked to the network where actual connections do not exist. For example, if a zone is bounded by a river with no bridges then a centroid connector should not be coded on this side of the zone. The number of centroid connectors typically ranges between 2 and 4 as needed to represent underlying connectivity. For large traffic generators consider coding as many centroid connectors as possible in order to minimize the overloading impacts on the network in the vicinity of the centroid connector. Ideally centroid connectors should not connect directly to an intersection, but should connect mid block.

External Stations

External stations represent external traffic analysis zones and perform similar to zone centroids. They are located along the planning area boundary at every point where a network roadway crosses the planning boundary. These nodes represent all traffic generated by and attracted to regions outside of the planning area. A typical way of coding external stations is to carry the network link to the planning area boundary and attach the external station via a short centroid connector link. External stations typically have only one connector since they represent a single access point.

Screenlines, Cordons, and Cutlines

Screenlines, cutlines, and cordons are imaginary lines that are critical to the model validation process. When developing multi-county models, the county boundary should always be identified as either a screenline or cordon to facilitate the use of Census Journey to Work data in the validation of trip distribution. *Screenlines* are used to validate regional flows across the transportation network. They typically run north-south and east-west from one end of the planning area boundary to the other. Ideally screenlines should be associated with geographic features that have minimal roadways crossing, such as rivers, and should avoid bisecting heavily developed areas or areas with dense roadway patterns. Screenlines should be located in such a manner as to capture directional flows across the region while minimizing the number of roadway crossings. A *cutline* is an imaginary line that does not completely bisect the area where flow is to be captured, but rather captures flow along a particular axis. Cutlines are often used to capture flow through a corridor or in areas with minimal count locations. *Cordons* are used to identify the boundary of the study area, but they are also useful for validation when they are used to cordon off unique regions or sub regions within the study area. The planning area boundary can be thought of as a cordon in that it completely encompasses the planning area. Good examples of where internal cordons may be useful include the CBD, college campuses, unique districts, and small communities within larger multi-community models.

Traffic Counts

Traffic counts are used to validate the overall highway assignment. Counts should be taken during the same time period for which the land use data and highway network data are collected. This should represent the "snap shot" of time against which the model is validated. Since the screenlines, cutlines, and cordons in the model represent all modeled flow across the boundary, traffic counts should be taken for all roadways crossing one of these imaginary lines whether the roadway being counted is in the model or not. The traffic counts for roadways not in the model should be allocated to the adjacent modeled roadway links that cross the screenline, cutline, or cordons in question.

Performance/Reasonableness Checks for Transportation Data

The most likely sources of error in a travel demand model result from errors in the underlying network coding or zonal data. For this reason it is most important to spend adequate time reviewing the transportation networks and associated data attributes. Validation checks for the roadway network should include an overall visual inspection, but should focus on checking ranges of speeds, capacities, and facility types. Network connectivity, missing nodes, missing links, and one-way links going in the wrong direction can also cause significant problems with network path building. Use minimum path techniques to check for coding errors in link values that impact travel time calculations. Traffic counts should be reviewed for reasonableness using measure such as volume per lane and historic growth rate trends if historic data is available.

Land Use / Demographic Data

Land use data is a critical element of any planning analysis work. The collection of the land use data needed to support planning analysis work can be expensive and time consuming. Various approaches exist for collecting this data needed ranging from 100% field inventories to utilizing existing data sources such as the US Census. The Table E-1, extracted from *A Manual of Regional Transportation Modeling Practice for Air Quality Analysis*, outlines various data types and suggested sources.

Table E-1. Suggested Data Sources

Data Type	Best Source	Back-Up Source	Alternate Estimation Method
Socio-Economic Data			
Households by structure type by zone	Latest U.S. Census. Split tracts as necessary	Aerial photos and field counts	Building permits; utility company records
Employment by zone by type	Latest Census Transportation Planning Package (CTPP). Split census tract data as necessary.	State employer; office data by zip code. Split zip codes as necessary.	Derive from surveys of floor space and average employee densities (not recommended).
Households stratified by income	Latest U.S. Census	Derive from median income (less satisfactory)	State income tax records (if available)
Households stratified by auto ownership	Latest U.S. Census	Use median income to estimate auto ownership	Motor vehicle department records

Performance/Reasonableness Checks for Land Use Data

The land use data is a critical building block for the travel forecast model. As such it is essential to perform reasonableness checks on this data at the zonal, regional, and aggregate levels. Basic checks should include a review of the following:

- Total population;
- Total households or dwelling units;
- Total employment;
- Total employment by employment type;
- Persons per household or persons per dwelling unit;
- Population/employment ratio (typical ranges are between 40-60%);
- Vehicles/household (if used);
- Workers/household (if used);
- Vehicle ownership trends (if used); and
- Plots of densities and density changes for FY data.

Trip Generation

Overview

The trip generation step is the process of calculating the total number of trips produced and attracted to each zone in the planning area. The most common forms of the trip generation model are regression equations and cross-classification tables. Trip rates are typically developed from local survey data. In lieu of developing rates from local data, trip rates can be borrowed from another region with survey data or default rates from NCHRP Report 365 can be used.

Recommended Practice

For most models the recommended practice is to stratify trips by trip purpose. This stratification allows the analyst to capture differences in average trip length for the various types of trips. The most common trip purposes used are Home-Based trips and Non-Home-Based trips. Home-based trips are further stratified into work and non-work. For more advanced models these trip purposes may be stratified even further to include home-based retail, home-based school, non-home based work, and non-home based non-work. For small urban models three internal trip purposes, (HBW, HBO, NHB) with a simple regression model formulation should be sufficient to capture trip making in the region.

Performance/Reasonableness Checks for Trip Generation

The results of the production model and the attraction model should be checked separately and then the unbalanced productions should be compared to the unbalanced attractions. If this ratio is not between 0.90 and 1.10 then the production and attraction model specification should be reviewed and the land use data should be further reviewed. If there is confidence in the land use data then the production and/or attraction rates should be adjusted such that you are within the range of the acceptable standard for unbalanced productions and attractions. In trying to determine whether to adjust production rates on attraction rates, use the reasonableness checks below to guide your decision.

- Review total trip productions per household for reasonableness – some typical ranges of production rates from previous survey efforts are shown in Table E-2.
- Calculate total trips by purpose and compare percentages by trip purpose to the ranges provided in Table E-3.
- Compare attraction rates with other areas as a reasonableness check. Attraction rates from the Triangle Region are shown in Table E-4.

- Review home-based work trip attractions per total employment.
- Review home-based school trips per school enrollment (if used.)
- Review home-based shopping trips per retail employment (if used.)
- Evaluate productions, attractions, and land use variables for reasonable relationships.
- Calculate trip rate per capita (total trips/population). This value should be over 3.0 and generally in the range of 3.5 – 4.0.

Table E-2. Vehicle Trip Production Rates

Housing Classification	1995 Triangle Survey	Triad Survey	National Data *[FHWA]*
Excellent	9.4*	9.3	11.2
Above Average	9.4*	9.1	11.2
Average	8.3	7.7	8.3
Below Average	6.2*	6.3	5.4
Poor	6.2*	5.7	5.4
All Dwelling Units	7.8	7.4 – 8.0	7.8

*Categories had to be combined to achieve a statistically significant sample

Table E-3. Trip Purpose

Purpose	Triangle Survey*	Triad Survey*	Charlotte Survey*	National
HBW	22%	20%	19%	18 - 25%
HBO	46%	49%		47 - 58%
NHB	32%	31%		18 - 28%
Non-HBW			81%	

*Incorporates urban and non-urban households

Table E-4. Vehicle Trip Attraction Rates*

Employment Type	HBW	HBO	NHB	IX
Industry	1.2	0.63	1.1	0.34
Retail	1.2	3.4	1.0	0.49
Highway Retail	1.2	4.2	4.0	0.28
Office	1.2	1.2	1.1	0.28
Service	1.2	2.0	1.9	0.28
Dwelling Units	0	0.9	0.13	0.33

*Rates obtained from 1995 Triangle Household Survey

External Station Analysis

<u>Overview</u>

Traffic entering, exiting and passing through the study area on a daily basis must be accounted for in the travel model. These trips are commonly referred to as Internal-External (I-E), External-Internal (EI), and External-External (E-E, thru trips.)

<u>Recommended Practice</u>

For a small urban area the analyst may want to consider treating all external station traffic as through traffic to simplify the model development process. If IE and EI trips are specified in the model then the through trip table should be synthesized first and attraction equations developed to pair the remaining

ADT with trip ends for each traffic analysis zone. If IE/EI trips are specified in the external station analysis then this step must take place in conjunction with the trip generation step.

To estimate through trip percentages the NCDOT SYNTH program can be applied, but caution is urged when applying this model to communities outside of the parameters under which the original model was specified. The theory behind the applications program SYNTH is covered in *Technical Report 3: Synthesized Through Trip Table for Small Urban Areas, 1980 NCDOT Thoroughfare Planning Unit.* When applied to any size community, the percent through trips estimated from this model should always be reviewed and modified to best represent the region. It is rare that the output value for through trips at all stations will accurately reflect travel through the planning area.

Another recommended approach that gives the user more control over the estimation process is to directly estimate the through trips for the region by considering first the interaction of land use activity within the region and how this activity will influence trips in and out of the planning area. Understanding this relationship will allow the analyst to first estimate the number of IE/EI trips. The IE/EI estimate combined with the total average daily traffic (ADT) for all external stations can be used to estimate the total number of through trips. These through trips can then be allocated to each of the external stations considering factors such as regional connectivity, ADT, functional classification, and percent trucks. To determine the allocation of through trips from each origin station to each destination station the regression equations developed in *Technical Report 3* can be applied and results manually adjusted as needed. It is important to note that the origin station will not have any through trips with destinations to itself.

The approach discussed above can be applied following the steps outlined below:

1. Estimate the number of trips that will be produced by the households in the region using the average trip rate per household.
    a. (TOT_HHOLDS)*(AVG_RATE) = II_TRIPS
2. Calculate the percentage of trips that would need to be produced by the external stations in order to match the number of trips produced by the households within the planning area.
3. Now ask several clarifying questions:
    a. Does it seem reasonable that the number of trips produced by the external station zones would be greater than trips from internal households?
    b. Do you believe that trips produced by households outside of your planning area and attracted to urban activity within the study area will be the same as households within the planning area?
    c. Do you believe that trips produced by households outside of the study area will be less attracted to businesses within the planning area due to more attractive land use in communities outside of the planning area?
    d. How many of the trips produced by households within the region do you believe will leave the region to go elsewhere?
4. Use these guidelines to determine an initial value for trips into/out of the area and trips through the area.
    a. (II_TRIPS) * (assumed %) = (IE/EI_TRIP_PRODUCTIONS)
    b. (IE/EI_TRIP_PRODUCTIONS)/ (EXTSTA_ADT) = %IE/EI
    c. TOT_THRU_TRIPS = (EXTSTA_ADT) * (1 - %IE/EI)
5. Using knowledge of the region along with factors such as regional connectivity, ADT at the external station, functional classification of the roadway, and percent trucks, allocate the estimated total through trips to each one of the external stations.
6. Apply the equations in *Technical Report 3* to estimate initial allocations for trips from origin station to destination stations. Applying this procedure will result in trips being distributed from the origin station to the origin station. Since this is illogical a manual adjustment is needed. The

recommended adjustment is to reallocate the trips initially distributed to the origin station to all of the other stations proportionate to their relative attractiveness. An example is shown in Table E-5.

7. Use allocation percentages to calculate the through trips for each OD pair.
8. The calculated trips for each OD pair can be converted to an OD trip table and balanced using the Fratar technique to assure that the zone origins and destinations balance.

Table E-5. Example of Manual Reallocation of Through Trips

Origin Station	Destination Station	Trips Distributed via Formula	Proportion of Total for Reallocation	Number Reallocated	Manual Adjustment
18	18	112	-	-	-
18	19	61	0.04	5	66
18	20	68	0.05	5	73
18	21	562	0.39	43	605
18	22	0	0.00	0	0
18	23	642	0.44	50	692
18	24	116	0.08	9	125
18	25	0	0.00	0	0

IE/EI trip attractions are calculated using regression equations during the trip generation step. The IE/EI trip productions are paired with IE/EI attractions during trip distribution using the gravity model. This procedure is further demonstrated using the Wendell case study which follows later in this Appendix.

Performance/Reasonableness Checks for External Station Analysis

It is rare for the number of trips produced by the external stations to be greater than the trips produced by households within the planning region. It should always be confirmed that the value is not higher. The majority of the traffic on major facilities in a small urban area can be considered through traffic.

Trip Distribution

Overview

Trip distribution is the step in the modeling process where trip productions from each traffic analysis zone are paired with trip attractions across the region. The pairing of these trips is based on a distribution curve that typically reflects the allocation of trips over slices of travel time from zero minutes to the maximum travel time in the region.

Recommended Practice

The most common model structure for applying the trip distribution step is the gravity model. This model is patterned after Newton's law of gravity that specifies that the attractive force between any two bodies is directly related to the mass of the two bodies and inversely related to the distance between the two bodies. For travel demand modeling, the mass is analogous to urban activity (trip attractions) and distance is often represented as travel time. An additional parameter in the travel demand formulation of the gravity model is a parameter called a friction factor. The friction factor can be thought of as a calibration parameter used to adjust the trip length distribution curve to match the measured or synthesized data. For most small urban areas, observed trip length data is not available from a household travel survey, but depending on the size of the area, work trip length data may be available from the census. Another approach to determining an appropriate trip length distribution for the planning area in question is through field studies designed to collect travel time data between the various traffic analysis zones in the region. By mapping out traffic analysis zones with high concentrations of housing, employment, and retail and using a standard stop watch, average travel times can be field estimated between various zones for work trips and shopping trips. These average values can be used as a starting point for developing and adjusting friction factors.

Initial friction factors can be developed using the estimated average travel time for each trip purpose and the formula provided below.

$$F = e^{at_{ij}}$$

Where:
a = inverse of the average travel time;
t_{ij} = travel time between zone i and zone j.

Performance/Reasonableness Checks for Trip Distribution

After applying the initial friction factors calculated with the formula provided above, the output from the gravity model should be reviewed for reasonableness. In particular, pay close attention to the average trip length and a plot of the trip length distribution. These are described in more detail below. Calibration of the gravity model is an iterative process and without observed data can only be checked for reasonableness during the first or initial iterations. However, additional adjustments to the gravity model may be necessary to achieve final highway calibration using observed traffic counts.

Check Trip Lengths and Distances

Estimated average trip lengths by trip purpose should be reviewed for reasonableness based on the knowledge of the planning area. Average travel speeds can be calculated by dividing the average distance for each trip purpose by the average travel time for each trip purpose and multiplying by 60. The average travel speed should be reasonable given the knowledge of the area. Plot trip length frequency distributions for each trip purpose and check for reasonableness; adjust friction factors if necessary to obtain reasonable distributions.

Trip Interchanges

The trip table should also be reviewed for reasonableness. Key elements to check and compare include the percent of intrazonal trips by trip purpose and trip interchanges between major land uses.

Friction Factors

Always make sure that the friction factors go out to the maximum zone-to-zone travel time in the network.

Traffic Assignment

Overview

Traffic assignment involves the estimation of traffic on each individual link of the highway network. This final step is the step that, after calibration, gives the data needed to:

- Test alternative transportation plans.
- Establish priorities between different transportation investment strategies.
- Analyze alternative locations for roadway improvements.
- Forecast design volumes needed to adequately design and construct new roadway facilities.

The reliability of the output from this step is dependent upon the reliability of all the proceeding steps.

The algorithms used in traffic assignment attempt to replicate the process of identifying the best path between a given origin and a given destination. Some algorithms assume that all users of the system view the path variables, such as travel time, the same. Other algorithms assume that the users of the system view the path variables differently. The most common algorithms used in highway traffic assignment for travel demand models are:

1. All-or-nothing (AON) – all trips between an O-D pair get assigned to the minimum network path. This algorithm does not account for congestion or peoples differing perceptions of travel time.
2. Capacity restraint – basically an AON algorithm where all trips between an O-D are assigned to the minimum path. The difference between this approach and a pure AON approach is that it is an iterative process where the link travel times are adjusted to account for link flows as compared to link capacities and new minimum paths are calculated. This assignment technique is most affective using hourly capacities. There are two basic types of capacity restraint, equilibrium and iterative.
3. The equilibrium assignment assigns the full trip table for each iteration. Link travel times are recalculated at the end of each iteration using the total link demand. The number of iterations is determined by a user defined closure parameter (0.0001 recommended) or until the system reaches equilibrium which is defined by the condition where no individual traveler can improve his/her travel time by selecting an alternative path. The final assignment is an average of the iteration (*i*) assignment and iteration (***i-1***).
4. The iterative assignment approach assigns a portion of the trip table for each iteration. Link travel times are recalculated at the end of each iteration using the portion of the total link demand resulting from the current iteration and all previous iterations. The number of iterations is determined by the user defined portions of the trip table. For example, if the trip table were divided into 3 portions then 3 iterations would occur.
5. Stochastic assignment – in a stochastic assignment the minimum path varies based on user perception of what the minimum path is. This is also referred to as equally likely paths. The proportion of trips allocated to equally likely paths is controlled by *theta* (Θ) where a high value of *theta* produces a heavy bias towards the shortest path and a value of 0 produces an equal share between all equally likely paths. A value of Θ=5 is recommended for initial assignment. This value can be adjusted to achieve better link assignment results.

<u>Recommended Practice</u>

While an all-or-nothing (AON) assignment is the most common algorithm applied for small urban areas, extreme caution should be used when selecting this technique because it can over estimate the demand for new high speed facilities in future year analysis, often overstating the forecast volume. Another drawback to an AON assignment is that there are no parameter adjustments during the assignment process. In order to change the results of an assignment for better calibration the user would need to adjust link attributes which can be difficult to defend and which may bias the base year model and make it less predictive to changes in future travel demand.

The recommended approach for small urban networks is a stochastic assignment with a small diversion parameter, or an iterative capacity restraint using a 40-30-20-10 division of the trip table. To achieve better calibration using the stochastic assignment, values of Θ can be adjusted to change the proportions of trips that are allocated to the equally efficient paths. In the iterative capacity restraint the portions of the trip table can be adjusted to achieve better link assignments. It is critical to note that the assignment technique and associated parameters applied for base year calibration must also be applied for future year analysis.

Performance/Reasonableness Checks for Trip Assignment

Reasonableness checks for highway assignment are recommended at three levels: system wide, corridor level, and link specific. System wide checks are generally made on daily volumes. System wide checks include vehicle miles of travel (VMT), cordon volume summaries and screenline summaries. In addition to checking summations of VMT and volumes, the average VMT per household and per capita should also be checked. Corridor specific problems are generally identified through observation of cutline volumes or volumes on major facilities.

After validation of the VMT, the next level of validation of the highway assignment is the comparison of observed versus estimated traffic volume on the highway network:

- Compare observed versus estimated volumes by screenlines and cutlines;
- Compare observed versus estimated volumes for all links with counts;
- Calculate R^2 (Coefficient of Determination) comparing region-wide observed traffic counts versus estimated volumes. R^2 region-wide should be greater than 0.88;
- Plot a scatter plot of the counts versus the assigned volumes. Review any data points (links) that lie outside of a reasonable boundary of the 45-degree line; and
- Various validation targets by facility type and volume group are provided in Table E-6 and E-7.

Table E-6. Percent Difference Targets for Daily Traffic Volumes by Facility Type

Facility Type	FHWA Targets (+/-)
Freeway	7%
Major Arterial	10%
Minor Arterial	15%
Collector	25%

Source: FHWA, *Calibration and Adjustment of System Planning Models*, 1990

Table E-7. Percent Difference Targets for Daily Volumes for Individual Links

Average Annual Daily Traffic	FHWA Desirable Percent Deviation
< 1,000	60
1,000 - 2,500	47
2,5000 - 5,000	36
5,000 - 10,000	29
10,000 - 25,000	25
25,000 - 50,000	22
> 50,000	21

Case Study

Wendell Transportation Data

Transportation data for the Wendell case study was extracted from the Triangle Regional model and represents a 2002 base year. The highway network for Wendell consists of 94 links and 79 nodes. Seventeen of these nodes (1 – 17) represent internal zone centroids and eight nodes (18 – 25) represent external zone centroids, also referred to as external stations. Traffic analysis zones are based on census block geography that was aggregated to represent a zone structure consistent with the network modeled. The highway links include all functionally classified roadways, collector and above. Locally classified roadways are included where necessary to provide connectivity. Traffic counts are available on 16% of the highway links. Link attributes are listed below:

- LANESAB(BA)
- LENGTH
- POSTSPD
- Functional Classification
- Facility Type (based on roadway attributes)
- AB(BA)HRCAPACITY
- AB(BA)TOTCAPACITY
- AB(BA)LINKTIME
- COUNT

Roadway capacities are based on the 2000 Highway Capacity Manual and were applied to each link using a lookup table of facility types. A screen shot of the network and supporting zones is shown in Figure E-2.

Wendell Land Use / Demographic Data

Land use and demographic data for the Wendell case study was obtained from the Triangle Regional Model data set. The housing and population data for the Triangle model was obtained from the 2000 census and adjusted by MPO staff using building permit data to reflect 2002 conditions. Employment data for the Triangle model was obtained from InfoUSA and verified by the MPOs. The data available from the Triangle model was more disaggregate than needed for this case study. For the purposes of this study, zonal household data was aggregated into total households and employment data by type was aggregated to Retail and Non-Retail employment types. The data for each zone is shown in Table E-8 below. Data for the external stations is also provided in the data table. This table can be joined with either the network node geography or the TAZ geography for creating thematic maps or performing data validation checks.

Wendell Trip Generation

The trip generation model was applied using several different approaches:

1. TransCAD quick response method using default TransCAD rates and assuming that all external station traffic is through traffic.
2. TransCAD quick response method using adjusted rates for a new category of population and assuming that all external station traffic is through traffic.
3. North Carolina specific trip rate table applied using the TransCAD standard methodology for trip generation and estimating EI and IE external station traffic.

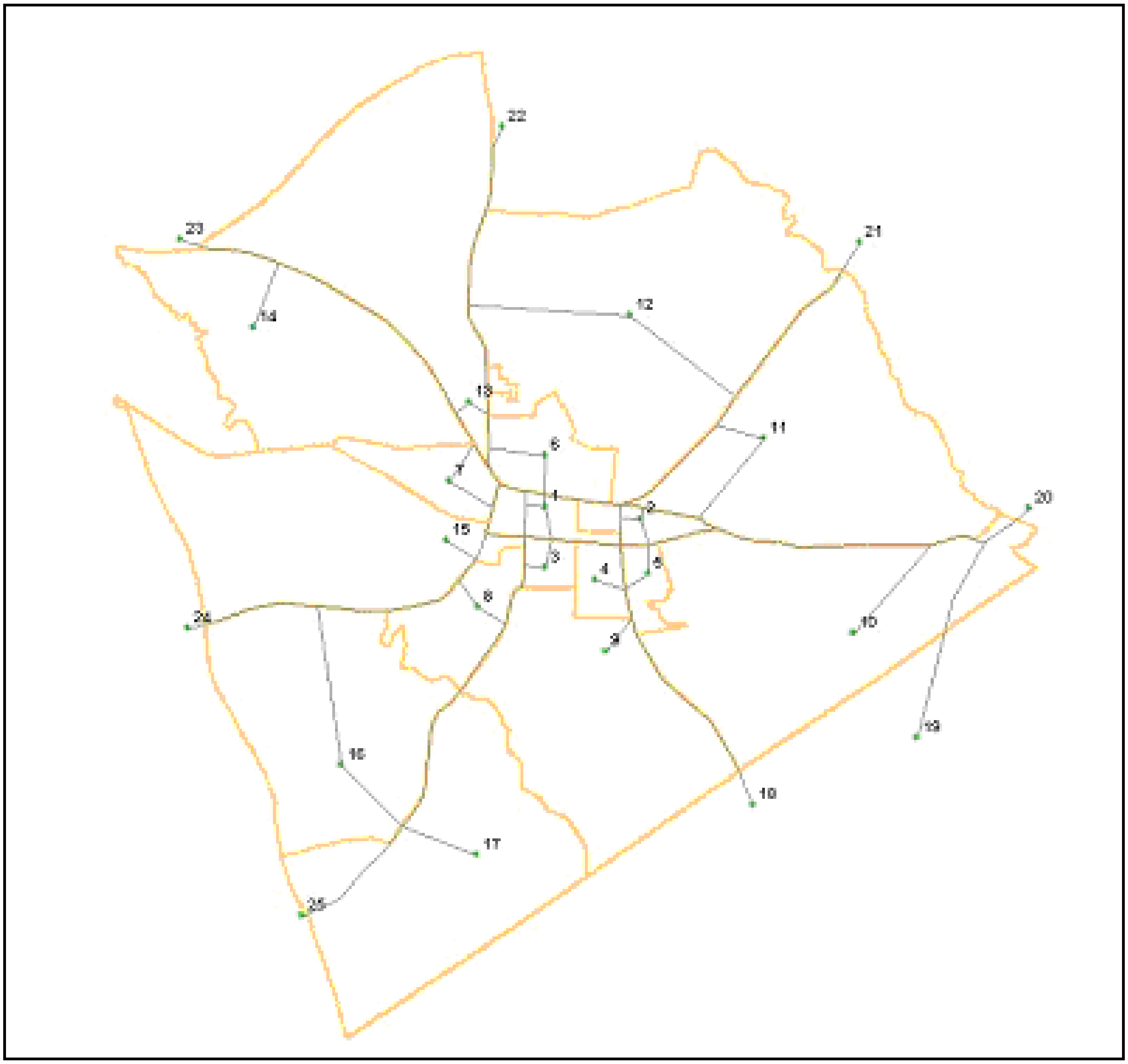
TransCAD Quick Response with Default Rates

TransCAD provides two default trip rate tables, one for production rates (PROD_TGP.DBF) and one for attraction rates (ATTR_TGP.DBF). The production rate table is grouped by population range, providing different rates for urban areas with populations ranging from 100,000 up to 2,000,000. There are no default rates specific to communities below 100,000. The trip production variables available in the rate table provide the user with some flexibility in specifying the form of the production model. The model can be specified using:

- average trip rate per household
- average trip rate for households stratified by income

- average trip rate for households stratified by auto ownership
- average trip rate for households cross-classified by income and auto ownership

Figure E-2. Traffic Analysis Zones for Wendell



Total trips are calculated for each traffic analysis zone and then trip purpose percentages for the default community are applied to the total trips to get trips by purpose. The user is allowed to specify trip purposes for HBW, HBNW, and NHB.

The attraction trip rate table allows the user to specify only one formulation of the attraction model with variables for retail employment, non-retail employment, and dwelling units. Attraction rates are provided for trip purposes matching those provided in the trip production model.

The default trip rate tables were applied using the TransCAD Quick Response technique. The results of this application are shown in Table E-9.

Table E-8. Zonal Data Values

TAZ	TOTHH	RET	NONRET	ADT	THRU	IXADT
1	51	39	68			
2	50	2	40			
3	77	23	52			
4	83	2	35			
5	98	0	2			
6	227	0	106			
7	176	13	72			
8	141	2	29			
9	451	7	18			
10	59	0	105			
11	170	25	79			
12	239	0	160			
13	380	130	117			
14	67	6	178			
15	108	378	250			
16	51	0	24			
17	85	8	22			
18				5200	3120	2080
19				1900	1710	190
20				2100	1365	735
21				8100	7695	405
22				2600	0	2600
23				11000	10450	550
24				5300	3445	1855
25				600	0	600

Table E-9. TransCAD Quick Response Results with Default Rates

Trip Purpose	Productions	Attractions	P/A Ratio
HBW	4775	3386	1.41
HBNW	10313	9542	1.08
NHB	4011	5919	0.68
Total	19099	18847	1.01

TransCAD Quick Response with Rates Adjusted for New Population Category

This approach has the same structure and format as the previous approach, the only difference is that the trip production rate table was modified to include additional population categories for urban areas with population ranges of less than 5k, 5k – 10k, 10k – 30k, and 30k – 50k. The new trip production rate table (PROD_TGP_NC10K.DBF) along with the default trip attraction rate table (ATTR_TGP.DBF) was applied using the TransCAD quick response technique. The results are shown in Table E-10.

Table E-10. TransCAD Quick Response Results with Rates Adjusted for Population

Trip Purpose	Productions	Attractions	P/A Ratio
HBW	4011	3386	1.18
HBNW	10313	9542	1.08
NHB	4775	5919	0.81
Total	19099	18847	1.01

Cross-Classification Approach with North Carolina Default Rates

The third approach that was tested was the development of a trip rate table specific to North Carolina (NC_TRIPRATES.DBF). The table has data related to production rates for each trip purpose, attraction rates for each trip purpose, and variable type descriptions. The format of the trip rate table applied to this case study is shown in Table F-11. The user has unlimited flexibility in changing the variables, the trip purposes, and the trip rates. For the purposes of this case study, initial production and attraction rates were derived from the Triangle survey data and then modified as necessary to achieve performance targets for unbalanced productions and attractions. The final rates applied are also shown in Table E-11.

Table E-11. Adjusted North Carolina Trip Rates

VARTYPE	R_HBWP	R_HBOP	R_NHBP	R_IXP	R_HBWA	R_HBOA	R_NHBA	R_IXA	TYPE
1	1.400	4.100	2.130	0.000	0.000	0.500	0.130	0.130	HHOLDS
2	0.000	0.000	0.000	0.000	1.700	7.600	3.400	3.400	RETAIL
3	0.000	0.000	0.000	0.000	1.700	3.830	2.000	2.000	NONRET
4	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	IXADT

Once the trip rate table has been developed, the approach can be applied using the following steps:

1. Planning – Trip Productions – Cross classification (while the step says “trip productions” the trip attractions will also be calculated if the attraction variables are specified.)
2. Fill out dialog box:
    a. Zone Data = SE Data
    b. Records = All Zones
    c. Zone or sub-zone sizes = TOTHH, RET, NONRET, IXADT
    d. Trip Rate Table – NC_TRIPRATES
    e. Trip Purposes – R_HBWP, R_HBOP, R_NHBP, R_IXP, R_HBWA, R_HBOA, R_NHBA, R_IXA
    f. Match Fields – use the “Match Fields for:” window to select in turn each of the variables in your SE Data table and match with the appropriate variable type in the trip rate table by typing in the VARTYPE number in the window for “Zone Data Field or Value”. In this example the SE Data fields are matched with the VARTYPE as shown below:
        i. TOTHH match with value 1
        ii. RET match with value 2
        iii. NONRET match with value 3
        iv. IXADT match with value 4
    g. OK – to apply model
3. Review unbalanced productions and attractions and adjust rates as needed until within +/- 10%

The final results are shown in Table E-12.

Table E-12. Productions, Attractions and P/A Ratio by Trip Purpose

Trip Purpose	Productions	Attractions	P/A Ratio
HBW	3518	3386	1.04
HBNW	10303	11280	0.91
NHB	5353	5200	1.03
IE/EI	9015	8586	1.05
Total Internal Trips Only	19174	19866	0.97

When balancing the productions and attractions, the productions should be held constant since trip rates are typically developed from travel behavior measured at the household (production) end and not the employment (attraction) end. After balancing the attractions to the productions the NHB productions should be set equal to the NHB attractions since NHB productions do not actually occur in the zone where the household is located, but rather in the zone where the attraction is located.

Findings and Recommendations for Trip Generation Analysis

The benefits of applying the TransCAD Quick Response approach are clearly the ease of use and application. The weakness of this approach is that in the existing format it can be applied to internal trips only and requires the user to apply a different approach to IE/EI trips or assume that all external trips are through trips, which seems unreasonable even for a very small community. Another shortcoming of this approach is that changes to the default trip rate table can be confusing for a novice modeler.

Due to the greater range of flexibility and user control it is recommended that the cross-classification approach with North Carolina Default rates be applied for small urban areas. In Phase II of this project this approach will be expanded and further tested on small MPO models. A TransCAD tool will be developed to facilitate the application of this approach.

<u>Wendell External Station Analysis</u>

Internal-External and External-Internal Trips (IE/EI)

The IE/EI trips were estimated using the following steps:

1. The number of trips produced by the households in Wendell was estimated using 2,513 households and an average trip rate of 7.6.
   (2513)*(7.6) = 19099
2. After considering the guidelines and the urban activity within Wendell a value of 0.47 was selected as the rate to apply to the number of trips made by households within the planning area. This calculated value represents an estimate of trips made into the area by households outside of the area and trips made by households within the area with trip ends outside of the area. The value is meant to serve only as a guide and can be adjusted later if needed.
   (19099) * (0.47) = 8976
3. Determine the percentage of external station traffic that this value represents by dividing the 8976 by the total external station ADT – this will be your percent IE/EI trips.
   8976 / 36800 = 0.24 of trips at external station are IE/EI trips

Through Trips (EE)

The through trips were estimated using the following steps:

1. Use the value estimated for IE/EI trips to determine the total number of through trips at the external stations.

36800 * 0.76 = 27968

2. Based on knowledge of the region along with factors such as regional connectivity, ADT at the external station, functional classification of the roadway, and percent trucks, the through trip percentages were estimated for each of the external stations. Through trip percentages were rounded yielding a final total through trip value of 27785. As a point of comparison, the through trip equations from *Technical Report 3* were also applied to each external station. The comparison is shown in Table E-13. This comparison shows that the initial estimates using the regression equations will need to be adjusted quite a bit to provide a better representation of through trips, otherwise the analyst would be assuming that households outside of the region make trips into the region at a higher rate (23,485) than trips made by households within the region (19,099). This is counterintuitive.

Table E-13. Comparison of Through Trips and IX Trips

Station	ADT	%EE_CAL	EE_CAL	IX_CAL	%EE_EST	EE_EST	IX_EST
18	5200	33	1701	3499	60	3120	2080
19	1900	18	346	1554	90	1710	190
20	2100	19	393	1707	65	1365	735
21	8100	40	3260	4840	95	7695	405
22	2600	20	521	2079	0	0	2600
23	11000	48	5257	5743	95	10450	550
24	5300	33	1747	3553	65	3445	1855
25	600	15	89	511	0	0	600
TOTAL	**36800**		**13315**	**23485**		**27785**	**9015**

Where CAL represents calculated values using regression equations and EST represents percentages estimated using recommended technique

3. While the equations developed to estimate the percent of through trips at each station are not recommended, the equations developed to allocate the through trips originating at a station to all of the other stations appears more reliable, but still require some user modifications. As such, these equations were used to estimate initial allocations of through trips from origin station to destination stations.
4. The destination station allocations can be converted to a percentage of through trips and then through trip values can be calculated. The initial values will have to be adjusted because the initial application of the allocation equations will allocate trips between the origin station and all other stations, including the origin station. Since through trips typically do not enter and exit a region at the same location, these trips need to be manually set to zero and the trips allocated for that trip pair reallocated to the other external stations. It is recommended that these trips be allocated to the other stations using a ratio of trips for that station over the sum of the trips for all stations.
5. The sum of the through trips at each origin station should equal the through trip productions for that station.
6. The calculated trips for each OD pair can be converted to an OD trip table and balanced using the Fratar technique to assure that the zone origins and destinations balance.

Findings and Recommendations for External Station Analysis

The NCDOT SYNTH program is an effective procedure for estimating through trips for communities that fall within the urban area population range of 4,000 to 50,000, under which the original model was specified. However, even when applied for a community falling within this range, caution should be applied to the through trip percentages estimated as they may not be reflected of the character of the community being studied. A more robust approach is recommended in this analysis and requires that the analyst estimate the percent of through trips for the entire region based on a relationship between the total ADT at the external stations and the land use within the planning area. Once regional through trips are estimated they can be allocated to each external station based on the characteristics of the roadway. To create OD trip pairs between the external stations the regression equations applied in SYNTH are a suitable approach with manual modifications required.

Wendell Trip Distribution

Assuming that the results from the trip generation model are robust and that recommended reasonableness checks have been performed, the key adjustment parameter for a robust application of the gravity model depends largely on the friction factors initially selected and then finally adjusted to match either observed or synthesized average trip length and trip length distribution. For the Wendell case study several approaches for estimating friction factors were tested, these are described below.

Using an Adjusted Mean Time from Network Skims

A required input for the gravity model is the zone to zone travel times skimmed from the highway network. For the purposes of determining a mean zone to zone travel time for internal zone interchanges only, a selection set of all internal TAZs was created. This selection set was used to create zone to zone travel times for the internal zones and then the mean travel time was estimated. This value was used as the starting point for estimating the average travel time for each internal trip purpose. For the HBW trip purpose the mean travel time (4.30) was used directly. For the HBO and NHB trip purposes a relationship was derived using the relationships between the average travel time as shown in Table E-14.

A factor of 0.87 for the HBO trip purpose and 0.80 for the NHB trip purpose was applied to the HBW travel time to yield values of 3.7 and 3.4, respectively. The travel time for the IE/EI trip purpose was determined by calculating the mean travel time from the minimum path matrix for all zonal interchanges. Final values are shown in Table E-15.

Table E-14. Average Travel Times by Trip Purpose

Trip Purpose	>250K	50 - 250K
HBW	15 to 20	7 to 10
HBO	13 to 17	6 to 9
NHB	13 to 17	6 to 8

Source: Calibration and Adjustment of System Planning Models

Using a Population Based Approach

The *Calibration and Adjustment of System Planning Models* provides a set of equations that can be used to calculate the average travel time by trip purpose using the urban area population. The equations were developed using survey data from the 1960s. These equations were applied using the population for Wendell to estimate an average travel time.

Home-Based Work: $t = 0.98 \times P^{0.19}$

Home-Based Social Recreation (substituted for HBO): $t = 2.18 \times P^{0.12}$

Non-Home-Based: $t = 0.63 \times P^{0.20}$

Using a population of 6245 for Wendell, the average travel time values shown in Table E-15 were calculated.

Resulting Average Travel Times

It can be seen from Table E-15 below that the average travel times calculated using the two different methodologies differ by nearly a minute for the HBW trip purpose and by nearly three minutes for the HBO trip purpose. The NHB trip purpose shows the greatest similarity between the two methods with almost identical travel times. The mean travel time values appear more reasonable for a community the size of Wendell where the maximum internal travel time is just over ten minutes.

Table E-15. Average Travel Time by Trip Purpose by Methodology

	Average Travel Time			
Methodology	HBW	HBO	NHB	IE/EI
Mean TT	4.3	3.7	3.4	4.95
Population Based	5.16	6.2	3.6	n/a

Formula to Calculate Friction Factors Based on Average Travel Time

Using the friction factor formula discussed earlier and shown again here for convenience, initial friction factors were developed for each of the trip purposes. These are shown in Table E-16.

Table E-16. Friction Factors by Trip Purpose by Time

Time	HBW	HBO	NHB	IE/EI
1	7925	7654	7477	8171
2	6281	5859	5591	6676
3	4977	4485	4181	5455
4	3945	3433	3126	4457
5	3126	2628	2338	3642
6	2477	2011	1748	2976
7	1963	1539	1307	2431
8	1556	1178	977	1987
9	1233	902	731	1623
10	977	690	546	1326
11	774	528	409	1084
12	614	404	306	885

Application of Gravity Model

The trip distribution model was applied using a doubly constrained gravity model with friction factors developed using the adjusted mean approach described above. The resulting average travel times are shown in Table E-17 below.

Table E-17. Average Travel Time by Trip Purpose

Trip Purpose	Average Travel Time
HBW	3.72
HBO	3.55
NHB	3.14
IE/EI	4.5

Findings and Recommendations for Trip Distribution

Based on this case study analysis it appears that estimating the average travel time using population results in average travel times that are too high for a community of this size. However, the mean travel time from the zone to zone minimum path matrix shows promise as a robust approach to estimating initial friction factors for a small urban study with a population between 5,000 and 10,000.

<u>Wendell Traffic Assignment</u>

Traffic assignment for the Wendell case study was performed using three different algorithms: all-or-nothing, equilibrium, and stochastic with varying values of ϴ. For a modeled area of this size, values for VMT and VHT were not significantly different. The equilibrium assignment was initially applied using a daily trip table requiring only one iteration. An equilibrium assignment with one iteration is the same as an AON assignment so no differences exist between the AON and equilibrium. The variation in the assignments is best demonstrated by comparing the different loadings for link pairs that represent equally likely travel paths. A summary of this comparison is shown in Table E-18.

Table E-18. Different Loading for Link Pairs Using AON and Stochastic Algorithms

	AON		ϴ = 5		ϴ = 2		ϴ = 0.1	
Link ID	AB	BA	AB	BA	AB	BA	AB	BA
6411	1725	1786	2091	2101	2238	2156	2276	2196
6421	8036	7978	7636	7649	7495	7655	7574	7803
6418	401	329	587	952	617	1472	638	1905
22287	2113	2123	1936	1639	1921	1274	1925	1048

As can be seen from the link comparisons, the stochastic assignment provides a better distribution of traffic across the available links. This accounts for the fact that rather than one optimum path being present for any given OD pair there are several equally likely paths where the travel time from origin zone to destination zone may vary by less than a minute.

An attempt was made to perform a comparison of the link assignment to the traffic counts, but this comparison was inconclusive due to the limited number of count locations available in the data set.

Findings and Recommendations for Traffic Assignment

The all-or-nothing assignment algorithm does not allow the user to adjust assignment parameters to achieve assignment results that better reflect traffic count measurements, assuming that parameters for all previous submodels have been adjusted. Instead the user would need to modify link attributes directly in order to change a link assignment. There is an inherent risk in making link level adjustments as the adjustments may be masking a system relationship problem that may bias the future year forecast.

An equilibrium assignment is not recommended for a 24-hour trip table because a daily capacity is not a true measure of capacity. A better approach for an equilibrium assignment is to use hourly trip tables or peak period trip tables with an hourly capacity. This will result in a more theoretically robust application of the volume-delay function. For a community the size of Wendell the use of an hourly trip table can be burdensome to the analyst unless automated procedures are developed for the assignment step.

The stochastic assignment is fairly straight forward to apply and comes closer to replicating the “real world” path, finding where several optimum paths may exist between a given origin and a given destination. The value of Θ can be adjusted to reflect a more conservative assignment where fewer optimum paths are allowed versus an assignment where many optimum paths are utilized.

For the reasons outlined above it is recommended that a stochastic assignment be used for a community of this size. The value of Θ should initially be set to five which will favor paths most like the original minimum path. This value can be adjusted as needed to improve link level assignments once all other model parameters have been tested.

References:

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4. *A Manual of Regional Transportation Modeling Practice for Air Quality Analysis*, Deakin, Harvey, Skabardonis, Inc., Berkeley, CA, 1993.
5. *Technical Report 3: Synthesized Through Trip Table for Small Urban Areas*, NCDOT Thoroughfare Planning Unit, 1980.
6. *Travel Demand Modeling with TransCAD 4.5*, Caliper Corporation.

APPENDIX F: DEVELOPMENT OF MANUAL TRAVEL ALLOCATION

Introduction

The development of a travel allocation model is based on *NCDOT Technical Report #11: Allocation Type Approach to Estimation of Travel for Small Urban Areas* (Poole, 1989). Manual travel allocation models are useful for small urban areas with a population less than 5,000 where new growth and new thoroughfares are anticipated. The development of a travel allocation model can provide the analyst with “hands-on” knowledge of existing and future travel patterns and flows. This knowledge leads to better decisions with respect to location decisions, design requirements, and the evaluation of user benefits for proposed improvements.

By employing the manual travel allocation model, transportation planners are able to manually accomplish trip generation and trip distribution. The traffic assignment procedure can be handled by either manual allocation or computer assignment process depending on the complexity of the highway network in the planning area. Because the manual travel allocation model can produce estimates of future travel patterns in a fast, low cost, and easy to apply manner, the benefits should be increased product output and reduced costs. Secondary benefits should be staff development leading to a greater understanding of the concepts of transportation planning and transportation modeling. Appendix D provides a case study application of the method to Pilot Mountain.

Travel Allocation Model Criteria

A travel allocation model should be the standard analysis methodology for all small urban areas meeting the following criteria:

- Population < 5,000
- Anticipated growth within the planning area
- Anticipated new transportation facilities

Input Data

In order to develop a travel allocation model for a small urban area, some necessary input data needs to be obtained from DOT, MPO or local governments and agencies. Typical input data for developing a travel allocation model is listed below:

I. Mapping of Planning Area

II. Inventory Existing and Proposed Land Use

   1. Existing Land Use
      - Residential
      - Commercial
      - Industrial
      - Public
   2. Proposed Land Use
      - Comprehensive Land Use Plan
      - Location of Existing Growth Areas
   3. Constraints / Regulations / Policies
      - Desire of Town to Grow
      - Availability of Water/Sewer
      - Parks / Recreational Facilities
      - Churches / Schools / Neighborhood Cohesion
      - Natural and Historic Properties
      - Water Quality / Wetlands / Stream Crossings

- Economic Considerations
- Zoning Ordinances / Planning Boundary

III. Inventory Existing and Proposed Transportation System
1. Existing Transportation System
   - Street Network and Function of Major Routes
   - Geometrics and Characteristics at Critical Intersections
   - Signal Locations and System Operation
   - Existing Traffic Count Coverage
   - Any Noticeable Capacity Problems
   - Five Year Accident History
2. Proposed Transportation System
   - Thoroughfare Plan
   - Transportation Improvement Plan Projects

IV. Historical Socioeconomic Data
1. Population / Households
2. Employments

V. Historical Traffic Data for Network Roadways and External Stations

For the manual allocation spreadsheet, the specific input data includes:

I. General Information about Planning Area
1. Name of County and Township
2. Specific Base Year and Design Year
3. Number of TAZs and External Stations

II. Population
1. Historical and Projected County Population
2. Historical Township Population

III. Land Use
1. Zonal Housing Data in Base / Design Year
2. Zonal Employment Data in Base / Design Year

IV. External Station Information
1. ADT at External Station in Base / Design Year
2. Through Trip Ends at External Station in Base / Design Year
3. Base / Design Year Through Trip Table

V. Parameters
1. Percentage of Planning Area Population of Township Population
2. Occupancy Rates for Base / Design Year
3. Dwelling Unit (DU) Vehicle Trip Rates for Base / Design Year
4. Percentage of Commercial Vehicle (CV) Trips
5. Percentage of Internal-Internal (I-I) Trips
6. Percentage of Secondary Internal-Internal (I-I)Trips

By using US census information, the population of the county and township can be determined for the base year and projected for the future year, respectively. By collecting and analyzing past and present land use data in the planning area, zonal households and employments can be forecasted in the future year. Efforts need to be conducted to know traffic patterns at each external station in order to develop through trip tables for the base year and design year, respectively. This procedure needs to be completed before other steps. The parameters which play important roles in the model development can be estimated by knowledge of the planning area or analysis of past trends. Reasonable checks need to be conducted to make sure each estimated value of the parameters is reliable and applicable.

Approach

In general the procedure is an allocation type approach beginning with areawide totals and "backing down" to more detailed estimates. The modeling procedure will be outlined in a step-by-step approach.

<u>Step 1 – Define Planning Area and Traffic Zones</u>

As in larger urban areas, the planning area should include all the areas anticipated to become the urban. The planning area should additionally include, to the extent possible, all anticipated thoroughfares. The number of traffic analysis zones should be limited to 6 – 10. Few zones allow for an easy manual assignment of trips. The larger the number of zones the more difficult this becomes and it may be necessary to use a computer assignment process.

<u>Step 2 – Estimate the Existing and Future Population</u>

It is suggested that a step-down approach be used starting with the county population, then to the township(s), and subsequently to the planning area. The Office of State Budget prepares and maintains current and future estimates of population for all North Carolina counties. These are official estimates and should be used for the model development. The township is the next sub-unit for population in a county and is important since township boundaries almost never change. The township population, existing and future, is best estimated by looking at the historical trend of township population as a percentage of county population. The population of the planning area is subsequently estimated as a percentage of the township population, or as a percentage of several townships if there or more than one involved with the planning area.

<u>Step 3 – Estimate External and Through Trips for External Stations</u>

External stations are the points where the roads on the roadway network cross the planning area boundary. Two types of trips cross the boundary at the external stations: *through trips* and *external to internal (E-I) / internal to external (I-E) trips* (called *IX trips* together). Through trips travel through the planning area without stopping, while IX trips cross into or out of the planning area.

The SYNTH program can be employed to estimate the through trip percentages at each of the external stations. These percentages are a starting point for determining the through trip percentages and may have to be adjusted based on knowledge of the planning area. If a recent Origin-Destination survey exists for the planning area, then the through trip percentages may be taken directly from that survey.

Once the through trip percentages have been determined, multiply this percentage by the total ADT for that station to get through trip ends. Then use the following formula to determine the IX trips at each external station:

$$IX_{trips} = ADT - THRU$$

Where:

IX_{trips} = total external to internal / internal to external trips at the external station;

ADT = average daily traffic at the external station;

$THRU$ = through trip ends at the external station.

Step 4 – Estimate Trips Generated by Population and Development

This step estimates trips generated by population and development in the planning area. This is done by multiplying the dwelling units (DU) by an assumed appropriate trip generation rate, and adding trips assumed generated by commercial vehicles (CV) by assuming commercial vehicle trips as a percent of dwelling unit trips (usually 12.5%).

In order to obtain the number of dwelling units in the planning area, two approaches may work:

- converting population to dwelling units by using occupancy rates
- available housing survey data

For the two approaches, the DU trips can be calculated using the following two formulas respectively (the spreadsheet model employs the first approach):

$$DU\ Trips = (Population\ /\ Occupancy\ Rate) \times (Trip\ Rate)$$
$$DU\ Trips = DU \times (Trip\ Rate)$$

Commercial vehicle trips are estimated by using the following formula:

$$CV\ Trips = (Percent\ Commercial\ Vehicles) \times (DU\ Trips)$$

Step 5 – Account for Trips Made by Residents Leaving the Planning Area

Internal to internal (I-I) trips are those trips that originate in the planning area and remain inside the planning area. The percentage of I-I trips for an area is generally 80% - 90% of all trips made by residents who live within the planning area. A study area that has numerous attractions (such as Charlotte) would have a higher percentage of I-I trips, while a bedroom community having fewer attractions would have a lower percentage of I-I trips. Use the following formula to determine the I-I trips:

$$II_{Trips} = (DU_{Trips} + CV_{Trips}) \times (Percent\ II_{Trips})$$

Internal to external (I-E) trips are those trips that originate in the study area and then leave the study area. Use the following formula to determine the I-E trips:

$$IE_{Trips} = (DU_{Trips} + CV_{Trips}) - II_{Trips}$$

Step 6 – Account for Non-home Based Trips Made by Non-residents

External to internal (E-I) trips are those trips that originate outside of the study area and end inside the study area. Use the following formula to determine the E-I trips:

$$EI_{Trips} = (ADT - Through_{Trips}) - IE_{Trips}$$

In general, the E-I trips will result in secondary internal to internal (I-I) trips in the planning area. The secondary I-I trips are usually estimated by assuming a percentage of the E-I trips (usually 17% - 40%). Use the following formula to determine the secondary I-I trips:

$$Secondary\ II_{Trips} = EI_{Trips} \times (Percent\ Secondary\ II_{Trips})$$

The total internal to internal trips is the sum of I-I trips calculated in Step 5 and the secondary I-I trips, as the following formula shows:

$$Total\ II_{Trips} = II_{Trips} + (Secondary\ II_{Trips})$$

<u>Step 7A – Develop Through Trip Table</u>

Through trips are produced outside the planning area and pass through in route to a destination which is also outside the planning area. Based on the SYNTH program or an Origin-Destination survey, the through trip table can be developed. If the SYNTH program is used, the output needs to be checked in conjunction with engineering judgment and knowledge of the region.

The spreadsheet model will directly use the through trip tables as given information to develop the PA matrix. Therefore, through trip tables should be done before other steps.

<u>Step 7B – Develop IX Trip Table</u>

IX trips have one end of the trip inside the planning area, with the other end located outside of the planning area. These trips are generated at the external station as a component of the external station traffic count. These trips are made up of external to internal (E-I) trips and internal to external (I-E) trips.

E-I Trip Table
In Step 6, the total E-I trips attracted to the planning area are calculated. The total E-I trips can be firstly allocated to each external station and subsequently allocated to internal zones based on relative trip attractiveness judged by knowledge of land uses in zones. This procedure is shown by the formula below:

$$EI_{ij} = EI_{total} \times \frac{IX_i}{\sum_i IX_i} \times \frac{Employment_j}{\sum_j Employment_j}$$

Where,

EI_{ij} = E-I trips from external station i to zone j;

EI_{total} = total E-I trips attracted to the planning area, calculated by Step 6;

IX_i = IX trips at external station i;

$Employment_j$ = employment of zone j.

I-E Trip Table
In Step 5, the total I-E trips produced by the planning area are calculated. The total I-E trips can be firstly allocated to each internal zone in terms of zonal production, and then allocated to each external station. This procedure is shown by the formula below:

$$IE_{ij} = IE_{total} \times \frac{Household_i}{\sum_i Household_i} \times \frac{IX_j}{\sum_j IX_j}$$

Where,

IE_{ij} = I-E trips from zone i to external station j;

IE_{total} = total I-E trips produced by the planning area, calculated by Step 5;

$Household_i$ = households of zone i;

IX_j = IX trips at external station j.

Step 7C – Develop I-I Trip Table

Internal to internal trips (I-I trips) have both their origin and destination inside the planning area. Internal trips should be allocated between zones based on relative attractiveness between zones and production of each zone. The total internal trips have been calculated in Step 5, and they are subsequently allocated between zone pairs by using the following formula:

$$II_{ij} = II_{total} \times \frac{Household_i}{\sum_i Household_i} \times \frac{Employment_j}{\sum_j Employment_j}$$

Where,

II_{ij} = I-I trips from zone i to zone j;

II_{total} = total I-I trips in the planning area, calculated by Step 5;

$Household_i$ = households of zone i;

$Employment_j$ = employment of zone j.

Step 8 – Assign Base Year Trips and Check against Ground Counts

Steps 7A through 7C just give the Production-Attraction (PA) matrices. The PA matrices need to be converted to OD matrices by using the "folding" method (Modeling 101, NCDOT), before allocating trips to the roadway network.

According to small urban areas, the traffic assignment can be done by hand or by computer traffic assignment. For small urban areas which have up to four internal TAZs, up to five external stations and an extremely simple road network, it is probably easier and quicker to do a hand assignment. A hand assignment will also provide intimate knowledge of travel movements which will be useful in subsequent benefits analysis. If the planning area has more internal TAZs, more external stations, or a more complicated road network, the computer traffic assignment will be preferred for efficiency and accuracy.

While checking the results of the loadings against ground counts, screenline analysis is recommended. A screenline is an imaginary line on a map, composed of one ore more straight line segments. In screenline analysis, all the links crossed by each screenline form a group which the total directional ground traffic counts and the total directional assigned volumes are calculated. The ratio between the two sums is then used as an indicator for the accuracy for the assignment results at the screenline location.

Step 9 – Assign Future Year Trips

If the travel allocation model yields an accurate estimate for the base year scenario, use it to forecast the travel demand in the future year.

Repeat Steps 3 through 8 using the estimated future year data. Assume that traffic will travel using the same routes used to complete the base year assignment. Make adjustments to these routes if any significant development changes in the planning area.

Step 10 – Determining Any Existing or Future Roadway Deficiencies

Roadway deficiencies exist anywhere that the volume of traffic is close to or exceeds the practical capacity of the roadway. TPB typically uses the capacity that corresponds to a level of service (LOS) D as the practical capacity for roadways within the study area.

Volume-to-capacity (V/C) ratio can be used as a reference to indicate roadway deficiencies. Determine any location along the roadway that meets the following deficiency characteristics:

- Near Capacity – the V/C ratio is between 0.8 and 1.0; and
- Over Capacity – the V/C ratio is greater than 1.0

These are the locations of the capacity deficiencies.

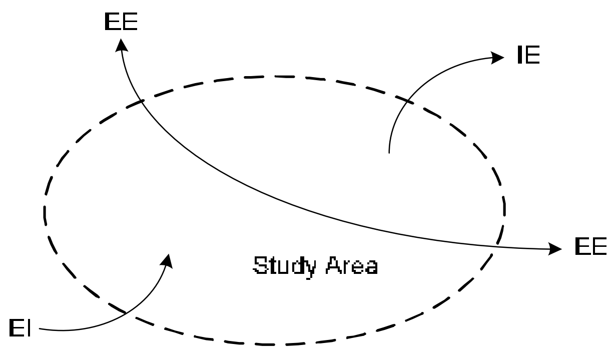
Appendix D provides a detailed application of these procedures to Pilot Mountain.

APPENDIX G: SYNTHETIC THROUGH TRIP MODEL

Introduction

External travel estimation is an important component of the travel demand model (TDM). External travel estimation captures the external trips in the study area. External trips are trips that have at least one end outside the study area defined by an encircling cordon line. When both the origin and destination of a trip are outside the cordon line, the trip is termed a through trip or external-external (E-E) trip. When one trip end is outside the study area, the trip is classified as an external-internal (E-I) or internal-external (I-E) trip. Figure G-1 displays the various types of the external travel.

Figure G-1. External Travel Diagram



The preparation of through trip tables for small and medium communities is usually overlooked, because most of the conventional planning processes were designed for use in large urban areas and metropolitan cities in which the proportion of through trips is small relative to total travel and the effort in measuring and modeling through travel has been less intensive than for internal travel. Smaller urban areas have a need for serviceable through trip tables, because through trips constitute a sizable part of the traffic in a region.

In order to build through trip tables, two standard methods are usually applied in the travel demand modeling process. The first method is to conduct an external station survey at the region cordon. In this type of study, vehicles entering town are stopped and their drivers are asked their final destination. However, its use has diminished due to the increasingly rising costs and the concern that stopping vehicles on the highway would be perceived as an unacceptable intrusion on the motorist. Moreover, poorly conducted external station surveys have resulted in unnecessary delays and extended queues of vehicles. The second method makes use of regression equations based on previous external survey data. This method represents the current practice used for forecasting through trips where an external survey is not available or possible. Therefore, the regression model is being widely used to estimate through trips in most small communities and some medium urban areas where the external survey are cost prohibitive.

Research Needs

The transportation planning process is based on the systems approach to problem solving and is quite general in its structure. The most common application is in urban areas, where it has been mandated by law since 1962, when the Federal Aid Highway Act required that all transportation projects in urbanized areas with populations of 50,000 or more be based on a transportation process that was continuous, comprehensive, and coordinated with other modes [Garber and Hoel, 2001]. Moreover, transportation planning activities in small and medium urban areas is becoming increasingly important since the popularity of these areas has risen over the past several decades. Currently, almost 40 percent of the United States population lives in communities with a population between 2,500 and 50,000. This growth of residence selecting smaller urban communities has resulted in a greater awareness of transportation problems in these areas as the populations continue to increase.

The need for good through trip tables is greatest for small- to medium-sized communities, which have a comparatively larger amount of through traffic. Serving as a significant part of the total trips in small and medium communities, the through trips definitely affect the decision makers' judgment with some degree of confidence, such as improvements to facilities that carry high percentages of through trips or building a highway bypass in order to keep trucking and other through trips proceeding unimpeded and avoiding congestion for the downtown areas. In many cases, however, these smaller areas may not have the financial or personnel resources to conduct an expensive external survey to obtain good through trip tables. Therefore, a reliable through trip model is very appropriate for these small and medium urban areas because it is more cost-effective.

More and more studies show that the behavior of external travel is strongly related to the unique geographic characteristics of each urban area and the economic activities in the market area surrounding the city. Unfortunately, the most widely used estimation procedure does not take these causal factors into account. Moreover, this procedure was developed based on external surveys conducted in some small communities in North Carolina two decades ago. It is clear that the outdated data and limited city samples weaken the opportunity for transferring this procedure between urban areas.

Therefore, accounting for multiple causal factors, a new methodology needs to be developed based on new survey data to improve the through trip estimation procedure. This procedure is expected to satisfy the needs of transportation planning in small and medium urban areas so that lots of money and time can be saved.

Research Scope and Objectives

The proposed research project aims at developing new synthesized models to estimate through (external-external) trips in small and medium areas. It will build upon previous studies and analysis of through trip behaviors. It also depends on mathematical programming, statistical methods and Geographic Information System (GIS). Based on the varied efforts, a new methodology will be developed to predict through trip generation and distribution and thus establish through trip tables.

This proposed research will study small and medium sized urban areas with population less than 200,000 because of the usual finical scarceness to conduct travel surveys and the need to decrease the burden on the planning staff in these areas.

The project goal is to improve the results of the through trip estimation for all small and most medium communities with little or no assistance from outside agencies. Thus it can enhance the whole planning process while making it more efficient and less time consuming. The objectives of the proposed research are:

- To evaluate the current through trip estimation technologies.
- Identify causal factors which affect through travel behaviors.
- To improve the through trip modeling process and make it more efficient and transferable between different sized urban areas.
- Develop guidelines and tools for best through trip modeling in small and medium urban areas.

Literature Review

The urban classifications are generally considered in the context of places with population of 5,000 or more. However, the concept of small communities, also known as a rural community, cannot be narrowly defined. In practice, the U.S. Department of Transportation defines rural in two ways: first, for highway functional classification and outdoor advertising regulations, rural is considered anything outside of an area with a population of 5,000; second, for planning purposes, rural is considered to be areas outside of metropolitan areas of 50,000 or greater in population. This definition leaves a lot of room for significant differences within these categories. Therefore, it is prudent to describe rural based upon what is seen across the country. For the purpose of this research, “rural” or “small community” is to be non-metropolitan cities with population less than 50,000.

There is not a standard definition for the medium urban area for the planning purpose. Original home-interview surveys for the 50,000 to 200,000 population category were limited [Martin and Mcguckin, 1998]. Therefore, there is an urgent need to decrease the burden on the planning staff in the smaller urban areas within this category compared with other larger urban areas. For the purpose of this research project, the medium urban area will be defined to be urbanized cities with population between 50,000 and 200,000.

Twenty years ago, Pigman and Modlin conducted early attempts to create similar empirical relationships for the structure of a through trip table in Kentucky and North Carolina, respectively. The principle methodology developed by Modlin was a formidable achievement at that time. The model was based on multiple regression analysis of through trip tables in fourteen small communities in North Carolina. Based on Modlin’s work, NCHRP Report 365 [Martin and Mcguckin, 1998] published a set of well-known regression models to estimate through trips at external stations and the distribution of through trips between any two external stations. Nowadays, they are still the most widely used through trip estimation technique in small urban areas. The models are shown as below.

$$Y_i = 76.76 + 11.22\times I - 25.74\times PA - 042.18\times MA + 0.00012\times ADT_i + 0.59\times PTKS_i + -0.48\times PPS_i - 0.000417\times POP$$

Where:

Y_i = percentage of the ADT at external station i, that are through trips;
I = interstate (0 or 1);
PA = principal arterial (0 or 1);
MA = minor arterial (0 or 1);
ADT_i = average daily traffic at external station I;
$PTKS_i$ = percentage trucks excluding vans and pickups at external station i;
PPS_i = percentage of vans and pickups at external station i; and
POP = population inside the cordon area.
Interstate (destination station):
$Y_{ij} = -2.70 + 0.21\times PTTDES_j + 67.86\times RTECON_{ij}$

Principal Arterial (destination station):

$$Y_{ij} = -7.40 + 0.55\times PTTDES_j + 24.68\times RTECON_{ij} + 45.62\times \frac{ADT_j}{\sum_{j=1}^{n} ADT_j}$$

Minor Arterial (destination station):

$$Y_{ij} = -0.63 + 86.68 \times \frac{ADT_j}{\sum_{j=1}^{n} ADT_j} + 30.04 \times RTECON_{ij}$$

Where:

Y_{ij} = percentage distribution of through trip ends from origin station i to destination station j;
$PTTDES_j$ = percentage through trip ends at destination station j;
$RTECON_{ij}$ = route continuity between station i and j: 1 = Yes, 0 = No; and
ADT_j = average daily traffic at the destination station j.

In practice, the procedure discussed above produces reasonable results for small urban areas, particularly those with populations of 50,000 or less. For interstates and principal arterials, the rates appear to be reasonable for areas with a population up to about 100,000. For areas with population greater than 100,000, the method produces through trip percentages that are less than zero, an illogical conclusion [Martin and Mcguckin, 1998]. One of the potential reasons causing the problem seems to be that the methodology was developed based on external survey data of only some very small communities. Another weakness of the model is that it was built upon twenty year old data. Traffic patterns, economic and social characteristics and some key factors (e.g. truck percentage) in the model have changed in the past two decades. Moreover, the empirical model heavily relies on high quality, system wide traffic counts, and ignores economic and geographic factors, which have effects on through trip patterns. All of these deficiencies may weaken the performance of the model.

The SYNTH method seems to place the city of interest on an island and perform the analysis without factoring in the surrounding area [Anderson, 1999]. By examining some spatial economic models, Anderson found that Huff's probability contour model was useful when it met certain specifications, but it could not be used as a reliable model to find the through trip rates for small areas [Anderson, 2005]. In another study recently completed by Anderson, a through trip rate methodology was developed based on a combination of the community characteristics, facility type, and economic characteristics of the surrounding communities [Anderson, 2005]. The study showed that the effect of nearby cities, expressways or businesses on through trips in a small community plays an important role in all three developed regression models. However, serving as a dummy variable in regression equations, this factor is limited to areas with a major city or expressway within reasonable distance. Further studies need to be conducted to determine a specific measurement to represent the effect of the nearby major city or transportation facility. This methodology still did not consider the geographic factors such as the location relationship between external stations and barrier effects. In addition, limited survey data of only two cities was used to develop the through trip models, which may weaken the reliability of the model.

The *Quick Response Freight Manual* recommends that through trip tables be estimated by a set of doubly-constrained trip matrix equations similar in structure to a gravity model, but where friction factors are replaced by subjective weights. The through trip table may be approximated by:

$$t_{ij} = O_i D_j X_i Y_j w_{ij}$$

Where:

$$X_i = \frac{1}{\sum_j D_j Y_j w_{ij}};$$

$$Y_i = \frac{1}{\sum_i O_j X_j w_{ij}};$$

t_{ij} = the number of trips between origin station i and destination station j;

O_i = the number of trips from origin station i;

D_j = the number of trips to destination station j,

X_i, Y_j = balancing factors so the trip table is consistent with all O_i's and D_j's; and

w_{ij} = an external weight associated with station pair i and j.

Horowitz and Patel improved the model in the *Quick Response Freight Manual* by calculating the external weight factor w_{ij} which accounts for the network topology or other aspects of the urban area geography [Horowitz and Patel, 2000]. By approximating the study area as a circular region, they defined w_{ij} as being the probability that a trip between the catchment area (external territory) of an external station i and the catchment area of an external station j crosses the study region or crosses a barrier. In their study, w_{ij} was expressed as:

$$w_{ij} = \int_{S_i}\int_{S_j} \frac{g(d(P_{ik}, P_{jl}))}{\int_{S_i}\int_{S_j} g(d(P_{ik}, P_{jl}))dP_{ik}dP_{il}} (I(P_{ik}, P_{jl}) \vee B(P_{ik}, P_{jl}))dP_{ik}dP_{jl}$$

Where:

P_{ik} denotes the Cartesian coordinates (x_{ik}, y_{ik}) of point k of catchment area i, for i = 1, 2, ..., n;

S_i is the set of all points of catchment area i, for i = 1, 2, ..., n;

$g(d(P_{ik}, P_{jl}))$ is a distance decay function of the Euclidean distance between the points P_{ik} and P_{jl};

$I(P_{ik}, P_{jl})$ is an indicator function, equal to one if the line segment joining points P_{ik} and P_{jl} passes through the intended region, and otherwise equal to zero;

$B(P_{ik}, P_{jl})$ is an indicator function, equal to one if the line segment joining points P_{ik} and P_{jl} crosses a barrier, and other otherwise equal to zero;

$\vee$ is the Boolean "or" operator representing $I \vee B$ to be equal to one if I and/or B is equal to 1, and $I \vee B$ to be equal to zero otherwise; and

dP_{ik} is the same as $dx_{ik}dy_{ik}$.

The model developed by Horowitz and Patel successfully accounted for the effects of barriers to travel and geographic location relationships among external stations on the through trip distribution. However, their approach to approximate the external territories was arbitrary and may yield inaccurate w_{ij}. Their approach to calculate w_{ij} is similar to the "finite element" method, and it was complicated and time-consuming.

Data Collection

In order to update or improve the local travel demand modeling procedures, a few external travel surveys were recently conducted in some towns, counties, and MPOs in Alabama, North Carolina and Texas.

These external surveys provide new through trip data observed in communities with varied size, traffic patterns, economic and geographic characteristics. This research project will use these data for analysis.

Considering the possibly unusual travel activities of the United States compared to other nations, the Texas communities at the border of the United States were removed from the dataset. In order to match the urban size of interest in the research project, the survey data observed for urban areas with population more than 200,000 was removed. Therefore, sixteen urban areas in Alabama, North Carolina and Texas were selected as case cities and for model development and validation. The basic information of the selected communities is shown in Table G-1.

Table G-1. Basic Information of Case Communities

State	Urban Area	Population	# of Stations	ADT	Truck %	Through Trip Counts at Stations	Through Trip Counts between Stations
Alabama	Alexander City	15,008	6	Y	Y	Y	Y
	Arab	7,174	4	Y	Y	Y	Y
	Hartselle	12,019	4	Y	Y	Y	Y
	Roanoke	6,563	4	Y	Y	Y	Y
	Russellville	8,971	4	Y	Y	Y	Y
	Sylacauga	12,616	5	Y	Y	Y	Y
	Troy	13,935	5	Y	Y	Y	Y
Texas	Bryan/College Station	152,415	15	Y	Y	Y	N
	Longview MPO	256,152	60	Y	Y	Y	Y
	Midland/Ector County	237,132	19	Y	Y	Y	N
	San Angelo	88,439	23	Y	Y	Y	N
	Texarkana	129,749	16	Y	Y	Y	Y
	Tyler MPO	174,706	32	Y	Y	Y	Y
North Carolina	Goldsboro	86,752	32	Y	Y	Y	Y
	Jacksonville	66,715	9	Y	Y	Y	Y
	Wilmington	172,322	8	Y	Y	Y	Y

For the purpose of this research project, the seven communities in Alabama are small urban areas because their populations are between 5,000 and 50,000. The communities in North Carolina and Texas fall into the category of medium urban areas because the populations are between 50,000 and 200,000.

There are a total 246 external stations in the fourteen case communities. This large sample can be used to develop through trip models with confidence. As Table G-1 shows that the general information of the traffic patterns at each external station are available in the survey reports. Other information of the communities which will be used in the model development, such as demographic data, nearby major cities and transportation facilities, network topology and urban area geography, is readily available by online sources, survey reports or other sources.

Research Methodology and Tasks

Based on previous valuable studies, the research methodology follows the general through trip modeling approach: data collection, definition of categories of study areas, identify causal variables, through trip generation modeling, through trip distribution modeling, model calibration and establishment of through trip tables.

A sequence of specific tasks accomplish the research methodology and objectives:

1. Review the literature for best practices and select techniques and tools appropriate for through trip modeling in small and medium urban area.
2. Procure needed software and organize a schedule to develop methods and tools.
3. Determine available sources for model data including new external station survey data, demographic data and urban area geography, etc. Process the data for the analysis.
4. Define distinct categories for study areas based on size primarily and other factors such as transportation needs. Design tested scenarios under which the model is developed.
5. Analyze the causal factors which may affect the through trip generation at external stations. Borrow or develop efficient sub-models to estimate through trip generation.
6. Analyze the causal factors which may affect the through trip distribution between external stations. Borrow or develop efficient sub-models to estimate through trip distribution.
7. Develop the procedure to calibrate estimated through trips so as to build applicable through trip tables.
8. Evaluate the models against newly collected data and available datasets.
9. Demonstrate and verify the modeling approaches, sub-models, tools and guidelines with case studies previously accomplished by NCDOT.
10. Prepare conclusions and recommendations.

As Task 4 denotes, this research focuses on small and medium urban areas. For the purpose of the research, the case cities are divided into two groups: small urban areas with population under 50,000 and medium urban areas with population between 50,000 and 200,000. The through trip models will be developed under two scenarios:

- Pool all case communities together to develop models;
- Develop models for small urban areas and medium urban areas, respectively.

The better one will be chosen in terms of model fit, predictive ability, efficiency and simplicity.

Tasks 5 – 7 describe the model development. This research will synthesize previous through trip studies to identify all variables which may affect through trip generation and distribution, respectively. According to those complicated factors, which are not easy to calculate or simulate, efforts will be made to simplify them. The preliminary independent variables to be analyzed in the research are listed as below.

For through trip generation at external station:

- population of the study area
- employments of the study area
- city area
- average daily traffic (ADT) at the external station
- truck percentage at the external station
- highway functional classification
- nearby attraction sources (major city or transportation facility)
- number of the lanes at the external station

For through trip distribution between external stations:

- population of the study area
- employment of the study area
- city area
- percentage of through trip ends at the destination station
- ADT at the destination station
- the ratio of ADT at the destination station to the sum of ADT at all destination station
- truck percentage at the destination station
- highway functional classification

- route continuity between stations
- nearby attraction sources (major city or transportation facility)
- number of lanes at the destination station
- geographic factors, such as the location relationship between stations and effects of barriers to travel.

Statistical analysis, such as MSE, R^2, C_p statistic, and stepwise selection procedures, will be performed to select significant variables and thus develop the best-fitting multiple regression models. In order to establish the applicable through trip tables, this research will borrow or develop reasonable procedures to calibrate the through trips predicted by the developed regression models. Finally, a balanced through trip table can be built and directly applied to the traffic assignment procedure.

Task 8 includes the validation of model assumptions and the evaluation of model performance. By using the newly collected survey data, this research will also compare the new through trip model with previous models and check if the new model is a better method to estimate through trips.

In Task 9, a few NC case studies will be conducted to demonstrate and verify the new approaches, models and tools.

Anticipated Results and Significance

The specific research products are expected as follows:

- Identification of causal factors which significantly affect the through trip patterns in small and medium urban areas
- New reliable and efficient through trip models and guidelines which can be transferable among small and medium communities during the travel demand modeling process.
- Case study demonstration of the recommended approaches, models and tools for the through trip estimation in the small and medium communities.

These products will allow transportation modelers to build reliable through trip tables for small communities and most medium communities with a minimum of resources. The methodology of through trip estimation developed in the research should help transportation planners for smaller communities avoid conducting expensive external surveys thus saving time and money.

APPENDIX H: TRIP GENERATION RATES

Introduction

The purpose of trip generation estimation is to determine the number of person or vehicle trips to and from activities in a planning area. Trip generation is functionally related to the land use. Factors influencing the amount of travel in a region include automobile ownership, income, household size, and density and type of development. Trip generation models consist of two sub-models including trip production models and trip attraction models. Trip productions are the trip ends associated with the traveler's home. Trip attractions are the trip ends associated with the non-home end of the trip, such as a workplace, shopping center, or school. The most common forms of the trip generation models are regression equations and cross-classification tables. Trip rates are typically developed from local survey data.

Problem

Transportation planning activities in small urban areas is becoming increasingly important since the popularity of these areas has risen over the past several decades. Currently, almost 40 percent of the United States population lives in communities with a population between 2,500 and 50,000 (Bureau of the Census, 1983). This growth of residence selecting smaller urban communities has resulted in a greater awareness of transportation problems in these areas as the populations continue to increase (Khisty, 1987). However, the conventional urban travel modeling techniques have not found widespread use in small urban communities because traditional forecasting models, designed for use in large urban cities, are very data intensive.

Previous transportation planning research efforts directed towards small urban areas have identified the need for planning techniques that are less data intense, less expensive, and less time consuming to implement when compared to traditional transportation modeling methods. The limited transportation modeling requirements are necessary because smaller urban areas have limited staff and budget resources to conduct planning studies and many lack detailed knowledge of the transportation planning process. In 1998, based on more recent travel survey data, the Transportation Research Board (TRB) published the National Cooperative Highway Research Program (NCHRP) Report 365, *Travel Estimation Techniques for Urban Planning* (Martin and Mcguckin, 1998), to update the old NCHRP Report 187, *Quick-Response Urban Travel Estimation Techniques and Transferable Parameters* (TRB, 1978). The usefulness of the quick response techniques and parameters is questionable for small urban areas because they were not originally designed for use in areas with population less than 50,000 people. For example, Table H-1 shows the national trip rates provided by NCHRP 187 and NCHRP 365.

Table H-1. National Person Trip Rates

Urbanized Area Population	Person Trips/Household NCHRP 365	Person Trips/Household NCHRP 187
50,000 to 200,000	9.2	14.1
200,000 to 500,000	9.0	11.8
500,000 to 1,000,000	8.6	7.6
> 1,000,000	8.5	7.6

Source: NCHRP Report 365

Trip generation estimation is data intensive and important in the traditional travel demand modeling. If simplified and efficient trip generation models could be developed, the whole work of travel demand modeling for small communities with population less than 50,000 would be greatly reduced and improved.

Approach

In this research, efforts will be firstly made to develop trip production rates for small fringe towns near major urban centers, and to test the feasibility of borrowing national default trip production rates for applications in small towns.

Next, a sensitivity analysis is conducted to check if significant differences exist when using three different trip rates (national default rates, North Carolina average and local rates) with a single trip purpose in the travel demand modeling for small communities.

The Impact on Travel Behavior of Proximity to Major Urban Centers

Scope and Objectives

Our goal is to provide concrete tools for planners working with small and medium sized towns in North Carolina. As in many other regions, North Carolina's large cities are growing quickly and are transforming pre-existing, smaller, surrounding towns. Planners in these towns are beset by several difficulties:

- It is likely that they do not have abundant resources for planning, so surveys are difficult to perform.
- Sources such as NCHRP 365 do not provide averages for small towns.

There is no simple way to quantify the impact of the large city on travel behavior in the small town.

The intent is to add to the small town planner's toolkit by identifying situations where they can safely reuse data tools and national average values originally intended for larger cities. Our hypothesis is that large cities exert an influence on their neighbors, and people in smaller towns begin to change their travel habits even before their town is subsumed by the larger city.

To address the needs of these planners, this report attempts to accomplish the following:

- Identify situations outside the published scope for NCHRP 365 rates where those rates may still reasonably be applied.
- Identify systematic variations from NCHRP 365 rates so that correction factors can be applied where needed.
- Identify a minimal set of trip types required to describe travel behavior in towns within the fringe area of urban centers.

The Dataset

The data set consists of 3316 household surveys conducted across a 10 county area surrounding Charlotte, NC (the Metrolina MPO). The surrounding towns range up to 50 miles from the center of Charlotte, and the population within the entire survey area is over one million. The survey area includes 68 cities and towns with individual city populations ranging from over one half million (Charlotte) down to a few hundred. Survey responses were collected from 320 census tracts and 1428 traffic analysis zones (TAZ) as defined by the Metrolina MPO. The data was collected from January to May of 2002. The dataset classifies each TAZ in the study area according to population density. The thresholds are not apparent from the data, but there are three categories: Urban, Suburban and Rural.

Analysis

- Urban Proximity Classes

Definitions

The analysis begins by defining urban proximity classes. The purpose of these categorizations is to classify towns according to the level of influence they experience from the urban center. There are three classifications:

- CENTER – areas belonging to the urban center proper
- FRINGE – areas outside the urban center which behave largely as if they were part of the urban center
- OUTLYING – areas which behave demonstrably differently from the urban center

To analyze the Metrolina data we have used the following criteria to assign towns to classes: the CENTER consists of the city of Charlotte itself, OUTLYING towns are those with a travel time to Charlotte greater than 55 minutes and a population of less than 11,000, FRINGE towns are all those in the study area which are not in either other class. The criteria for OUTLYING towns were established by inspecting a matrix of average trip rates classified by distance from Charlotte and town size. The towns at the extremes stated above jumped out as having obviously different trip rates from the data as a whole.

We are confident that our classification criteria capture the present reality on the ground in Charlotte. However, as currently cast, they are not satisfactory as a reusable or portable definition. The principal shortcoming is that the travel time criterion is defined as a travel time to the urban city center. Over time this measure will not be a good indicator of the progress a major urban center makes as it grows towards a small town. A better metric would be travel time from the small town center to the point of closest approach of the urban central area. We did not have the resources to make that type of measurement for this study.

It is important not to confuse the urban proximity classes with population density classes. In the Metrolina dataset some of the TAZs within the CENTER proximity class have population densities low enough to be considered rural zones. In addition, the FRINGE area contains many dense urban areas. In this particular dataset all of the OUTLYING regions are rural, but this need not always be the case.

Comparison of Proximity Classes

The overall trip rates for each proximity class appear in Table H-2. There is a clear, statistically significant difference ($Pr(t > 2.24) = 0.027$) between the rates for the CENTER and OUTLYING areas. The significance level between the FRINGE and OUTLYING area just misses the 95% confidence range ($Pr(t > 1.86) = 0.066$). There is no significant difference between the CENTER rates and the FRINGE rates. This represents the heart of our eventual claim that planners working in FRINGE towns can defensibly use the NCHRP 365 rate dictated by the nearby urban center.

Given that all of the OUTLYING areas are sparsely populated enough to be classified as rural, we need to be sure that the differences in overall trip rates are not simply attributable to differences in population density. When we compare the means for the three proximity classes and restrict the data to only rural zones we get much of the same results. There is a highly significant difference between CENTER and OUTLYING ($Pr(t > 2.51) = 0.013$), and a marginally significant difference between FRINGE and OUTLYING ($Pr(t > 1.67) = 0.098$). The only comparison which does change when restricting the data to rural zones is that between CENTER and FRINGE zones. A mildly significant result ($Pr(t > 1.82) = 0.072$) appears. This indicates an interesting interaction between proximity classes and population density classes which will be discussed below.

Table H-2. Mean Trip Rates by Proximity Class

Proximity Class	CENTER	FRINGE	OUTLYING
Mean	8.23	8.57	10.18
Upper limit 95% confidence interval	8.56	8.85	11.88
Lower limit 95% confidence interval	7.90	8.29	8.48

The mean trip lengths and trip durations by proximity class appear in Table H-3. The difference in trip distance is significant for all class pairs. The difference in trip duration is not significant between any class pair. This is not a contradictory result since both distances and speed limits will tend to increase as one moves away from the urban center.

Table H-3. Trip Distance and Duration by Proximity Class

Proximity Class	CENTER	FRINGE	OUTLYING
Trip Duration (mins)	22.56	22.99	24.03
Trip Distance (miles)	5.60	6.46	7.47

While the means are all the same for trip duration, the distributions are not. The trip duration distributions by proximity class appear in Figure H-1. The distributions for CENTER and FRINGE zones are remarkably similar. The OUTLYING distribution differs in that it peaks at a shorter duration but falls off the peak more slowly than the other classes. We take this as more evidence that CENTER and FRINGE classes can be treated more or less the same, but that the OUTLYING class cannot be considered the same as the CENTER. This result stands when the analysis is further broken down by trip type. We compared the mean values for trip duration by trip type between the CENTER and FRINGE classes. There was no significant difference in trip duration for any trip type.

The distributions by trip type are virtually identical for CENTER and FRINGE, and show small variations for OUTLYING. Table H-4 shows trip type percentages by proximity class. This further argues that FRINGE towns behave like the urban center.

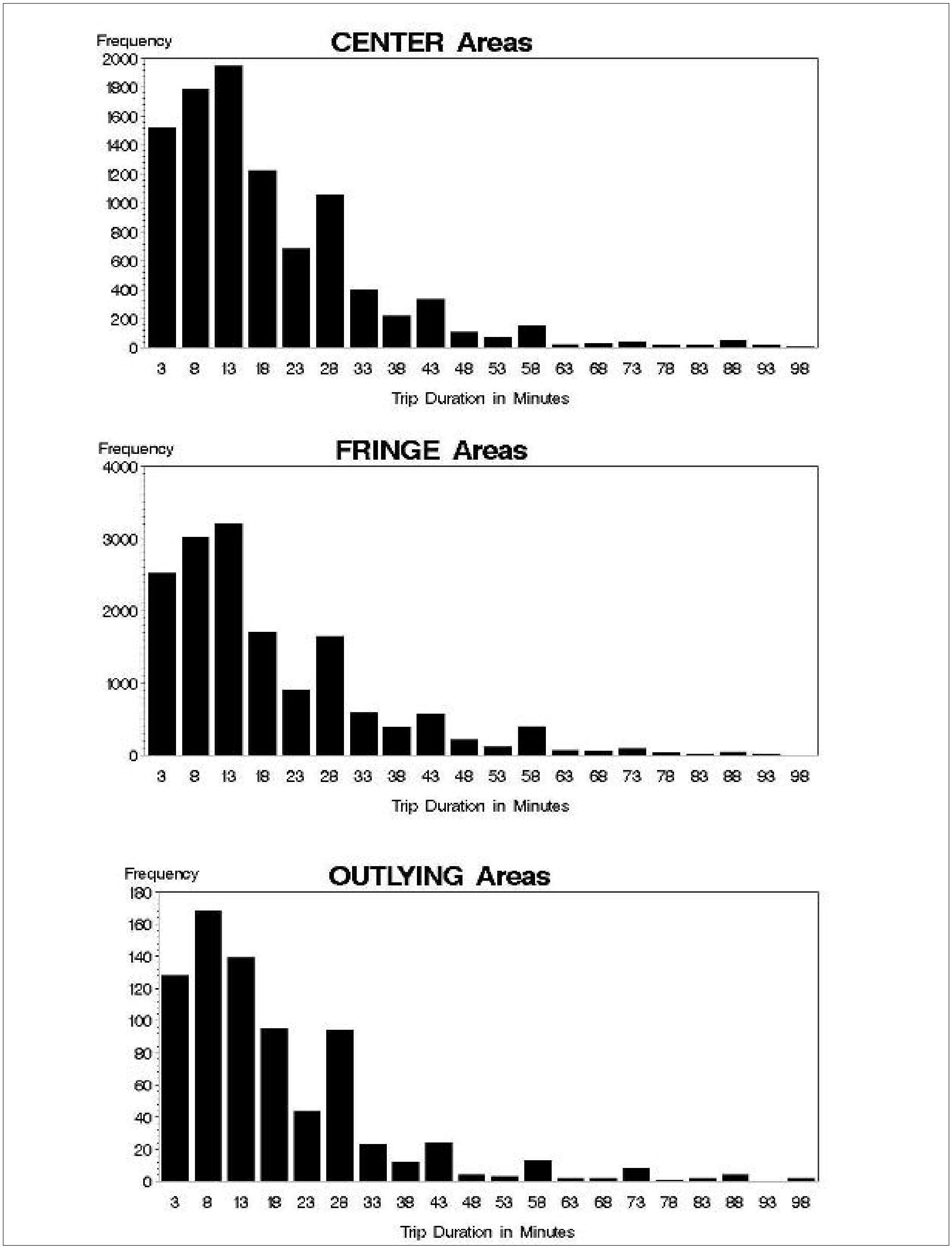
Table H-4. Trip Type Percentage by Proximity Class

	CENTER	FRINGE	OUTLYING
Home Based Work	17.54	18.84	15.33
Home Based Other	48.89	47.90	52.22
Non-Home Based	33.57	33.25	32.46
Total	100	100	100

- Interactions between Proximity Class and Other Variables

The focus of this report is the relative treatment of FRINGE and CENTER zones, so we now restrict the discussion to those two classes. The trip rates in the Metrolina dataset exhibit a fascinating interaction between income levels and proximity class. For most income levels there is no significant difference between the two classes. However, for a few income classes there is a dramatic difference. Most notably, in the household income range from $30,000 to $50,000 rates differ sharply. In this range the trip rates for

Figure H-1. Trip Duration Distributions by Proximity Class



the FRINGE class are much higher than for the CENTER class. It would seem that in this particular income band the lifestyles offered by the two regions are very different. Table H-5 shows the household trip rates for all combinations of proximity class and income class.

Table H-5. Household Trip Rates by Income Class and Proximity Class

	CENTER	FRINGE	T Test result	90% Conf.	95% Conf.
$0 - $10K	3.69	3.89	Pr(t > 0.32) = 0.752		
$10K - $20K	6.33	4.79	Pr(t > 1.81) = 0.073	x	
$20K - $30K	5.87	5.74	Pr(t > 0.24) = 0.811		
$30K - $40K	6.47	7.62	Pr(t > 2.13) = 0.037		x
$40K - $50K	6.62	8.31	Pr(t > 3.12) = 0.002		x
$50K - $60K	8.55	8.82	Pr(t > 0.38) = 0.702		
$60K - $75K	8.58	9.69	Pr(t > 1.59) = 0.112		
$75K - $100K	10.33	10.87	Pr(t > 0.74) = 0.462		
$100K - $125K	10.01	11.82	Pr(t > 1.77) = 0.079	x	
$125K - $150K	9.91	10.7	Pr(t > 0.53) = 0.600		
> $150K	11.16	11.23	Pr(t > 0.05) = 0.958		

There is also a mild interaction between proximity class and population density. For urban and suburban TAZs there is no significant difference between the CENTER and FRINGE classes. For rural TAZs, however, there is a difference. Table H-6 shows the results. The trip rates for rural zones within the CENTER class are actually lower than for other population densities. This is an unexpected result. Generally rural trip rates are higher than other rates. This may be an anomaly in the data, or there is something very unique about low density zones within a generally high density area. Further study is suggested.

Table H-6. Household Trip Rates by Population Density and Proximity Class

	CENTER	FRINGE	T Test result	90% Conf.	95% Conf.
Urban	7.87	7.78	Pr(t > 0.19) = 0.851		
Suburban	9.03	8.64	Pr(t > 0.97) = 0.330		
Rural	7.59	8.71	Pr(t > 1.82) = 0.072	x	

While the FRINGE class behaves largely like the CENTER class, these interactions indicate circumstances where the planner must take care when attempting to reuse a model based on a CENTER city. If the planner in a FRINGE city wants to reuse a cross classification or regression model which depends on rural population densities or household incomes between $30K and $50, then the coefficients in the borrowed model for those terms need to be adjusted.

- Performance of National Average Trip Rates

One of the most valuable data tools which we would like to reuse for small towns are the accepted NCHRP 365 trip rates. In this section we assess how well those rates would perform if used in the FRINGE towns. The population of the CENTER and FRINGE zones combined is over one million, so we use the NCHRP 365 value for urban centers with populations greater than one million. The NCHRP 365 rate is 8.5, and the actual mean for FRINGE households from the survey is 8.57 with a 95% confidence interval of 8.29 to 8.85. That is a very encouraging degree of agreement. There is, however, a great deal of variation in the data, and simply using the national average value may not produce acceptable results.

In order to compare the performance of national averages against other possibilities we constructed regression models based on the Metrolina data. The models aggregated rates at the TAZ or census tract level and were based on census data values for quantities such as income distribution, number of vehicles per household and population density. All of the regression models fit the data very poorly. We believe the poor fits are due to natural variance in the data and the relative geographic sparsity of the survey data. The survey contains 3316 observations spread across 1428 TAZs. Over two thirds of the TAZs are represented by either one or two observations. There is better representation at the census tract level, and for comparison purposes we present the results of three models built against census tract data. Table H-7 compares the root mean square error of the models when using the national average value. The national average, of course, has the highest error value. However, the difference in error is quite small. This indicates that the benefits associated with compiling survey data and calibrating models for small towns probably does not justify the costs. The national average values provide very similar results at essentially no cost.

Table H-7. Comparison of Regression Model and National Average Results

	Root Mean Square Error
Income Based Model	1.83
Vehicle Count Based Model	1.80
Income/Vehicle Count Combined Model	1.80
National Average of 8.5	1.89

- Trip Type Difference in the FRINGE Class

We compared trip distances by trip type for households in the FRINGE area. Table H-8 shows the results. The HBW trips are dramatically longer than all others. There is no statistical significance in the difference between HBO and NHB trips. This would indicate that HBO and NHB trips can be lumped together in a model. Planners in FRINGE towns can use just two trip types: one for HBW and one for all other trips.

Table H-8. Trip Lengths for FRINGE Households by Trip Type

	Trip Duration (minutes)
Home Based Work	28.84
Home Based Other	21.37
Non-Home Based	21.77

<u>Conclusions</u>

We have established that households within the FRINGE class behave very much like households in the CENTER class. We have defined criteria for defining these urban proximity classes around major urban areas. The current definition is not portable, and needs to be generalized. Planners in FRINGE towns can defensibly use data tools and national averages based on the nearby urban center. We have shown that in the case of the Metrolina data the results of using the national average value for trip rates produces similar results to other methods. We have identified two areas of interaction between proximity class and other variables (income levels and population density). Our results suggest corrective values if FRINGE planners need to adapt tools based on these data items. Finally we have established that FRINGE models require only two different trip types.

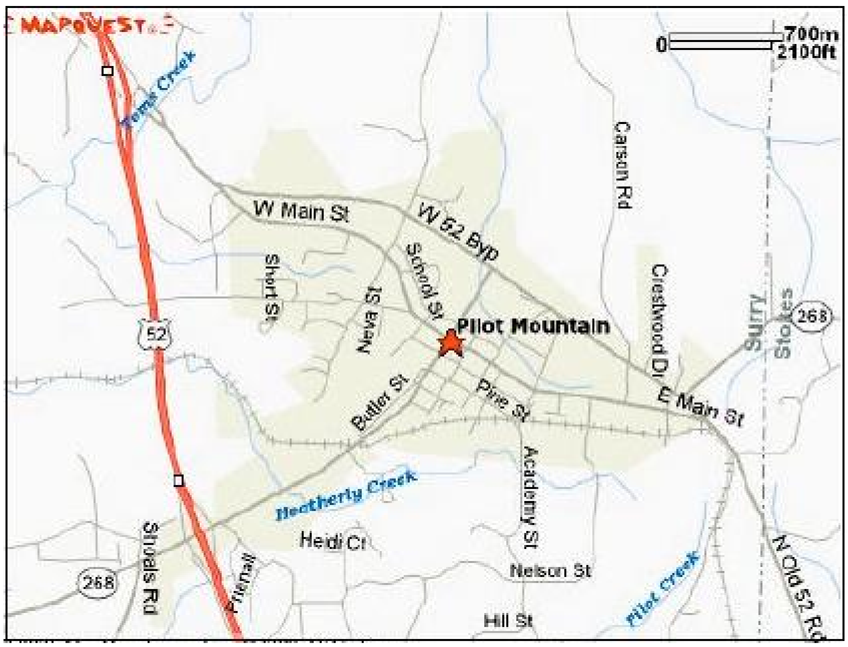
Sensitivity Analysis of Trip Rates in Small Urban Areas

Scope and Objectives

For this trip rate sensitivity analysis, the category of the study area is small urban areas with population less than 5,000. Pilot Mountain in North Carolina is taken as the case study in this study.

Settled on the eastern edge of Surry County, North Carolina, Pilot Mountain is a small town with 1,274 population (2,912 in the planning area) and extremely slow population growth rate. Pilot Mountain is situated 25 miles north of Winston-Salem, 130 miles from Raleigh, and 101 miles from Charlotte. US 52 is the main highway that serves this small town. NC 268 is the main artery through the town, and intersects US 52 about three quarters of a mile southwest of the CBD. NCDOT's plans for extending I-77 along US 52 will have a significant impact on the town. Figure H-2 shows the major routs throughout the study area.

Figure H-2. Major Routes in Pilot Mountain



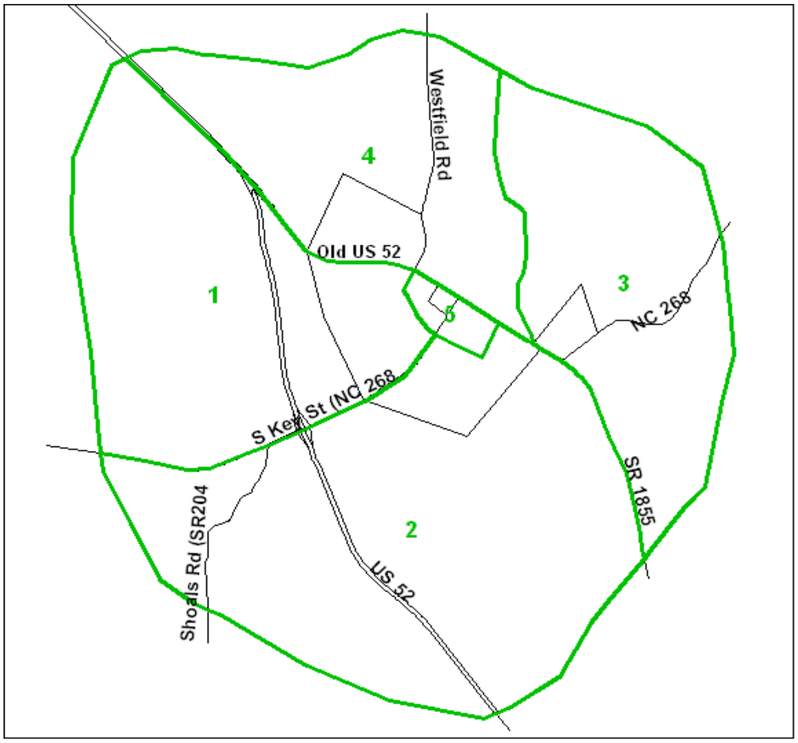
The manual travel allocation model is used to conduct the sensitivity analysis in this analysis. See Appendix D for details of the manual allocation model. Five traffic analysis zones (TAZs) and a simplified highway network are developed in the planning area, as shown as Figure H-3.

Three trip production rates of single trip purpose (US national default rate, NC average rate and a Pilot Mountain local rate) are applied to test if significant differences exist when performing trip generation.

The objectives of this study are:

1. To test if different trip production rates will significantly affect traffic operations on the highway network in a small community like Pilot Mountain.
2. To evaluate travel demand modeling results in small urban areas by different trip rates in small urban areas.
3. To test the feasibility of using single trip purpose to model small urban area traffic.

Figure H-3. TAZ and Network of the Pilot Mountain Planning Area



<u>Analysis</u>

- Tentative Trip Rates

The National Cooperative Highway Research Program (NCHRP) Report 365 (Martin and Mcguckin, 1998) published rates for a variety of communities which depend on urban size, auto per household and income, etc. Table H-9 summarizes of the national default vehicle trip rates.

Table H-9. National Default Vehicle Trip Rates

Urbanized Area Population	Vehicle Trips / Household
50,000 to 200,000	8.1
200,000 to 500,000	7.8
500,000 to 1,000,000	7.5
>1,000,000	6.9

Source: NCHRP Report 365

This table clearly shows that the vehicle trip rate decreases with the climbing of the population in the urban area. The lowest population threshold given by this table is 50,000, which is much larger than small communities such as Pilot Mountain. However, if we only consider the effect of urban size on the trip rate, 50,000 people will be the closest one to Pilot Mountain. Therefore, we take the corresponding vehicle trip rate 8.1 as one of the tentative trip rates.

Another trip rate which should be taken into account is the NC average trip rate. Based on survey data and professional experience, the average usually falls between eight and nine trips per household per day. Therefore, the mean value of the rate range, 8.5 trips per day, will be tested in this study.

The *Thoroughfare Plan Study Report for The Town of Pilot Mountain* (NCDOT, 1998) provided an average vehicle trip generation rate for households in the Pilot Mountain planning area in 1995. This vehicle trip rate is equal to 7.56, which is believed to be generated from a local survey throughout the planning area. In the sensitivity analysis, the value of 7.5 will serve as the local trip rate.

In brief, there are a total of three types of vehicle trip rates used in the sensitivity analysis: national default rate, NC average and local rate. Table H-10 gives a summary of the varied vehicle trip rates.

Table H-10. Tentative Vehicle Trip Rates

Type	Vehicle Trips / Household
National default	8.1
NC average	8.5
Local rate	7.5

- Effect of Trip Rates on Traffic Operation

Using a travel allocation model and 1995 housing & employment data, three travel demand forecasting results for the Pilot Mountain planning area are developed by three different trip rates, respectively. The modeling procedures and all parameters are kept constant except the trip rate. Capacity restraint method is used in the procedure of traffic assignment. By three different trip rates, the traffic assignment results on the network are shown as Figure H-4, H-5 and H-6.

Figure H-4. Travel Demand Forecasted by National Default Rate

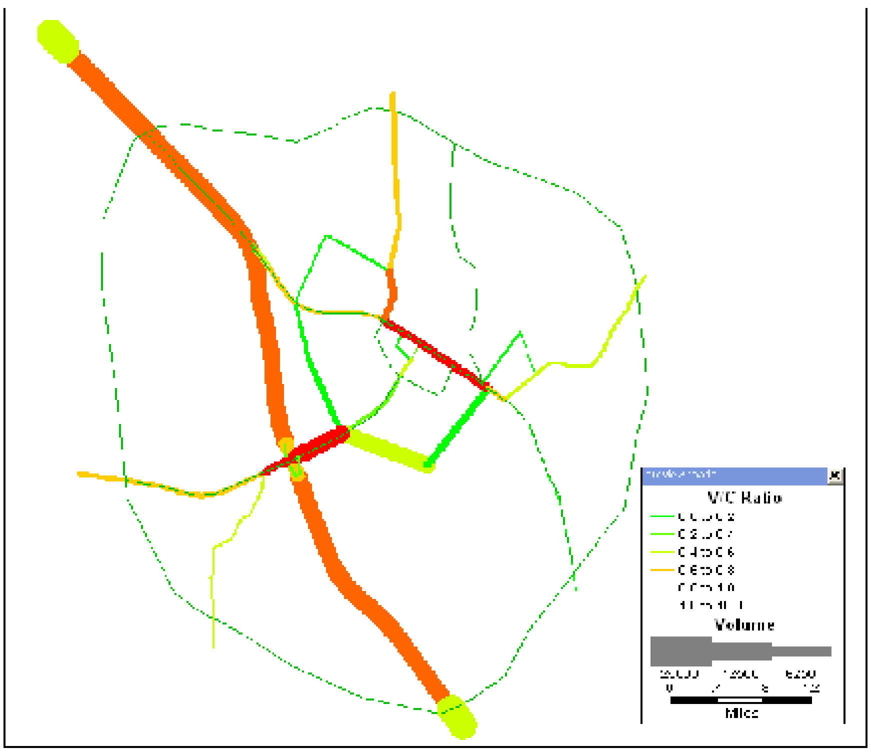


Figure H-5. Travel Demand Forecasted by NC Average Rate

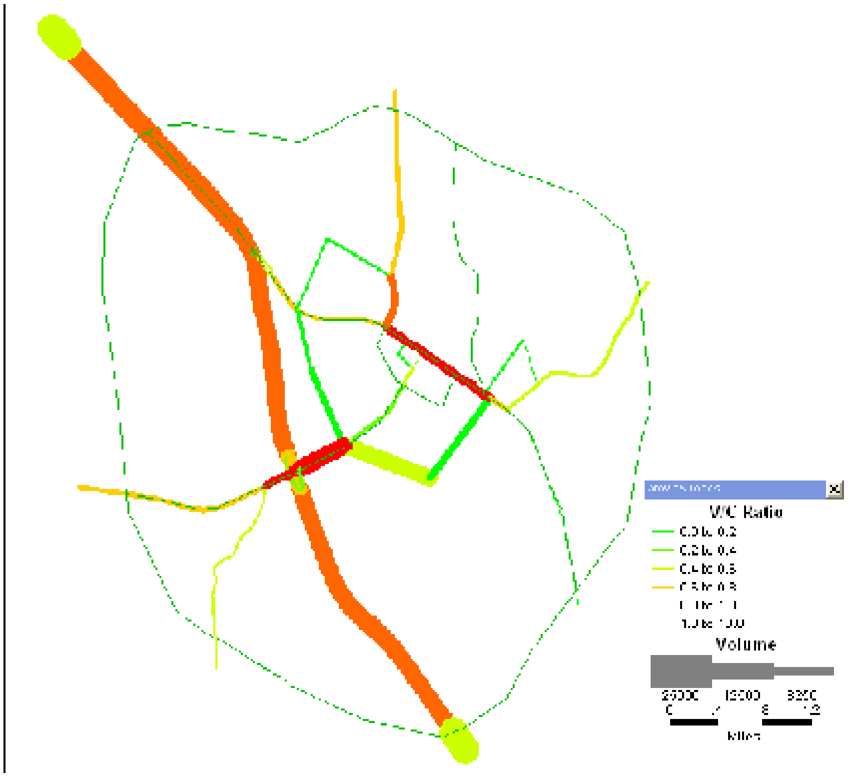


Figure H-6. Travel Demand Forecasted by Local Rate

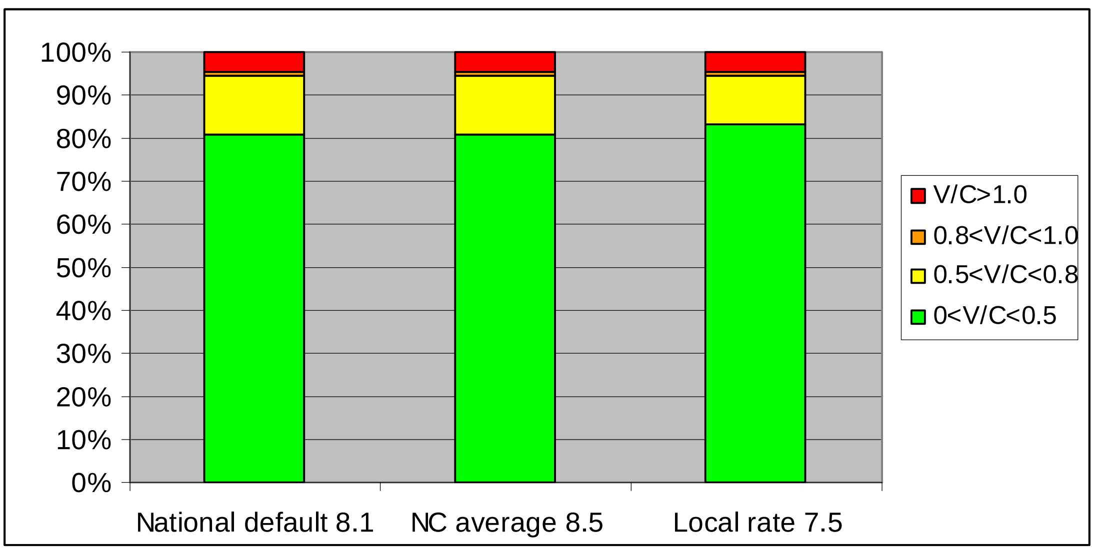
According to the estimated traffic flows, we do not find any significant difference of the forecasted traffic demand on the network by the three trip rates. And at the same time, all three assignment map indicate that US 52, NC 268 near the interchange with US 52, and old US 52 (52 bypass) near the CBD have fairly high v/c ratios. The modeling results match the truth in Pilot Mountain. Most of the trips in the planning area are through trips which go through US 52 and NC 268, and trips attracted to CBD also account for a fairly large proportion. Therefore, the traffic conditions at these places will be relatively severe.

In order to concretely evaluate the traffic demand changes caused by different trip rates, the v/c ratio is calculated for each route segment, and then all segments are grouped by four intervals of the v/c ratio. Table H-11 and Figure H-7 summarize the proportion of each group, according to the different trip rates.

Table H-11. V/C Ratio Changes on the Network by Trip Rates

Trip Rate	0<V/C<0.5	0.5<V/C< 0.8	0.8<V/C< 1.0	V/C > 1.0
National default (8.1 trips/HH)	80.8%	13.6%	1.1%	4.5%
NC average (8.5 trips/HH)	80.8%	13.6%	1.1%	4.5%
Local rate (7.5 trips/HH)	83.0%	11.4%	1.1%	4.5%

Figure H-7. V/C Ratio Changes on the Network by Trip Rates



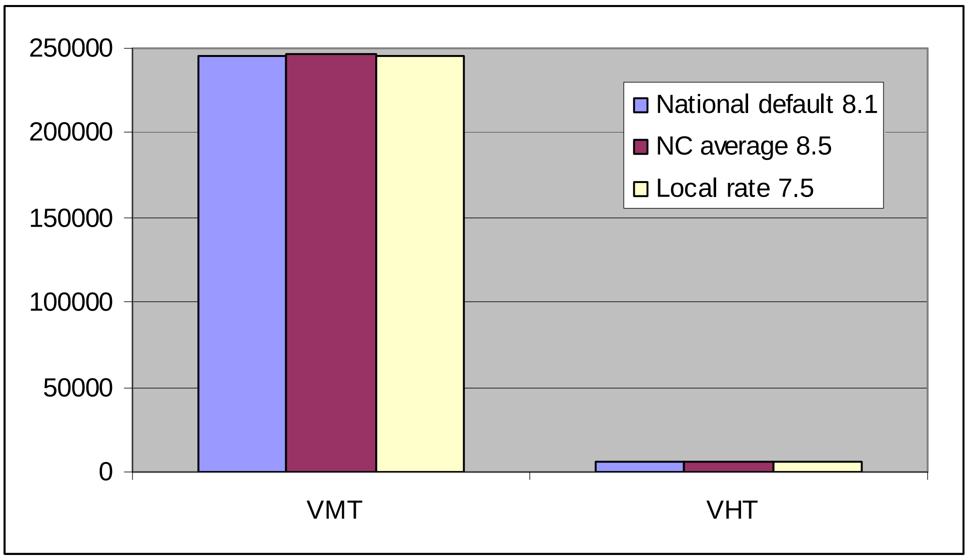
It is clear that, while different trip rates are used in modeling, the proportion of route segments with high v/c ratios (greater than 0.8) will keep constant. A slight change of the proportion distribution will happen when the local trip rate is used. The lower trip rate improves around 2% of route segments by reducing their v/c ratio from over 0.5 to below 0.5. Because the v/c ratio is a widely-used measurement of traffic condition, the trip rate seems to have no significant effect on network operation based on the above analysis.

Vehicle Miles Traveled (VMT) and Vehicle Hours Traveled (VHT) are useful criteria to evaluate network operation, which negatively impact both environment and economy. Table H-12 and Figure H-8 show a comparison of VMT and VHT by different trip rates.

Table H-12. Comparison of VMT, VHT and Average Speed by Trip Rates

Trip Rate	VMT	VHT	Average Speed
National default (8.1 trips/HH)	245812	5688	41.27
NC average (8.5 trips/HH)	246355	5707	41.26
Local rate (7.5 trips/HH)	245045	5659	41.27

Figure H-8. Comparison of VMT and VHT by Trip Rates



According to the comparison, we can find that higher trip rate will cause larger VMT and VHT. According to different trip rates, although the expected VMT and VHT on the whole network are different, the average travel speeds are almost the same. Therefore, it also means these three types of trip rates will not change the traffic condition that much in terms of the whole network. This conclusion keeps the same as the network v/c ratio analysis above.

- Travel Demand Modeling Results by Different Trip Rates

Trip rate is an important parameter in travel demand modeling, which directly impact the amount of expected trips on the whole network and thus impact the modeling accuracy. In the Pilot Mountain planning area, ground counts are available at seventeen route segments on the network in the base year. Table H-13 summarizes travel forecasting results by the three different trip rates It is clear that all three mean ratios are close to 1. This fact means the single trip purpose technique for the trip generation is an appropriate method. The mean ratio generated from the Pilot Mountain local rate (7.5 trips/HH) is the closest to 1 and has the narrowest confidence interval. At the same time, US default rate is better than NC average because its overall mean of the ratio is closer to 1 than NC average. This analysis indicates that, matching the professional experiences, the local trip rate is the comparatively appropriate one to be used for the small urban area. If the local rate is not available in small urban areas, the national default rates and NC average rates can be borrowed in order to save time and money. Furthermore, the national default rates seem to work better than NC average values according to the case study analysis.

Table H-13. Travel Forecasting Results

ID	Road Name	Facility Type	Traffic Counts/Estimated Flow		
			by Local Rate (7.5 trips/HH)	by NC average (8.5 trips/HH)	by National default (8.1 trips/HH)
1092	US 52	1	0.9993	0.9993	0.9993
1101	US 52	1	1.1355	1.1347	1.1350
1099	US 52	1	1.0945	1.0938	1.0941
1124	US 52	1	1.1318	1.1319	1.1319
1128	US 52	1	1.1318	1.1319	1.1319
1063	US 52	1	0.9993	0.9993	0.9993
989	NC 268	2	0.9111	0.9104	0.9107
1192	S Key St	2	0.3381	0.3482	0.3440
1227	SR 1855	2	1.0044	1.0033	1.0011
988	NC 268	2	1.5664	1.5662	1.5657
1210	NC 268	2	2.0000	1.9985	1.9990
562	SR 1855	2	1.0044	1.0033	1.0011
1010	Old US 52	2	1.2947	1.3309	1.3160
1009	NC 268	2	0.9844	0.9838	0.9834
865	Westfield Rd	2	1.1130	1.1130	1.1130
661	Shoals Rd	3	0.8330	0.8337	0.8327
1209	External	3	0.9996	1.0004	0.9992

Table H-14 shows the basic statistics for the ratio of traffic counts to estimated volumes.

Table H-14. Basic Statistics for Screenline Analysis by Trip Rate

	Traffic Counts/Estimated Flow		
	Local Rate	NC average	US Default
Observation	17	17	17
Minimum	0.3381	0.3482	0.344
Maximum	2.000	1.9985	1.999
Mean	1.0907	1.0931	1.0916
Standard Deviation	0.337	0.3368	0.3369
Lower limit 95% confidence interval on mean	0.9174	0.9199	0.9184
Upper limit 95% confidence interval on mean	1.2639	1.2663	1.2648

Conclusions and Recommendations

The analysis suggests:

- Different trip production rates (national default, NC average and local rate) lead to very similar VMT and VHT, so they do not significantly affect the traffic operations for small urban areas such as Pilot Mountain.
- We can borrow either National default rates or NC average rates for the travel demand forecasting in small urban areas where local rates are not available.

- For small urban areas like Pilot Mountain, the single internal trip purpose technique to generate zonal trips based solely on the aggregated number of households and employments is a legitimate method to perform trip generation that is less complex and data intensive.

APPENDIX I: TRIP DISTRIBUTION

Introduction

Trip distribution is the second major step in the travel demand modeling process. The first major step, trip generation provides a methodology for estimating trip productions and trip attractions in each zone. Trip distribution is the step that links the trip productions to the trip attractions for each zone pair. Trip distribution is a vital part of the planning process because it is the trip interchanges between each zone pair that eventually have to be accommodated by the transportation system.

Trip distribution models estimate trip interchanges between zones based on characteristics of the land-use pattern and the transportation system. The most widely used trip distribution model is the gravity model. As its name suggests, the gravity model for transportation planning is based on the gravitational theory of Newtonian physics. The gravity model of transportation planning predicts that the relative number of trips made between two TAZs, is directly proportional to the number of trip ends (productions or attractions) in each TAZ and inversely proportional to a function of the spatial separation (or travel time) between those two areas. Mathematically, the gravity model for trip distribution is defined as follows:

$$T_{ij} = P_i \left(\frac{A_j F_{ij} K_{ij}}{\sum_{k=1}^{zones} A_k F_{ik} K_{ik}} \right)$$

Where,

T_{ij} = the number of trips from zone i to zone j ;

P_i = the number of trip productions in zone i ;

A_j = the number of trip attractions in zone j ;

F_{ij} = the friction factor relating the spatial separation between zone i to zone j ;

K_{ij} = an optional trip-distribution adjustment factor for interchanges between zone i to zone j .

Gravity models are implemented as mathematical procedures designed to preserve the observed trip patterns (frequency distribution of trip length or travel time, etc) for each modeled trip purpose.

Problem

The gravity model structure can be calibrated and implemented using conventional transportation planning programs. Although the basic model structure is standard from area to area, there are differences in the methods of estimating calibration parameters and in the definition of the measure of separation between zones. The common procedure to calibrate the gravity model is an iterative process in which friction factor, the primary independent variable, is developed for each trip purpose and a mathematical function, such as an inverse exponential function or a gamma function, is used to describe spatial separation.

Two goals should be achieved when choosing or calibrating friction factors for use in a travel demand model:

- reasonable average trip length
- reasonable trip length frequency

If the trip length frequency distribution data is available (from a home interview survey, an existing model, or census data), an iterative process can be conducted to calibrate friction factors to match the observed trip length frequencies. This approach is time-consuming and usually unfeasible due to the unavailability of the household survey data in most small urban areas. Under this situation, another feasible and easier approach is to estimate reasonable average trip lengths based on local knowledge of the network, TAZ structures and land use, and then develop and adjust friction factors.

Approach

Average Trip Length Model

Three different average trip length models are evaluated. They are:

- NCHRP Report 365 Model
- Average Trip Length from Network Skims
- Population Based Model

NCHRP Report 365 Model

The closest correlation that has been found between average trip length and urban area size relates the average trip length to the land area of the urbanized area. According to *NCHRP Report 365: Travel Estimation Techniques for Urban Planning* (Martin and Mcguckin, 1998), the average trip length for HBW trips can be estimated using the following formula:

$$HBW\_ATL = 5.0 \times \sqrt{Area}$$

Where,

HBW_ATL = average HBW trip length;

$Area$ = area of the region (acre).

NCHRP Report 365 also suggests the average trip length for non-HBW (HBO and NHB) purpose trips according to different sized region, just as Table I-1 shows.

Table I-1. Average Trip Length for non-HBW Trips

Trip Purpose	Average Trip Length	
	Pop < 500,000	Pop >1,000,000
HBO	75-85% of the HBW Average Trip Length	60-70% of the HBW Average Trip Length
NHB		

Source: *NCHRP Report 365*

Average Trip Length from Network Skims

Based on the highway network and TAZ structures in the planning area, we can develop the zone to zone travel time matrix (shortest path matrix). This matrix provides a good starting point for the purpose of determining average trip length. By considering the set of internal TAZs, we can create zone to zone travel times and then calculate the mean travel time between zone pairs. Table I-2 provides default values for average trip length and relationships between different trip purposes. The average trip length of I-E/E-I trips can be estimated by calculating all the travel times between external zones and internal zones, according the shortest path matrix.

Table I-2. Default Values for Average Trip Length by Trip Purpose

Trip Purpose	Average Trip Length (minutes)	
	Large Urban Area	Small Urban Area
HBW	15 to 20	7 to 10
HBO	13 to 17	6 to 9
NHB	13 to 17	6 to 8

Source: FHWA, *Calibration and Adjustment of System Planning Models,* 1990

Population Based Model

Based on origin-destination studies done in the 1960s, the *Calibration and Adjustment of System Planning Models* (FHWA, 1990) provides a set of equations which can be used to estimate average trip length based on the urban area population. The equations are shown as below.

Home-Based Work: $t = 0.98 \times P^{0.19}$

Home-Based Social Recreation: $t = 2.18 \times P^{0.12}$

Home-Based Shopping: $t = 8.1$

Non-Home-Based: $t = 0.63 \times P^{0.20}$

Where,

t = average trip length;

P = population.

Estimated average trip lengths by trip purpose should be reviewed for reasonableness based on planner's knowledge of the planning area. Average travel speeds can be calculated by dividing the average distance for each trip purpose by the average travel time for each trip purpose and multiplying by 60. The average travel speed should be reasonable given the knowledge of the region.

Friction Factor

Initial friction factors can be developed based on an inverse exponential function using the estimated average trip length for each trip purpose. The formula is shown as below.

$$F = \exp\left(-\frac{t_{ij}}{ATL}\right) \times 10000$$

Where,

F = friction factor;

t_{ij} = travel time between zone i to zone j;

ATL = average trip length.

After applying the initial friction factors calculated with the formula provided above, the output from the gravity model should be reviewed for reasonableness. In particular, pay close attention to the average trip length and a plot of the trip length distribution. Calibration of the gravity model is an iterative process and without observed data can only be checked for reasonableness during the first or initial iterations. However, additional adjustments to the gravity model may be necessary to achieve final highway calibration using observed traffic counts.

Summary Results

Two North Carolina communities, Wendell (6,245 people in the planning area) and Fuquay-Varina (9,060 people in town and 29,276 people in the planning area) are taken as the case studies. Table I-3 shows the summary results of estimated average trip lengths.

Table I-3. Summary Results of Estimated Average Trip Length

Community	Model	Estimated Average Trip Length (min)			
		HBW	HBO	NHB	IE/EI
Wendell	Network Skims	4.30	3.70	3.40	4.95
	Population Based	5.16	6.20	3.60	N/A
Fuquay-Varina	NCHRP 365	5.74	4.59	4.59	N/A
	Network Skims	8.46	7.44	6.94	9.23
	Population Based	6.92	7.49	4.93	N/A

For Wendell, it can be seen from the Table above that the average trip length calculated using the network skims and population based models differ by nearly a minute for the HBW trip purpose and by nearly three minutes for the HBO trip purpose. The NHB trip purpose shows the greatest similarity between the two models with almost identical trip length. The average trip length estimated from network skims appear more reasonable for a community the size of Wendell where the maximum internal travel time is just over 10 minutes.

For Fuquay-Varina, according to the population based model, the estimated HBW average trip length is less than HBO. (This problem also happens in the Wendell case.) The result conflicts with the common situation that the HBW trip length should be greater than trip lengths of HBO and NHB trips. By comparing NCHRP Report 365 model with the other two models, we find that it yields less average trip lengths, especially for HBW and HBO trips. However, the maximum internal travel time is almost twenty minutes based on the local knowledge of Fuquay-Varina. Therefore, the average travel time from network skims seems more reasonable for an urban area such as Fuquay-Varina.

The trip distribution procedure is conducted by using a doubly constrained gravity model with friction factors developed using the average trip length from network skims. The resulting average trip lengths are shown in Table I-4 below.

Table I-4. Resulting Average Trip Length

Community	Average Trip Length (min)			
	HBW	HBO	NHB	IE/EI
Wendell	3.72	3.55	3.14	4.5
Fuquay-Varina	7.57	7.54	7.16	8.18

Findings and Recommendations

Based on case study analysis it appears that the mean travel time from the zone to zone minimum path matrix shows promise as a robust approach to estimating initial friction factors for a small urban study with a population between 5,000 and 10,000. This approach seems to work well for a medium urban area with population less than 30,000 as well.

APPENDIX J: MODE CHOICE FOR RURAL DEMAND-RESPONSIVE TRANSIT

Introduction

In 1959 North Carolina enacted legislation that required all municipalities to have a major street plan to address future travel needs. In 2001, this law was amended to address the provision of a “transportation” system to address future demand rather than just a “thoroughfare” system. In doing so, the transportation planning process for small urban areas was expanded to include not only highway travel, but other modes of travel as well. Therefore, it is necessary to develop an approach for estimating transit ridership in a small or rural community. Usually such communities with populations less than 10,000 persons cannot afford fixed-route transit so demand-responsive “paratransit” alternatives are used. They include taxis, dial-a-ride vans and informal ridesharing programs sponsored by social service agencies, churches and other organizations. The transit service support elderly and disabled mobility mostly and sometimes commuter and educational needs. The following discussion provides an approach to estimating the general level of ridership for demand-responsive transit.

Transit Cooperative Research Program (TCRP)

Transit Cooperative Research Program (TCRP) project B-3 conducted in 1993-1994 addressed the topic of “Demand Forecasting for Rural Passenger Transportation”. The results of this research are documented in the project final report and in a “Workbook for Estimation of Rural Passenger Transportation Demand”. To assist in the application of the methodologies developed in the TCRP research project a spreadsheet for application of the rural passenger demand estimation procedures was developed. The spreadsheet, TCRPB3.WQ1, was created in Quattro Pro for DOS Version 4.0. A version is also provided in Lotus 1-2-3 for DOS version 3.x, as TCRPB3.WK3. The Lotus version does not support the lines and other cosmetic features, but the calculations remain valid. The spreadsheet is available from McTrans Center and is easily read by current versions of Excel.

The various input, output, and calculation areas are arranged on a diagonal. From upper left to lower right, the spreadsheet consists of two input screens, two output screens, interim calculations, and lookup tables.

<u>Input Screen</u>

The input screen includes:

1. Service Area Characteristic Data Input (Figure J-1)
2. Program Data Input (Figure J-2)

The “Service Area Characteristic Data Input” screen is used to input data regarding the study area size, population characteristics, and information regarding non-program service levels and ridership. Not all data are required for all analysis options; those data items needed for specific calculations are noted in the right column. Please note that the formulae use the presence or absence of certain data to identify which calculation procedure is to be used. In particular, if “Base Year” data regarding Non-Program Ridership is entered, the “Incremental” methodology is used; if not, the “Synthetic” methodology is used. The “Program Data Input” is designed for entering data related to program transportation services. Program transportation services are those services that would not be operated but for the existence of a specific social service program. Examples are Headstart or a Developmental Disabilities program.

Figure J-1. Service Area Characteristic Data Input Screen

To print all input and output tables, {Alt}P

SERVICE AREA CHARACTERISTIC DATA INPUT

Service Area: Anycounty, Anystate
Analysis Description: Coordination of Program and Non-Program Related Services
Addl Description: Example D

	Units	Base Year	Forecast Year(1)	Data Needed For...
Area	Square Miles	800	800	Non-program Trips
	or Sq. Kilometers	0	0	Non-program Trips
Total Population	Persons	32,000	60,000	Non-program Trips
Persons Age 3 to 4	Persons	0		Head Start: Other
Persons Age 16 to 59	Persons	19,700	50,000	Job Training, Sheltered Workshop
Persons Age 16 to 64	Persons	0		Mental Health Service: Case Mgmt
Persons Age 16 and Above	Persons	24,400	60,000	Developmental Services
Persons Age 60 or Over	Persons	6,000	10,000	Non-program Trips: Elderly
Persons Age 75 and Above	Persons	2,000	5,000	Nursing Home, Senior Nutrition
Total Persons with a Mobility Limitation	Persons	6,400	15,000	Dev Svc: Pre-Sch, Gp Home, Mntl Hlth Svc
Persons Age 16 to 64 With A Mobility Limitation	Persons	500	750	Non-Program Trips: Mobility Limited
Families Below Poverty Level	Families	2,100	3,500	Headstart, Headstart: Home Base
Persons Age 65 or Less Residing in Households Below Poverty Level	Persons	4,900	65,000	Non-Program Trips: Low Income
Annual Non-Program Vehicle-Miles: All Providers				
Available to Elderly	Vehicle-miles	216,000	294,000	Non-Program Trips
Available to Mobility Limited	Vehicle-miles	216,000	244,000	Non-Program Trips
Available to Low Income				
- Taxi	Vehicle-miles	0		Non-Program Trips
- Non-Taxi	Vehicle-miles	216,000	244,000	Non-Program Trips
Annual Non-Program Ridership				
Elderly	1-way Psgr-Trips		--	Non-Program Trips Incremental Method
Mobility Limited	1-way Psgr-Trips		--	Non-Program Trips Incremental Method
Low Income	1-way Psgr-Trips		--	Non-Program Trips Incremental Method
Total(2)	1-way Psgr-Trips		--	Non-Program Trips Incremental Method
Estimate: Elderly	1-way Psgr-Trips	0	--	
Estimate: Mobility Limited	1-way Psgr-Trips	0	--	
Estimate: Low Income	1-way Psgr-Trips	0	--	
Forecast Year/Base Year Factor		1.88	(1)	Estimate of Future Demand

Note 1: Can be over-ridden by direct entry
Note 2: Only enter data if estimate of ridership by population group is desired.

Figure J-2. Program Data Input

PROGRAM DATA INPUT
Anycounty, Anystate
Coordination of Program and Non-Program Related Services
Example D

Program Type	Program Name	Indicate Program by "X" Base	Fore cast	# of Participants Base	Forecast	Annual Days of Operation Base	Forecast	Base Existing Ridership
Developmental Services								
Developmental Services: Case Mgmt								
Developmental Services: Pre-School								
Group Home								
Headstart								
Headstart: Home Base								
Headstart-Other								
Job Training								
Mental Health Services								
Mental Health Services: Case Mgmt								
Nursing Home								
Senior Nutrition								
Sheltered Workshop								
Other								

Output Screen

The output screen (Figure J-3) includes:

1. Program Demand Estimation Summary
2. Non-program and Total Demand Estimate

Figure J-3. Program Output Screen

171	Anycounty Anystate				
172	Coordination of Program and Non-Program Related Services				
173	Example 1				
174					Forecast
175					Year
176		Units	Base Year	Forecast Year	Method
177					
178	NON-PROGRAM DEMAND ESTIMATE				
179					
180	Ce: Elderly Service Factor		0.002942	0.002040	
181	Cm: Mob Limited Service Factor	--	0.001027	0.001055	
182	Cp: Low Income Service Factor	--	0.001505	0.001501	
183					
184	Elderly Demand	Annual Trips	13,581	24,455	Synthetic
185	Mobility Limited Demand	Annual Trips	1,096	1,676	Synthetic
186	Low Income Demand	Annual Trips	9,047	110,000	Synthetic
187					
188	TOTAL NON-PROGRAM DEMAND	Annual Trips	23,924	135,548	
189					
190					
191	TOTAL DEMAND ESTIMATE				
192					
193	Total Program Demand	Annual Trips	0	0	
194					
195	Total Non-Program Demand	Annual Trips	23,524	135,548	
196					
197	TOTAL DEMAND	Annual Trips	23,924	135,548	
198					
199					

This screen displays the output of the analysis of Program Transportation demand analysis and non-program transportation demand analysis, respectively. Here, the non-program demand is similar to general public demand.

Once the two input screens are entered, the spreadsheet will automatically calculate the ridership estimates. The results of these calculations can be reviewed by scrolling down and to the right, or by printing out the output screens.

Summary

The spreadsheet described by this Appendix estimates ridership levels for demand-responsive transit in small communities and rural areas. Actual ridership may vary depending on the level of service provided, quality of service, special programs, etc. Fixed route ridership will be addressed in Phase II of this research.