Guidelines for NCDOT Project-Level Traffic Forecasting Procedures

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16. Abstract

This project documents a methodology and related procedures to accomplish project-level traffic forecasting for NCDOT. While the methodology is general and can guide an engineer or planner through various steps including field visits, local discussions, data collection, analysis and documentation, the procedures provide explicit analytical tools appropriate for the forecasting task.

The methodology structures and systematizes the forecasting process using two general methods: (1) the hand method which utilizes spreadsheet procedures to address smaller, rather isolated projects, and (2) TransCAD which can evaluate larger projects that are part of complicated networks. Given Base Year traffic volumes, turning movements, land use and transportation network information, both methods provide estimates of future facility volumes and turning movements assuming alternative development scenarios. The methodology implicitly recognizes uncertainty in the forecasting process regarding development (trip generation) and the importance of truck traffic estimates for design.

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EXECUTIVE SUMMARY

Introduction

Engineers in the Traffic Forecasting Unit perform more than 300 annual traffic forecasts for highway projects. These forecasts show detailed information, such as that shown in Figure ES-1, for proposed highway projects. Traffic forecasts are the main input into design and operations analyses, which influence the geometric design requirements for a roadway including number of lanes, ramps, interchanges, intersections, and signalization.

Pavement design also depends on project-level traffic forecasts especially forecasts of truck traffic for correct selection of pavement thickness and type. As geometric design and pavement design have great effects on the final cost of a project, virtually all road and bridge improvements in the Transportation Improvement Plan (TIP) rely on the project-level traffic forecasts of the Traffic Forecasting Unit.

Many forecasts, however, do not follow systematic guidelines and do not have procedures that are as well defined. Traffic forecasting procedures may vary by project and responsible engineer. NCDOT traffic forecast engineers have developed ad-hoc procedures, spreadsheets, and methods based on regional models depending on the type and scale of the project under consideration. However, NCDOT has not formally documented those techniques or made them generally available to its staff. The project-level traffic forecasting problem is further fragmented when some engineers and consultants develop project forecasts from various software packages while others apply heuristic procedures based on expert judgment.

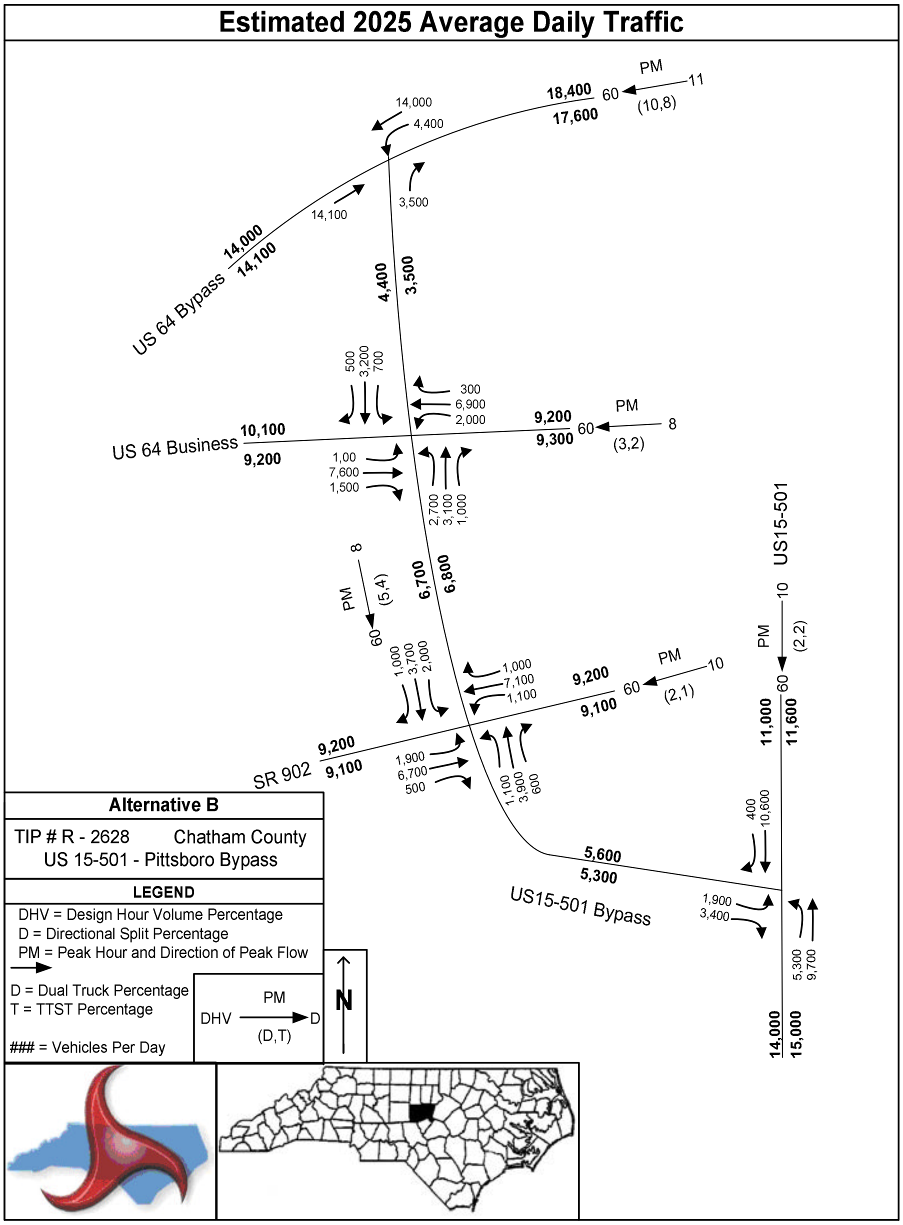
Project Scope and Objectives

This project identifies, demonstrates, and documents a systematic traffic forecasting methodology and associated tools and methodologies appropriate for urban and non-urban projects. For urban projects the goal is to apply unified and uniform modeling procedures that more fully integrate project-level “micro” traffic forecasting with systems-level “macro” traffic forecasting in regional transportation models. For non-urban areas without a regional model, the goal is to identify and demonstrate simplified methods that depend on the scale of the project and study area, and which build upon the resources and experience of NCDOT.

The specific objectives of the project are:

- To identify procedures to integrate systems level and project level traffic forecasts in urban areas.
- To identify appropriate systematic procedures for non-urban projects.
- To demonstrate and document the proposed urban and rural traffic forecasting procedures with case study examples.
- To discuss issues inherent in truck traffic forecasts.
- To discuss uncertainty inherent in the forecasting process.

Figure ES-1 – Hypothetical Project-Level Traffic Forecast



Project Review

This project documents a methodology and related procedures to accomplish project-level traffic forecasting for NCDOT. While the methodology is general and can guide an engineer or planner through various steps including field visits, local discussions, data collection, analysis and documentation, the procedures provide explicit analytical tools appropriate for the forecasting task.

The methodology structures and systematizes the forecasting process using two general methods: (1) the hand method which utilizes spreadsheet procedures to address smaller rather isolated projects; and (2) TransCAD which can evaluate larger projects as part of complicated networks. Given Base Year traffic volumes, turning movements, land use and transportation network information, both methods provide estimates of future facility volumes and turning movements assuming alternative development scenarios. The methodology implicitly recognizes uncertainty in the forecasting process regarding land use development and scheduled project completion. However, the models do not explicitly include uncertainty.

The project report provides guidelines to NCDOT staff and consultants as they prepare and document project traffic forecasts. In addition, the report, which includes detailed examples, can serve as a tutorial or manual to engineers and planners. Furthermore, the final reports serves as an informative reference to the citizens and public officials of towns and cities that are most affected by traffic forecasts and resulting projects.

Conclusions

This project provides guidance on data collection, analysis methods, documentation styles, and training recommendations to bring about an improvement in the project-level traffic forecasts prepared by NCDOT. Project conclusions follow:

- NCDOT uses a variety of quantitative and qualitative methods to perform project-level traffic forecasts. The variety of analysis methods used is attributed to the different types (urban vs. rural, large vs. small, etc.) of forecasting projects received by the Traffic Forecasting Unit.
- The selection of which method to use often depends on the analyst's preference and expertise rather than guidelines accepted by NCDOT.
- Systematic guidelines for selecting methods by project type are needed and were developed.
- The quality of traffic forecasts varies in terms of methods used and thoroughness of documentation.
- Systematic guidelines for traffic forecasting can improve the development and documentation of a forecast to ensure accuracy and repeatability.
- The guidelines can also serve as a manual to facilitate training.
- TransCAD is the state-of-the-art regional modeling tool used by NCDOT and it has the capability to develop turning movements, as well as link volumes, that are important in traffic forecasts. It should be used for project-level traffic forecasting when a regional model already exists.
- While TransCAD depends on aggregate traffic analysis zones, the transition toward GIS-based parcel level models will provide the finer focus that many traffic forecasts need.
- TransCAD is not the software to use for all traffic forecasts. Creating a TransCAD model is too time-consuming and data intensive for small projects.
- For small projects hand methods based on spreadsheets and complemented by expert judgment can quickly produce an accurate forecast.

Recommendations

With regard to traffic forecasting for highway projects NCDOT can improve its methodology, data collection, the use of spreadsheets, TransCAD, documentation and technology transfer. Specific recommendations for each topic follow. These recommendations may result in additional time requirements and resources for the forecasting process at NCDOT.

Methodology

- Review the proposed methodology of this study, modify it as necessary and train staff, clients, and consultants involved in project-level traffic forecasting.
- Consider the TransCAD methods and spreadsheets demonstrated in this study and adopt a preferred NCDOT "tool set" for traffic forecasting for highway projects.
- Incorporate an archival system for the data, analysis, methods and reports that result from the methodology and methods.
- Use the Internet to disseminate, apply and archive traffic forecasts.

Data Collection

- Improve analytical and staff resources for data collection.
- Incorporate GIS-based parcel-level datasets in regional models so that parcel-level forecasting is feasible.
- Incorporate traffic counts into the developing highway Linear Referencing System.
- Conduct truck counts annually.
- Adjust count schedules to include seasonal variations.

Forecasting Procedures

- Develop standardized spreadsheet templates and methods that can be tempered by professional judgment for smaller isolated projects.
- Develop TransCAD methods that can focus on sub-areas and include parcel-level data and analysis and/or develop sub-area methods that can accept TransCAD aggregate network flows in order to test parcel-level development scenarios.
- Use appropriate methods to explore hypothetically or retrospectively the sensitivity and uncertainty of traffic forecasts (and consequently project designs) to issues such as variable development scenarios, highway networks, and truck volumes.
- Standardize forecasting procedures and data sets so that forecasts are easier to review, interpret, and update.
- Adopt appropriate procedures to identify seasonal trend variations in automobile and truck traffic.

Technology Transfer

- Develop a one- or two-day traffic-forecasting workshop for presentation to current and future NCDOT staff and consultants.
- Promote a seminar for unit heads to consider issues and needs related to project-level traffic forecasting.
- Create a website for NCDOT information, procedures, data and reports on project-level traffic forecasting.

CHAPTER 1: INTRODUCTION

The Statewide Planning Branch is initiating significant changes in traffic forecasting, transportation modeling, and transportation planning. The new initiatives include:

- Introduction and use of TransCAD[1], which is a GIS-based land use and transportation systems modeling package.
- Formation of a new group for Systems Modeling.
- Examination of Smart Growth[2] land use options for mitigating congestion.

Fundamental to the success of the initiatives is an understanding of the relationships between land use and traffic forecasts in North Carolina for urban and non-urban transportation projects and between project and regional travel forecast procedures. Currently NCDOT has systematized methods[3] for regional travel forecasting to test system-wide, regional transportation alternatives. However, traffic forecasts for individual projects including major freeway projects, controversial local projects[4], business access[5], and bridge replacements may not be well defined or systematic. Traffic forecasting procedures vary by project and by responsible engineer. In the past few years traffic forecast engineers have developed detailed sub-area models from regional models in order to prepare local project traffic forecasts. However, those engineers no longer work in traffic forecasting and the techniques are no longer used. Currently some Urban Studies engineers develop project forecasts from urban area models while others apply more heuristic ad hoc procedures.

Thus, identifying and systematizing traffic forecasting procedures for highway projects is the goal of this study.

Background

The Statewide Planning Branch is responsible for long-range (20 to 30 years) transportation planning in more than 200 North Carolina large and small urban areas. The transportation network owned by the state (in contrast to local roads in cities) is larger than any other in the US. Within the Statewide Planning Branch are Units for Urban Studies, GIS, Traffic Surveys, Traffic Forecasting, and Systems Models. Each unit has important traditional roles in traffic forecasting, and each unit is developing new and integrated roles to carry out the new initiatives for TransCAD, Systems Modeling, and Smart Growth.

Traditionally the Urban Studies Unit has cooperated with North Carolina communities to develop transportation systems solutions to accommodate growth[6]. In addition Urban

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[1] TransCAD, Caliper Corporation, 2001.
[2] Specific Transportation Goals (draft), Transportation Working Group, NC Legislative Commission on Smart Growth, Growth Management and Economic Development, 11/22/00.
[3] Triangle Regional Model and other regional models, Urban Studies Unit, NCDOT, 2000.
[4] Eno River Drive Improvements, Durham, NC. NCDOT Traffic Forecasting Unit, 1999.
[5] Triad Center Drive Extension, Greensboro, NC. NCDOT Traffic Forecasting Unit, 2000.
[6] *North Carolina Travel Model Development Process* (draft), Prepared by the NCDOT Statewide Planning Branch, 2000.

Studies engineers now are beginning to look at land use and Smart Growth options to complement and perhaps reduce the size and cost of transportation projects. GIS-based TransCAD tools offer potential approaches for accommodating land use alternatives if appropriate land use and trip generation relationships at both the zone and parcel level are known. No longer will Urban Studies engineers have to accept one “snap shot” of a community’s future land use plan, rather they will have the opportunity to examine alternate, less traffic intensive land use options. In addition TransCAD promises the ability to examine street and corridor, “micro” level traffic impacts of projects, as well as the usual systems level “macro” impacts. Such a project level impact assessment capability within TransCAD will facilitate the traditionally difficult tasks of evaluating and prioritizing projects in a thoroughfare plan.

Engineers in the Traffic Forecasting Unit perform more than 300 project level traffic forecasts each year. Also some project forecasts are conducted in the Urban Studies Unit. The forecasts support other NCDOT units including Project Development and Environmental Analysis, Roadway Design, Pavement Management, and Feasibility Studies. Using future traffic forecasts from regional models if available, historical trend analysis of local traffic data, field reviews, technical expertise, past and present information on local development plans, national trip generation factors and other information, Traffic Forecasting engineers project traffic for up to 20 or 25 years. Their project level traffic forecasts are the basis for roadway designs including number of through lanes, ramps, and interchanges; intersection designs including geometrics and signalization; and pavement designs including thickness and type. Virtually all road and bridge improvements in the North Carolina Transportation Improvement Plan (TIP) are affected by the work of the Traffic Forecasting Unit. Hence, accurate traffic forecasts at the project level are mission-critical to NCDOT.

Clearly the missions of the Urban Studies Unit and the Traffic Forecasting Unit are related. While the Urban Studies Unit traditionally focuses on systems options, the Traffic Forecasting Unit focuses on projects. It is anticipated, however, that the new macro/micro capabilities offered by TransCAD will help to integrate the functions of the two Units.

Problem Definition

Traffic forecast broadly fall into two categories: urban projects and non-urban projects. For urban projects there exist regional models upon which to base traffic forecasts. For non-urban projects no such models exist and traffic forecasts may range from simple heuristics and expert assessment to hand (pencil and paper) methods supported by spreadsheet analysis.

Traffic forecasts are difficult to prepare for many reasons. For urban projects the regional model, which provides base year and future year calibration data, may be out of date or unavailable. If the urban model is available other difficulties may arise that affect its use in project-level traffic forecasts:

- Regional models assume planned land use and planned transportation projects over a 20 to 30 year time span. Land use and transportation projects do not usually develop as early as planned because of financial, environmental, and other reasons. Regional data and assumptions must be used with care in project-level traffic forecasts. If the assumed projects and land use vary in the project versus regional forecast, mainline, Y-line, intersection, and interchange traffic patterns will be different.
- Uncertainty exists in the character and size of future traffic generators (plants, shopping centers, residential developments, etc.), the amount of truck traffic, and intersection turning movements that will affect project traffic forecasts and resulting roadway designs for the project.
- The base year of the project is usually different from the base year and design year of the regional model.
- The level of detail for links, nodes, and zones in the regional models is often too aggregated for local project level traffic forecasting.
- Loaded volumes for the regional model may be unrealistic in magnitude or time frame compared to those anticipated for the local project.
- Regional models are calibrated to link volume traffic counts, not turning movements which are often critical for project-level traffic forecasts.
- Assessments for potential growth for the local project are based on highly variable field assessments and interviews and may be quite different from the region-wide forecasts.
- Regional models may have anticipated land use for a site that may be different from that for the project under study.

For non-urban projects regional models do not exist, and additional problems arise. The engineer must build simplified models based on historical growth trends, traffic counts, truck percentages, and qualitative assessment of potential growth near the project. Often the engineer must rely on intuition and years of experience in forecasting. There are no systematic institutional procedures at NCDOT for non-urban project traffic forecasting as there are for urban and regional travel forecasting. Some commonly used "sketch" methods[7,8] at NCDOT could be improved or replaced by new commercial procedures that run in the MS Windows operating system, offer interactive graphical network displays and up-dated trip generation parameters.

Urban Projects

Regional traffic forecasts derive from regional models that provide reasonable traffic estimates for relatively large traffic zones and summary networks of the most heavily traveled roadways like arterials and expressways. Traffic forecasts from regional models, however, become problematic for many "fine grained" urban projects. Traffic models for local projects require additional network details for streets, intersections, and driveways.

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[7] The Highway Emulator, Louis Berger & Associates, 1992.
[8] Quick-Response Urban Travel Estimation Techniques and Transferable Parameters: User's Guide, NCHRP Report 187, Transportation Research Board, 1978.

While regional models estimate daily volumes for major roadway, traffic forecasting models for local projects (such as intersection improvements and roadway widening) require information regarding the number or percentage of trucks in the traffic stream, vehicle turning movements at intersections, design hour volumes, and percentage directional distribution of traffic. Without such additional information local project traffic forecasts fall short of producing the critical information needed for pavement design, design of intersection geometrics, capacity analysis, and signal timing.

NCDOT engineers address the problem of forecasting local traffic for urban projects by using a variety of analytical[6, 7] and heuristic methods[8], local traffic counts including trucks and turning movements[9], historic trends and future projections for land development, traffic trends, and experienced "tweaks". Unfortunately such carefully constructed, project-specific, customized analyses that occur outside the regional model require specialized effort that few individuals can accomplish.

By developing a standard, systematized framework for urban project traffic forecasting that is integrated with standard regional TransCAD modeling the overall travel forecasting process should become more efficient, understandable and reliable. Furthermore, integrating project traffic forecasts with regional forecasts will capture local roadway and land use details that will be helpful for later regional model refinement and updates.

Using the regional travel model as the foundation for other steps in the planning process has proved beneficial for NCDOT before. With the advent of GIS capability in regional travel estimation software, linking environmental review and planning with transportation planning has become standard. The Phased Environmental Process[10] has shown that the community, NCDOT and review agencies can work more productively when proposed transportation improvements are linked through GIS with preliminary functional designs and environmental databases.

Similarly incorporating urban project traffic forecasting procedures within the context of the regional transportation model should prove productive. The increasing flexibility of regional model software (like TransCAD) and its GIS capabilities permit "zooming in" from the aggregate zone level to the parcel level for detailed project traffic forecasting analysis. For urban projects the regional model can become the framework to "vertically integrate" regional travel forecasting, systems evaluation, environmental review and project traffic forecasting.

NCDOT is constrained in terms of hiring and training programs. There is relatively little time for engineers to train on new procedures like TransCAD or any other tool. Thus, this project specifies simplified methods whenever possible to facilitate training. Furthermore, the forecasting guidelines in this project capitalize on existing, in-house

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[9] Highway Traffic Statistics, Traffic Survey Unit, North Carolina Department of Transportation, 1997.
[10] Stone, J. R. and C.R. Gresham. Computer Methods for Phase 1 Environmental Studies and Agency Review (Paper No. 98-1421), Annual Meeting of the Transportation Research Board, Washington, DC, January 1998.

knowledge so that Traffic Forecasting engineers can obtain help from Urban Studies engineers or others with knowledge of TransCAD or related tools.

Rural Projects

Besides relatively expensive urban projects for which local traffic forecasts are necessary, there are many smaller non-urban and rural projects like highway widening and bridge replacements[11] that require traffic forecasts. These projects are outside the study areas of regional models and may be treated with simplified (yet sometimes very detailed) traffic forecasting procedures. For example, simple traffic growth factor models, regression models or time series analysis may suffice for an isolated rural intersection improvement or plant entrance. Or, if NCDOT is considering a bypass outside a small town with no regional model, engineers have conducted detailed traffic forecasts using software such as The Highway Emulator[12]. For some non-urban projects NCDOT engineers may develop customized procedures[13] to account for non-typical special generator and heavy truck traffic.

Rural traffic forecasting procedures can be improved in ways similar to improving urban traffic forecasting:

- Adopt a standard, systematized framework of analysis.
- Incorporate GIS-based information on roadway networks, land use, parcel information, and other data that are available within NCDOT.
- Recognize the uncertainty inherent in future traffic forecasts that may reach 25 years into the future.
- Document traffic forecasting procedures so that results are repeatable and justifiable to others besides the responsible engineer.

Other Issues

As a result of nationally pace setting development in the 1980's and 1990's, some NCDOT professionals believe that North Carolina trip generation rates, especially for truck traffic, do not follow national averages.

At issue is the relative importance of uncertainty in trip generation rates versus other forecasting parameters. For example, uncertainty in development trends and population growth over a 20 to 25 year projection period may be as large as the uncertainty in North Carolina trip generation rates. The same may be said for the uncertainty in estimating the likelihood and scale over 20 years of a shopping center, business center or subdivision near a project location. Other technical factors complicate research on trip generation rates specific to North Carolina. Following the usual practice to determine trip generation rates, cordon counts at special generator access points like driveways would be necessary.

[11] Ballenger Road Bridge Replacement, Henderson County, Traffic Forecasting Unit, NCDOT, 1999.
[12] Havelock Bypass US Route 70, Craven County, NCDOT Traffic Forecasting, 1993.
[13] NCDOT Workshop on Statewide Travel Forecasting, Sponsored by USDOT Federal Highway Administration, July 1999.

The Traffic Survey Unit usually does not perform counts at driveways; rather, counts occur at critical intersections and across roadways.

Similar issues relate to evaluating truck generation rates that are specific to North Carolina. It is recognized that truck traffic in North Carolina has increased as it has elsewhere as a result of economic development, just-in-time delivery strategies, and advantages in shipping speed and cost[14].

There is another important issue in truck traffic forecasting. If truck traffic is increasing at a different rate than automobile traffic, should traffic forecast engineers consider truck traffic apart from vehicular traffic? Currently total traffic forecasts are developed in the future year considering historic traffic growth, area development and other factors as discussed above. As a result total traffic might increase 2% to 3% per year over the 20-year forecast. The truck forecast, however, is usually considered to be a percentage of total traffic and that truck percentage usually remains the same for the base and future year forecasts. While truck volumes increase, the percentage may incorrectly remain unchanged in current procedures.

Scope and Objectives

This project identifies, demonstrates, and documents a systematic traffic forecasting methodology and associated tools and methodologies appropriate for urban and non-urban projects. For urban projects the goal is to apply unified modeling procedures that more fully integrate project-level "micro" traffic forecasting with systems-level "macro" traffic forecasting in regional transportation models. For non-urban areas with no regional model, the goal is to identify and demonstrate simplified methods that depend on the scale of the project and study area.

Of special concern for both urban and non-urban traffic forecasting are several technical issues:

- Applying quantitative and qualitative traffic and land use information to forecast project-level traffic.
- Estimating truck traffic.
- Determining turning movements.

There are also several non-technical issues that are no less important:

- Capturing NCDOT traffic forecasting expertise for systematic application.
- Documenting procedures and case study examples that NCDOT personnel can apply and justify after suitable training.
- Maintaining detailed defensible data on traffic forecasts.

The specific objectives of the project are:

1. To identify procedures to more closely integrate systems level and project level traffic forecasts in urban areas.

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[14] Discussions with L. Goode regarding VDOT studies on Interstate 81.

2. To identify appropriate systematic procedures for non-urban project traffic forecasts.
3. To demonstrate and document the proposed urban and rural traffic forecasting procedures with case study examples.
4. To discuss issues inherent in truck traffic forecasts.
5. To discuss the types and potential levels of uncertainty inherent in the forecasting process.

The approach to satisfy these objectives, structure the methodology, and select and demonstrate the procedures begins with a significant assumption: build upon rich and respected experience and methods of NCDOT. While the methods and tools of other states and the literature are reviewed, choices are not made unless they significantly improve NCDOT methods considering financial and training constraints.

Chapter Summary

This first chapter introduces the issues related to forecasting traffic for urban and rural highway projects. As the report develops in subsequent chapters a simplified, yet systematic, methodology and "tool set" will be developed. The next chapter reviews sources for framing the forecast methodology and various software tools.

CHAPTER 2: LITERATURE REVIEW

Introduction

The need to collect and systematize the project traffic forecasting procedures at NCDOT motivates this project. One challenge lies with incorporating expert judgment into the procedures in a reproducible, justifiable manner so that assumptions about uncertain future land use; development, population growth and traffic can be documented and quantified. Another challenge is the incorporation of software tools including regional models to facilitate the forecasting process.

An important aspect of this research project is a review of existing literature on traffic forecasting. Ohio and Florida currently have on-line traffic forecasting guides. Applicable methods for urban and rural areas were found and reviewed to aid in developing a traffic forecasting methodology for North Carolina.

Many computer programs are available to aid in traffic forecasting. They range from simple spreadsheets to complex packages. A review of programs available from two major software suppliers (McTrans and PCTrans) was conducted to determine programs suitable for North Carolina traffic forecasting. The methods outlined in NCHRP 255 and their associated spreadsheets were also examined.

Throughout this paper footnotes are used to cite relevant documents for the specific issues, the problem, potential approaches, and other topics that are discussed.

NCDOT Traffic Forecasting Procedures

The art of traffic forecasting for roadway design, pavement construction and traffic control undoubtedly began with the first paved roads. Ancient records[1] report how well Babylonians constructed their roads. Today, however, a variety of national and state guidelines standardize roadway[2], intersection[2], pavement[3] and traffic controls[4].

Key to the roadway design are fundamental traffic characteristics:

- Daily and peak hour traffic projections
- Turning movements
- Truck volumes

Despite the fact that the forecasts are usually for a 20 to 25 year period, these parameters are estimated as deterministic values without associated uncertainty. Engineering judgment in the design process accommodates inherent uncertainty with margins of

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[1] De Camp, L. S., The Ancient Engineers, Ballantine Books, New York, 1988.
[2] A Policy on Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials, 2001.
[3] AASHTO Guide for Design of Pavement Structures, American Association of State Highway and Transportation Officials, 1986.
[4] Manual on Uniform Traffic Control Devices, USDOT Federal Highway Administration, 2001.

safety and conservative designs allowing for unanticipated vehicle and truck traffic, budget, right-of-way, schedule, environmental restrictions and other constraints.

As discussed previously, urban travel forecasting procedures at NCDOT are well defined and are based on commercial software packages such as Tranplan[5], Viper[6] and most recently TransCAD[7]. The procedures for project-level traffic forecasting are not well defined and do not depend on current NCDOT software packages. There are, however, publications that relate to project-level traffic forecasting, and there are promising software packages.

A traditional reference for project traffic forecasting at NCDOT is NCHRP Report 187[8]. While its concepts are sound, many have been computerized since it was written in the late 1970's. The update to Report 187 is NCHRP Report 365[9]. It focuses on urban areas, yet its methods are adaptable to project-level traffic forecasts. Other valuable reports are NCHRP 255[10] (which documents a variety of analytical models valuable for traffic forecasting, population growth and related issues) and the ITE Trip Generation Manual[11]. These references are known at NCDOT and may be used for appropriate steps in the current NCDOT forecasting methodology (Figure 2-1). It provides systematic "hand" methods for sketch planning and traffic forecasting.

Spreadsheet software and the above references provide the basis for developing tools for traffic forecasting.

NCDOT staff used standard statistical procedures in spreadsheets to develop a Trend Analysis Spreadsheet (TAS). It fits historical travel counts to linear, polynomial, and exponential models, and it develops trend lines for future traffic. The results, however, need to be tempered by professional judgement.

Balanced Turning Movement (BTURNS) derives from NCHRP 255 methods to iteratively balance base year traffic counts and future year traffic estimates at isolated intersections. It works well for isolated intersections but does not automatically balance subsequent intersections in a corridor or network.

Traffic attracted to new facilities is a well-known phenomenon that is not currently accounted for by NCDOT spreadsheet methods. The NCSU team used NCHRP 365 methods and a spreadsheet to program the Screenline Spreadsheet (SS) which is particularly used for proportioning traffic between old facilities and the new parallel project. These spreadsheets are discussed and demonstrated in Chapter 3.

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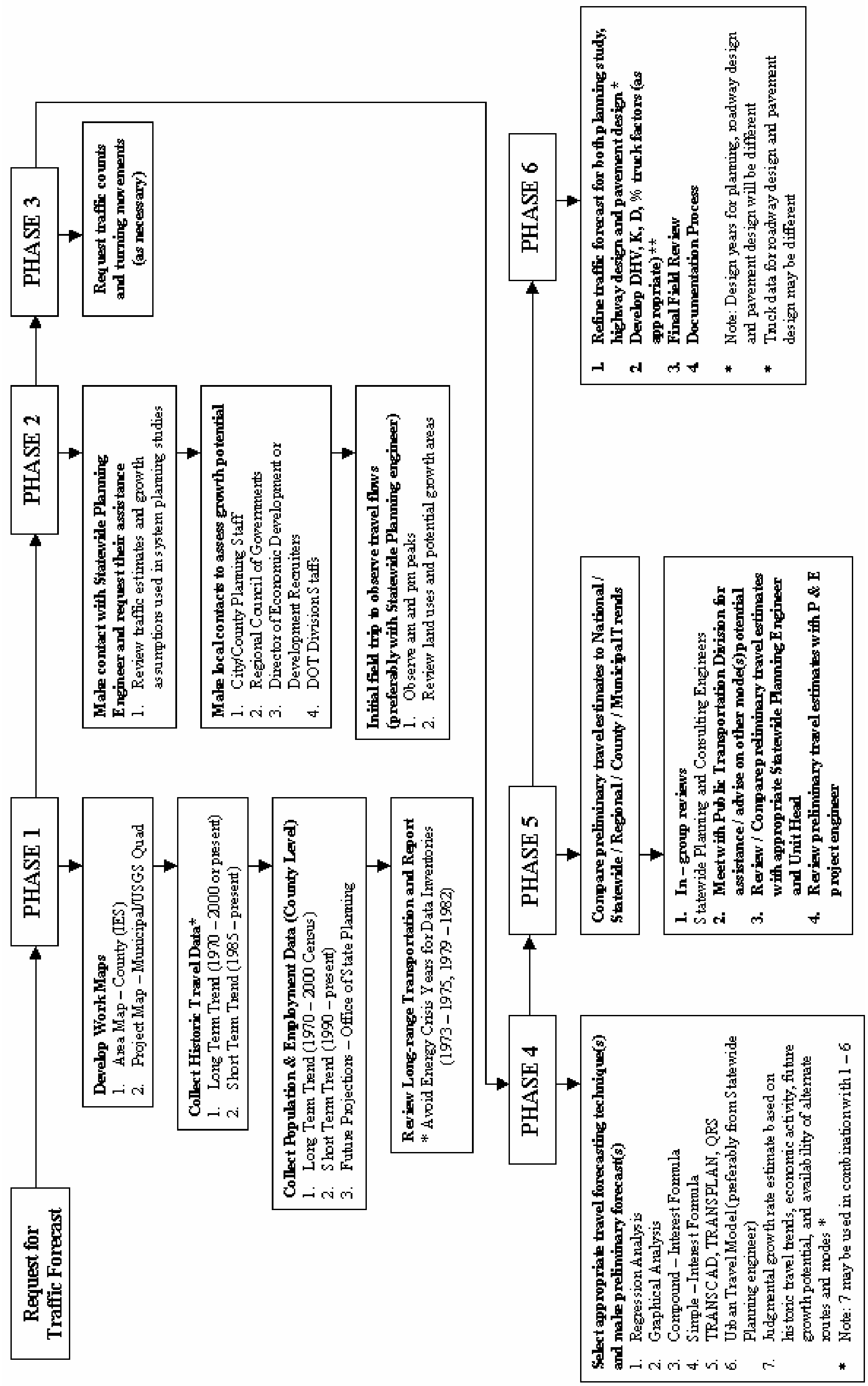
[5] Tranplan, CitiLabs/Urban Analysis Group, 1997.
[6] Viper, CitiLabs/Urban Analysis Group, 1997.
[7] Highway Capacity Manual, Transportation Research Board Special Report, 2000.
[8] Quick Response Urban Travel Estimation Techniques and Transferable Parameters, NCHRP 187, Transportation Research Board, 1978.
[9] Travel Estimation Techniques for Urban Planning, NCHRP 365, Transportation Research Board, 1998.
[10] Highway Traffic Data for Urbanized Area Project Planning and Design, NCHRP Report 255, Transportation Research Board, 1982.
[11] Trip Generation, Sixth Edition, Institute of Transportation Engineers, Washington DC, 1997.

Figure 2-1. NCDOT Forecasting Flowchart



As an example of how NCDOT integrates models in its project-level traffic forecasting methodology consider a recent paper[12] by an NCDOT staff engineer. This study involved applying various methods for estimating turning movements to data taken from the travel demand model for the Town of Plymouth, NC and comparing the resulting estimated turning movements to actual traffic counts (Appendix A). The methods include:

- Ratio Factoring (NCHRP 255) – Future year turning movements are proportional to the ratio of base year counts and base year model assignment.
- Directional Volume Iteration (NCHRP 255) – Future year turning movements derive from future year link volumes and base year turning movement percentages taken from counts (It is similar to BTURNS).
- TMOVES – A commercial program that estimates future turning movements to match or balance future year counts or estimates.
- Tranplan 8.0 – An integrated suite of programs for regional transportation planning. Link flows and turning movements are estimated.
- TransCAD 3.61 – A GIS-based software package for regional transportation modeling. It estimates link volumes and turning movements for base year and future year models.

The study clearly demonstrates how the various methods are used, especially in conjunction with a regional model. The three turning movement methods (ratio factoring, directional volume iteration, and TMOVES) produced similar results by incorporating base year turning movement counts and future year link volumes. Conversely, Tranplan 8.0 and TransCAD 3.61 did not estimate base year turning movement counts (only base year link volumes for calibration) and according to the study should not be applied directly to a project-level traffic forecast without the use of turning movement procedures such as those listed above. Note, however, that TransCAD 4.0 overcomes such limitations and faithfully reproduces turning movements. Thus, TransCAD can be used directly for future year estimates of turning movements, as well as link volumes. Detailed use of TransCAD is described in Chapter 3.

National truck percentages have dramatically increased over the past decade in many areas as a result of the economy and new shipping strategies such as just-in time deliveries[13,14]. NCDOT data suggests similar truck increases for many state highways; nevertheless, truck traffic forecasts are often neglected. It is commonplace to find forecasts that assume future year truck percentages are equal to the base year truck percentages. Until recently, research on truck traffic forecasting has not been emphasized. New research, however, gives emphasis to national and statewide truck

[12] Arellano, T. An Evaluation of Methods for Estimating Turning Movements for Project-Level Traffic Forecasts Utilizing Data Obtained from a Travel Demand Model, Department of Civil Engineering , NC State University, May 3, 2001.

[13] A Guidebook for Forecasting Freight Transportation Demand, NCHRP Report 388, Transportation Research Board, 1997.

[14] Quick Response Freight Manual, U.S. Department of Transportation, 1997.

traffic forecasting methods[15]. In spite of this, project level truck traffic forecasting procedures have not been systemically established[16].

Traffic Forecasting in Other States

Florida[17] and Ohio[18] have project-level traffic forecasting manuals available online. They present tools and methods that are candidates for NCDOT use.

Florida Manual

Florida's project-level traffic forecasting manual was written by the FDOT Planning and Projects Unit and the Roadway Unit. The manual provides guidelines for 20-year forecasts, which is shorter than NCDOT Statewide Planning's range of 25 to 30 years. However, the procedures can be used for a wide range of forecasts between 1 and 30 years. In this respect the Florida procedures are suited for the forecasting needs of the NCDOT.

The manual does not outline how to forecast truck volumes because Florida has no established method. The present approach is to assume that truck volumes will remain at the same percentage of all traffic in the future year as it is in the base year. An exception occurs if a known development will change the current statistic. However, the Florida manual assumes that 50% of daily truck percentage occurs during the peak hour of traffic, which establishes design criteria. This is similar to the Highway Capacity Manual rule of thumb. The importance of truck volumes is stressed by stating that trucks determine structure design loadings and intersection radii.

Three specific traffic-forecasting guidelines are laid out in the Florida handbook:

- Corridor Studies
- Project Level Studies
- KIP Equivalent Single Axle Loading (ESAL)

These guidelines do not specify particular software packages and spreadsheets. However, the guidelines recommend that tools be used to evaluate such factors as turn movements, traffic trends, and traffic balancing. NCDOT uses its own tools to do similar evaluations.

Corridor studies are used to determine future traffic volumes and assess the needs for improvements to existing roadways or the construction of new ones. These studies also

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[15] Park, M.-B., and R. L. Smith, Jr. Development of a Statewide Truck-Travel Demand Model with Limited Origin-Destination Survey Data. Transportation Research Record 1602, Transportation Research Board, 1997.

[16] Pendyala, M. R., V. N. Shankar, and R. G. McCullough, Freight Travel Demand Modeling – Synthesis of Approaches and Development of a Framework, Transportation Research Record 1725, Transportaion Research Board, 2000.

[17] Project Traffic Forecasting, Florida Department of Transportation, 2000.

[18] ODOT 5-Step Planning Process, Ohio Department of Transportation, 2001.

provide long range data needs. Project level studies are site-specific and focus on individual intersections. They are performed when more detailed data is necessary, such as turning movements and roadway geometry. KIP ESAL is necessary for pavement design on new projects, expansion projects, and resurfacing. This procedure stresses the importance of knowing the heavy axle loads generated by commercial traffic.

Florida enhances its traffic data by using a process called traffic smoothing. The smoothing process compares projected volumes to historical trends. During this step anomalies are sought out and eliminated to yield more consistent results. All differences between collected data and historical trends must be checked, explained, and documented.

Florida's manual also outlines some data analysis policies that aid in traffic forecasting. For example, project traffic forecasting uses the 30^{th} highest hourly volume of the year for its derivations. Florida's AADTs are also derived from the 30^{th} highest hour. These policies are consistent with AASHTO guidelines.

Ohio Manual

The Ohio 5-Step Planning Process is also a good source for candidate NCDOT procedures. Step 2 in particular describes software tools and different project approaches. The Ohio manual focuses on multiple build-out scenarios and stresses the creation of a list of potential traffic problems and solutions. This aspect is especially important when choosing software packages to fit the needs of the forecast, because some programs allow rapid data changes for testing multiple alternatives.

The Ohio manual also lists recommendations of data sources for existing travel patterns, performance of transportation systems, and previously proposed traffic solutions. Most of the references are specific to the state of Ohio, but some are relevant in other states. All of the data sources listed in the Ohio Process include World Wide Web addresses that quickly and efficiently direct forecasters to data.

The state of Ohio has 16 urban areas each with its own regional demand model. This allows projects to have specific background data. Each area has data collected on what are considered the key variables for trip forecasting:

- Population
- Households
- Employment
- Trip by trip purpose
- County to county trip flows

Also outlined in the process are technical tools used by Ohio DOT. ODOT favors the use of spreadsheets for the quick, easy calculations. The predominant regional model software package in Ohio is Tranplan.

Traffic Forecasting Software

For larger scale projects in urban areas integrated regional transportation software packages like TransCAD and Tranplan may be used to establish at least first estimates of link volumes and turning movements. These approaches have certain advantages; NCDOT has experience with the software packages, each urban area in North Carolina has a model in either Tranplan or TransCAD, and the models contain agreed upon future land use scenarios. These packages, however, model land use at a fairly aggregate level and engineers will have to adjust the models or model results for corridor and smaller projects.

Another approach for larger projects is the use of computer "sketch" methods for traffic impact analysis. Such models like QRSII[19] can evaluate urban and small area travel forecasting problems. Given a network and zone characteristics sketch methods 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.

Site planning software packages like Traffix[20] and SITE[21] are another type of interactive computer program that systematizes traffic forecasting studies for developments. They can accommodate large and small projects, import turn movements from other studies, forecast traffic impacts for new developments, and calculate level of service at signalized and unsignalized intersections and on arterials using the 2000 Highway Capacity Manual[22]. 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 major regional travel modeling software packages like TransCAD and Tranplan, there are a variety of other large and small software programs available. Some are expensive, others not. Some have extensive capabilities, others are limited. Many of the available software packages have become outdated based on operating system and other characteristics discussed in Appendix B. Table 2-1 summarizes a variety of the models and Appendix B provides details including cost and computer requirements.

[19] QRSII, AJH Associates, 2000.
[20] Traffix, Dowling Associates, Inc, 1999.
[21] TEAPAC/SITE, Strong Concepts, 2002.
[22] Highway Capacity Manual, Transportation Research Board Special Report, 2000.

Table 2-1. Forecasting Software Summary

Software Package	Software Characteristics								Cost
	GIS-Based	Graphic Output	Estimates Turning Movements	Land Use is a Variable	Uses AADT Volumes as Input	Urban Areas	Rural Areas	Small Areas	
TransCAD	**X**	**X**	**X**	**X**		**X**	**X**	**X**	$9,995
UfosNET	**X**			**X**					$9,500
QRSII		**X**	**X**	**X**		**X**	**X**	**X**	$195
TMODEL2		**X**	**X**	**X**		**X**	**X**		$3,800
TRAFFIX			**X**	**X**		**X**		**X**	$1,840
SPF				**X**				**X**	$60
RFM					**X**		**X**		$45
THE		**X**	**X**	**X**			**X**	**X**	$60
Trip Generation		**X**		**X**					$400
SITE/TEAPAC		**X**		**X**				**X**	$495
WINTASS				**X**					$295
Visual Traffic		**X**							$150
PPDS						**X**			$50
EZ-Turn			**X**						$490
TMOVES			**X**		**X**				$40

Chapter Summary

NCDOT is transitioning from Tranplan to TransCAD, which provides link volumes and turning movements directly for a project level-traffic forecast if a regional model is available. However, the traffic estimates are based on Traffic Analysis Zone land use descriptions that may be too aggregate for site-specific and corridor projects. Thus, the estimates may need adjustments based on spreadsheets, expert opinion, and local information. The next chapter of this report discusses how TransCAD can be used alone and how localized “hand” methods can be applied alone or integrated with TransCAD.

There are a variety of spreadsheet and software packages to accomplish traffic forecasts for highway projects. While they may be candidates for use at NCDOT, it makes sense, financially and training wise, to build upon existing methods the NCDOT uses. Thus, the proposed methodology of this study emphasizes TransCAD and spreadsheets currently available at NCDOT, or those easily acquired at relatively little cost.

CHAPTER 3: GUIDELINES FOR NCDOT PROJECT-LEVEL TRAFFIC FORECASTING

Introduction

There are two specific purposes of this chapter. The first is to give NCDOT Traffic Forecasting Unit engineers a sound forecasting methodology including key sources of forecast data, information, and forecast analysis tools. The second purpose is to give the public, traffic forecast clients, and decision makers a synopsis of the NCDOT traffic forecasting procedures. To achieve these goals the report presents background information concerning project-level traffic forecasts, a step-by-step methodology for performing forecasts, sample calculations, and case studies to illustrate the methodology. The proposed methodology offers a guide to forecasting and documenting the results. It will evolve and mature as more engineers and planners use it.

Background

NCDOT is the state agency responsible for maintaining and improving the state transportation system. The NCDOT Statewide Planning Branch is responsible for regional transportation planning. Within Statewide Planning, the Traffic Forecasting Unit is accountable for project-level traffic forecasts. Project-level traffic forecasts are essential for roadway and intersection design, pavement design, and environmental studies which lead to construction. Project-level traffic forecasts estimate future traffic volumes, including intersection-turning movements, for a defined study corridor.

Also fundamental to a project-level traffic forecast is a report that details the data inputs, assumptions, analysis tools, and results of the forecasting process. A well-documented forecast is essential for the approval of the traffic forecast and application of the results in project design. In later years good documentation will facilitate update and review procedures.

Uses of the Project-Level Traffic Forecast

Engineers in the Traffic Forecasting Unit perform more than 300 project-level traffic forecasts each year. Traffic forecasts are the main input into operations analysis with Highway Capacity Manual procedures, which influence the geometric design requirements for a roadway. Roadway design features impacted by project-level traffic forecasts include number of lanes, ramps, interchanges, intersections, and signalization.

Pavement design also depends on project-level traffic forecasts especially forecasts of truck traffic for correct selection of pavement thickness and type. Geometric design and pavement design have great effects on the final cost of a project. Virtually all road and bridge improvements in the Transportation Improvement Plan (TIP) rely on the project-level traffic forecast results of the Traffic Forecasting Unit.

The forecasts support other NCDOT units and outside agencies including:

- Project Development and Environmental Analysis
- Roadway Design
- Traffic Operations
- Pavement Management
- Feasibility Studies
- Construction and Maintenance
- Rail Division
- Highway Division Offices
- Metropolitan Planning Organizations (MPO)
- Rural Planning Organizations (RPO)
- County and City Engineers and Planners
- Consultants and Developers

Desired Output

All project-level traffic forecasts indicate 24-hour volumes for through and turning movements, peak hour percent, directional distribution, and include truck percentages for the study area network (Figure 3-1).

Besides a base year traffic volume, the forecasts may be 10, 20, or 30 years beyond the base year. The output of all project-level traffic forecasts is similar; however, the analysis used to arrive at the 24-hour volumes differs from project to project depending on the complexity of the study area, data available, and the tools available to the engineer. The specific traffic variables for a project-level traffic forecast are shown below.

1. Design Hour Volume (DHV) – According to the American Association of State Highway and Transportation Officials (AASHTO) the DHV is the volume for the 30^{th} highest hour in the year.[1] This represents 99.2% of all expected traffic. In practice the 30^{th} highest hour volume is assumed to be the heaviest PM peak hour flow and is selected by the NCDOT as the default DHV. Special projects may require the DHV to be the 30^{th} highest AM peak hour volume because of major influences on the morning traffic volumes. Projects that include schools, truck loading facilities, or businesses that operate a third shift in the study area may require AM peak hour volumes.

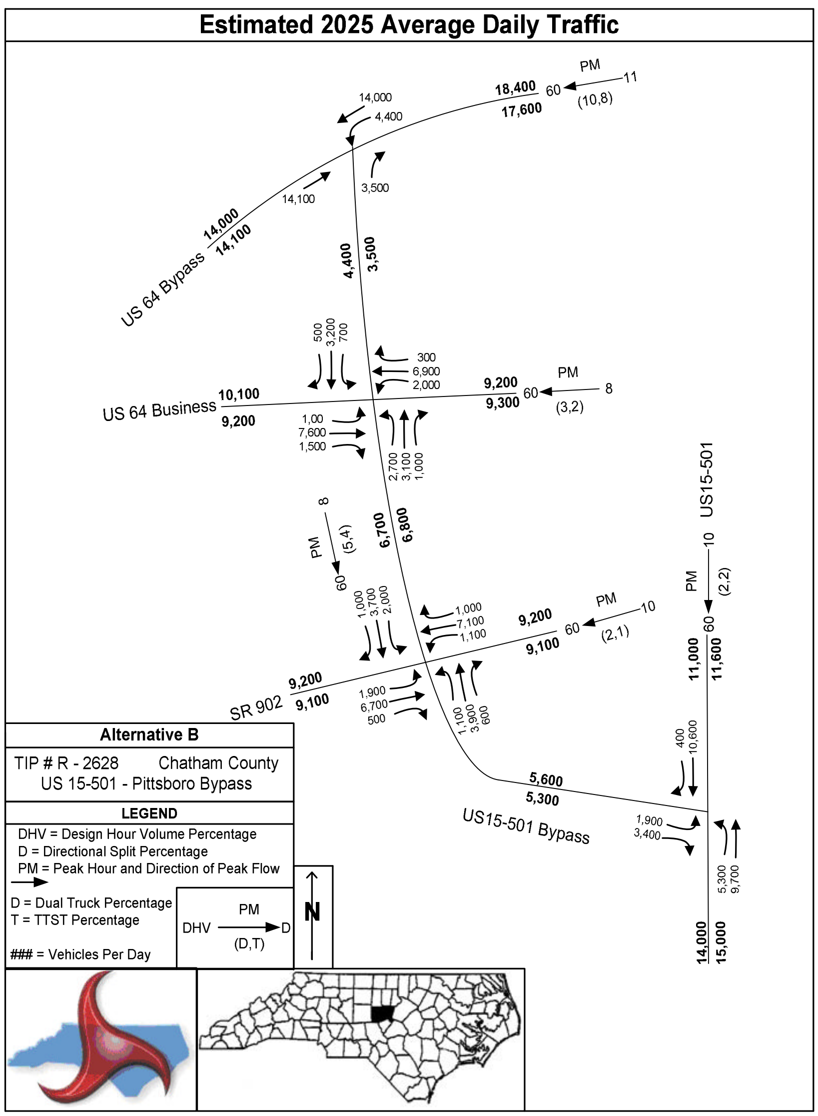
2. Average Annual Daily Traffic (AADT) – The AADT is the estimate of typical daily traffic on a road segment for all days of the week, Sunday through Saturday, over the period of one year[1]. The AADT's calculated at NCDOT represent the average of all typical days during a one year period. NCDOT applies seasonal and daily factors to traffic count data to determine an AADT for a roadway.

[1] A Policy on Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials, 2001.

The seasonal factors screen out atypical days including holidays and whether events, such as snowstorms and hurricanes, and days with traffic accidents and construction. The seasonal factors adjust a volume from the day it was collected to an AADT. For each seasonal group there are seven daily factors for each month of the year (94 total). NCDOT applies the seasonal factors; thus, adjust a count from a typical day of the week for any month to an AADT.

Another factor, the axle factor, converts a raw count from axle pairs to a volume. It accounts for trucks with more than two axles. The result is the volume in vehicles per day for the day counted. An AADT is validated by the Traffic Survey Unit by comparing it to previous AADT's (temporal) and checking continuity with neighboring AADT's (spatial). Individual stations that fail this check are recounted, and engineers should check with local agencies to determine what land use changes may have occurred.

Figure 3-1. Sample Project-Level Traffic Forecast



3. K Factor (K) – The K factor[1] is the proportion of AADT that occurs in the peak hour. K factors differ by location and facility type. K factors are based on data collected through a continuous count program. These are recorded by NCDOT automatic traffic recorders and show the percentage of daily traffic in each hour of the daily count. The relationship between K and ADT is expressed in the equation:
   DHV = AADT * K

4. Directional Split (D) – The D factor[1] is the percent of traffic in the predominant direction of flow applied to the DHV. The D factor will always be between 0.5 and 1. The percent of traffic in the minor direction is (1-D).

5. Turning Movements – Turning movements are counts of through movements, left turns, and right turns for intersections in the study area. Some projects require turning movements for heavily used driveways or parking lot entrances. Projects with truck stops, major distribution facilities, or shopping centers connected to roads by driveway access in the study area may require driveway-turning movements.

6. Truck Percentage – The truck percentage[1] for a roadway link is the average annual daily truck volume divided by the AADT. Special projects may require percentages for other vehicle classifications. Projects that include roadways sensitive to weight such as bridges or roadways traveled by unusual vehicles such as twin trailers may require additional vehicle percentages.

7. Volume Rounding Convention – The NCDOT uses AASHTO's rounding convention on AADT estimates[1]. The convention is:

Volume	Round to Nearest
0 – 999	10
1,000 – 9,999	100
≥ 10,000	1,000

   This convention is consistent with the level of precision that is achieved with techniques NCDOT uses to generate AADT.

Project-Level Traffic Forecasting Process

The NCDOT project-level traffic forecast process consists of three phases with multiple steps (Figure 3-2):

1. Input Phase
   a. Receive Forecast Request
   b. Contact Relevant Agencies
   c. Gather Data
   d. Conduct Field Investigations

    e. Request Traffic Counts
2. Analysis Phase
    a. Select Modeling Tool
    b. Model Study Area
3. Output Phase
    a. Document Forecast
    b. Review
    c. Forecast Dissemination

Input Phase

Step 1a: Receive Forecast Request

Various customers such as Roadway Design, Pavement Management, Project Development and Environmental Analysis, and Feasibility Unit send forecast requests to the head of the Traffic Forecasting Unit who gives them to individual engineers. Project-level traffic forecasts fall into five categories: new location (NL), update (U), bridge (B), widening (W), or special (S). The process for the different types of forecasts is similar; however, the analysis tools used maybe different. Depending on the type of project, the location, and the level of analysis needed the forecast request will be sent on to a Traffic Forecaster or a Statewide Planning engineer. If possible it is desirable for the forecaster to participate in project scoping meetings to understand the extent of the project and its schedule.

Step 1b: Contact Relevant Agencies

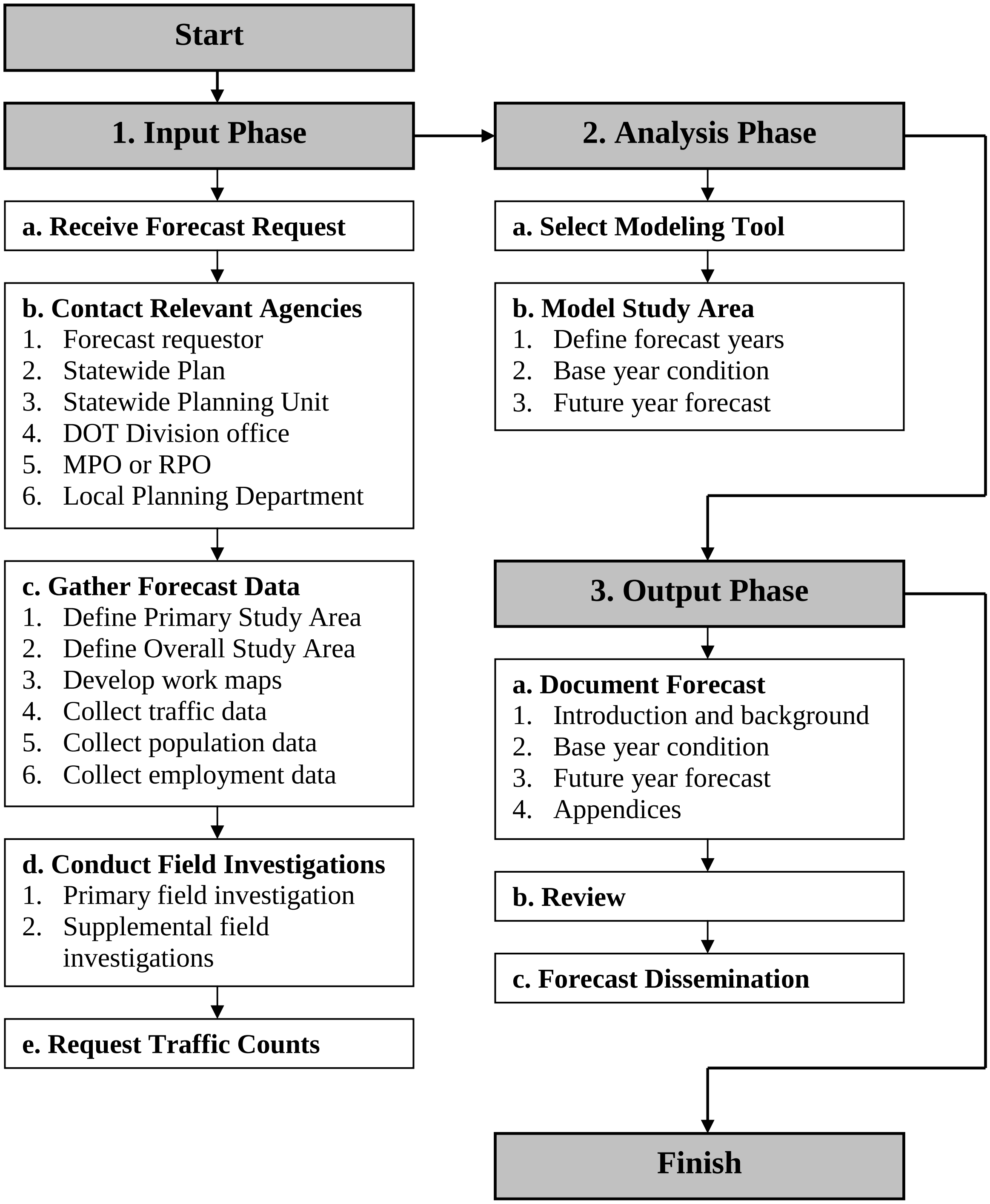
After receiving a request for a project-level traffic forecast the responsible engineer contacts all agencies that have an interest in the project. It is important to establish contact with various agencies so the latest data and information from the most knowledgeable individuals are used in the analysis.

Listed below are sources of information that are usually contacted for project-level traffic forecasts.

1. Forecast Requestor – Identify the project type and what data the client needs. Information the requestor may need includes:
    - Different study areas
    - Several land use scenarios
    - Multiple future year forecasts
    - Various alignment alternatives
    - AM and/or PM peak hour as DHV
    - Special truck or vehicle class analysis

   The forecast requestor may be the project-level traffic forecaster's best source of information because he or she is the most familiar with the project. Regular meetings and phone and email communication need to be set up between the

Figure 3-2. Forecast Flowchart



engineer and the requestor. This correspondence will guarantee the forecaster is privy to all project updates and that the requestor understands the project-level traffic forecast process. It is also important that the forecaster participate in any scoping meetings for the project. Without a clear understanding of the project scope and number of alternatives the forecaster cannot set an appropriate schedule and is subject to scope creep.

2. Statewide Planning Unit (SWP) – The SWP engineer assigned to the geographical area containing the project-level traffic forecast is a good source for regional data and traffic models. The SWP engineer may have already completed some work on the project or the surrounding area. In larger urban areas the SWP engineer has access to area models, key information on the regional transportation plan, and growth and development trends for the local area. The SWP engineer will review traffic estimates and growth assumptions used in system planning studies with the forecaster. A list of geographical locations, the most recent study for the area, and the assigned SWP engineer is located on the NCDOT webpage at: http://www.dot.state.nc.us/planning/statewide/smallurban/status.html

3. DOT Division Office – Talk to the NCDOT Division Engineer or District Engineer where the project is located. The Division Engineer can verify and expand on information from the SWP engineer and local officials. The Division Engineer can also provide knowledge about current and planned roadways, land uses, and local traffic patterns. A list of the Division Engineers is located on the NCDOT webpage at: http://apps01.dot.state.nc.us/apps/directory/toc.html

4. MPO or RPO – Depending on its geographical location, project-level traffic forecasts fall under the jurisdiction of an MPO or RPO. Projects in urban areas fall under the jurisdiction of MPOs. Projects outside urban areas fall under the jurisdiction of RPOs. RPOs are currently being formed by the NCDOT and may not exist for all rural areas. The MPO and RPO staff can provide local thoroughfare plans, growth studies, and historical data. A list of the MPOs is located on the NCDOT webpage at:
http://apps01.dot.state.nc.us/apps/directory/4651.html

5. Local Planning Department – Make local contacts to assess growth potential. People to contact include the local city or county planner, the Regional Council of Governments, the Director of Economic Development, or Development Recruiters. Forecasts cannot be performed properly without discussing the expectations of those most closely involved in the area. Typical discussions include what has occurred historically, what is expected to occur through your forecast horizon, and any information on developments already in the pipeline.

6. Other Sources – A variety of other agencies including the following can provide important information to the traffic forecast engineer depending on the type and location of the proposed project. Listed below are agencies that may be contacted for unique project-level traffic forecasts:

- Bicycle and Pedestrian Division – If the pedestrians or bicycles are a factor in the area of study. A list of the Bicycle and Pedestrian Division engineers is located on the NCDOT webpage at: http://apps01.dot.state.nc.us/apps/directory/3367.html

- Division of Aviation – If the area of study includes a local or regional airport. A list of the Division of Aviation engineers is located on the NCDOT webpage at: http://apps01.dot.state.nc.us/apps/directory/3364.html

- Ferry Division – If the area of study includes a ferry port. A list of the Ferry Division engineers is located on the NCDOT webpage at: http://apps01.dot.state.nc.us/apps/directory/3365.html

- Bridge Maintenance Unit – If the project-level traffic forecast is for a bridge. A list of the Bridge Maintenance Unit engineers is located on the NCDOT webpage at: http://apps01.dot.state.nc.us/apps/directory/2820.html

- Rail Division – If the area of study includes an at-grade crossing. A list of the Rail Division engineers is located on the NCDOT webpage at: http://apps01.dot.state.nc.us/apps/directory/3393.html

- Structure Design Unit – If the area of study includes a special structure. A list of the Structure Design Unit engineers is located on the NCDOT webpage at: http://apps01.dot.state.nc.us/apps/directory/682.html

Step 1c: Gather Forecast Data

After becoming familiar with the project-level traffic forecast request and the local area, the next step is to collect data for the analysis. Collecting all the necessary data for a project-level traffic forecast needs to be meticulously attended to. Leaving out important information in the data collection step could lead to a base year scenario that does not accurately describe the current traffic, highway facilities, and land use conditions around the project. Any mistakes made in formulating the base year conditions will be compounded in future year forecasts. To avoid missing important data the analyst should:

1. Define the Primary Study Area (PSA) – The PSA is defined as the geographical area around a project within which base and future year traffic levels are of interest. The project requestor will have an idea of the size of the PSA, but it is ultimately the forecaster's responsibility to define the PSA. Forecasters will base the PSA on the existence of alternate or parallel facilities in the area, special traffic generators, and special areas of interest. For large projects with multiple alternatives the PSA will be determined by the National Environmental Protection Act that describes environmental studies at a scoping of the parties at intrest.

2. Define the Overall Study Area (OSA) – The OSA is defined as the geographical area within which changes in population and employment substantially impact traffic levels within the PSA. OSA's are usually the city or county surrounding the PSA, however, large projects or projects crossing county borders may include more than one county in the OSA.

3. Develop Work Maps – Assemble an area map for both the PSA and OSA. The Geographic Information Systems (GIS) Unit has ArcView and Microstation digital maps that show the state maintained roads with in each North Carolina County. The digital maps are available in metric and English units along with downloading directions on the NCDOT webpage at:
http://www.dot.state.nc.us/planning/statewide/gis/DataDist/DD_CtyMps.html

   For assistance contact one of the GIS Unit engineers on the NCDOT webpage at:
   http://apps01.dot.state.nc.us/apps/directory/3240.html

4. Collect Traffic Data – The primary resources are turning movements (TM's) and AADT. The Traffic Survey Unit collects other data types on a smaller scale in terms of number of locations and frequency. These secondary resources are Manual Class Counts (MC), Daily Volume Counts (PTC), Seasonal Daily Volume Counts, Hourly Volume Counts, Hourly Vehicle Class Counts, Continuous Hourly Volume Data (ATR), and Continuous Weight and Vehicle Class Data (WIM). All these counts meet or exceed AASHTO standards and follow guidelines in the FHWA Traffic Monitoring Guide[2].

   All historical traffic count information is collected and archived in the NCDOT Traffic Survey Unit. The forecast engineer should assemble long term (eg. 1970 – present) traffic data collected from all locations within the PSA. Traffic data from energy crisis years (1973 – 1975, 1979 – 1982) should be carefully considered. Data from the energy crisis years is valuable because it may reflect traffic demand during the periods of lower economic growth, national emergency, and energy shortages. Traffic volume maps for each county in North Carolina are located on the NCDOT webpage at:
   http://www.dot.state.nc.us/planning/statewide/traffic.survey

   A list of the Traffic Survey Unit engineers is located on the NCDOT webpage at:
   http://apps01.dot.state.nc.us/apps/directory/3265.html

   Other sources of good historic traffic count data include MPO's and cities. These can include daily volume counts, classification counts, and turning movement counts. Many cities regularly count turning movements to better time their traffic signals. Cities and planning agencies may also be able to provide counts conducted by consultants for various studies or design projects.

[2] Traffic Monitoring Guide, Federal Highway Administration, USDOT, 2001.

5. Collect Population Data – Local county planning offices contained in the OSA will have area specific population data that is up to date. Likewise, they will have data for the PSA. The planners at the local level will also have a better understanding of the historical growth as well as growth projections for the OSA and PSA. The State Demographics Office also keeps up to date information on the population of every county. Specifically, the Demographic Office has county population totals, historical totals, projections through 2019, and population growth factors as well as person per household estimates for all North Carolina municipalities. Population data for each county in North Carolina is located on the Demographic Office webpage at: http://demog.state.nc.us/

   A list of local Demographic Office data center contacts is located on the Demographic Office webpage at: http://sdc.state.nc.us/frame_start_contacts.html

6. Collect Employment Data – Local county planning offices contained in the OSA will have area specific economic data that is up to date. Likewise, any local planning offices in the PSA will have area specific economic data that is up to date. The planners at the local level will also have a better understanding of the historical growth as well as growth projections for the OSA and PSA. The State Employment Security Commission also keeps up to date employment information for every county. Specifically, the Employment Security Commission has employment totals, income statistics, building permit information, and future employment estimates for all North Carolina counties. Employment data for each county in North Carolina is located on the Employment Security Commission webpage at: http://eslmi12.esc.state.nc.us/websaras/

   A list of Employment Security Commission contacts is located on the Employment Security Commission webpage at:
   http://www.esc.state.nc.us/Default.asp?openitem=5

Step 1d: Conduct Field Investigations

Throughout project-level traffic forecasts, and especially at the beginning, field trips to the PSA are necessary. The field trips allow the forecaster to become more familiar with the project area and are invaluable for establishing the base year conditions for the future traffic predictions. Field trips to the PSA serve primarily as information gathering opportunities for the following:

- General inventory of land use
- Observation of traffic flow (especially during peak periods)
- Identification of traffic data collection locations
- Location of proposed developments
- Location for undeveloped land and assessment of development potential
- Review of potential growth areas

During the several field trips the forecast engineer should meet with local professionals including:

- SWP Engineer
- Division Engineer
- Division Maintenance Engineer
- County Engineer/Planner
- City Engineer/Planner
- MPO/RPO Engineer/Planner

If local engineers and planners participate in the field investigations, the forecast analysis will be better. The local engineers and planners will be aware of historical traffic patterns, important intersections, existing and proposed land use, and growth trends for the study area. In some cases, local engineers or planners may have documented studies involving traffic or land use for the project area.

Two field trips are recommended for a project-level traffic forecast, however more are encouraged:

1. Primary Field Investigation – The primary field trip familiarizes the forecaster with the project area. This trip serves as a good time to meet all local planners and engineers as well as gather initial data.

2. Supplemental Field Trips – While traffic data collection is occurring, at least one additional field trip will be conducted. This trip is an opportunity to review all gathered data with local engineers and planners. Any additional questions or concerns with the forecast ought to be addressed before analysis begins.

Step 1e: Request Traffic Counts

After all the project maps, historical data, and growth projections are collected traffic counts need to be requested. Any of the counts may be requested, although TM's are predominant. Based on field observations, the forecaster should select several locations within the PSA that require traffic field data. Current counts are needed for major roads and intersections in the PSA. High volume driveways, large parking lot entrances, or any other special areas identified in the field trip should also be included in MTM counts. If needed, vehicle classification counts should also be taken. Four to eight weeks response time is typical for traffic count requests depending on number of other requests pending and number of counts. The Traffic Survey Unit conducts all field data collection for the NCDOT. Unit engineers will design special surveys like license plate surveys if the project, perhaps controversial, warrants such. All traffic count requests will be made through this webpage:
http://www.dot.state.nc.us/planning/statewide/traffic_survey/traffic.html

A list of the Traffic Survey Unit engineers is located on the NCDOT webpage at:
http://apps01.dot.state.nc.us/apps/directory/3265.html

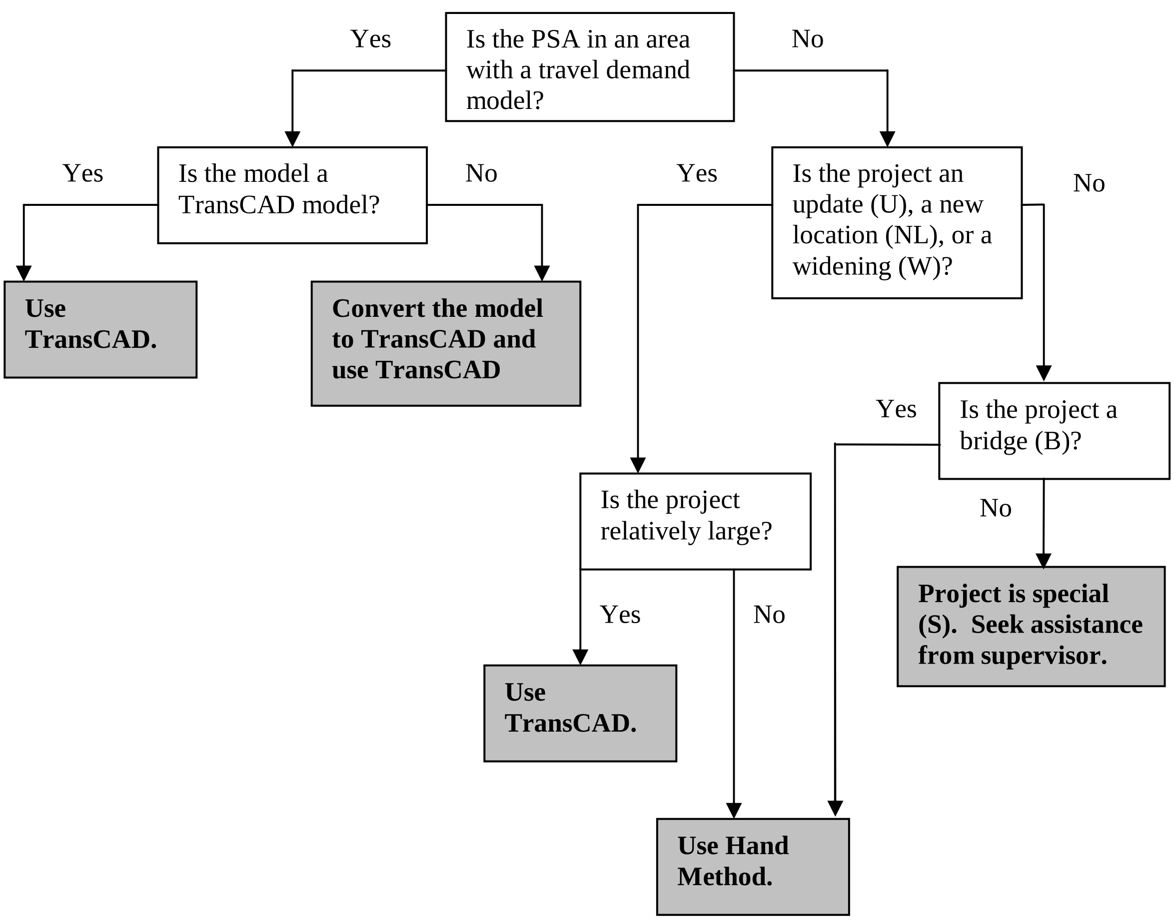
Analysis Phase

Step 2a: Select Modeling Tool

All NCDOT project-level traffic forecasts should be analyzed with appropriate software tools. This manual illustrates a variety of hand methods, spreadsheets, and TransCAD. Use the analysis method decision tree (Figure 3-3) to determine the correct analysis method for use on a particular project. The decision tree relies on yes/no questions concerning project type, size, and model availability to select the appropriate analysis approach.

Whether TransCAD is used as a tool may depend on the model used (if any) for the PSA. NCDOT began to transition from Tranplan to TransCAD in 2000. Some project forecast updates, for example, may rely on Tranplan unless the PSA is scheduled for conversion to TransCAD. The scale and the value of the project may also determine the desirability of a first-time use of TransCAD, especially if the PSA is not in an area with an existing regional model. In some cases TransCAD may not be the most appropriate method for detailed subarea analysis

Figure 3-3. Analysis Method Decision Tree



Step 2b: Model Study Area

As soon as the correct modeling tool is selected the engineer conducting the traffic forecast should model the study area. The input requirements, internal analysis steps, and output data differ for each analysis method and are explicitly described in the Analysis Methods section. The general analysis process is similar for all tools and follows this format:

1. Define Forecast Years – The calibrated base year of the forecast will be different from the opening year of the project. Typically base years need actual traffic counts for calibration. The base year may be the current year or it can be one or two years in the past. Likewise the future year forecast does not have to be project design year. Usually the forecast year is the project build out year but forecast years may be made for a sequence of years leading to the project completion date, especially if the project is phased.

2. Base Year Condition – Use known traffic counts and socioeconomic data to accurately describe the existing roadway and land use conditions. All traffic data must be adjusted for seasonal and daily factors. The base year DHV, AADT, vehicle classification percentages, K factor, and D factor all must be defined and used to develop traffic flow maps. Output from the PSA model may require calibration to eliminate inconsistencies and make results look realistic.

3. Future Year Forecast – Use estimated socioeconomic data, traffic counts, and land use information to forecast the future roadway travel. Identify all roadways, intersections, and important driveways included in the model. Define the TAZs and external zones to use in the model. Provide maps that detail the roadway network and socioeconomic zones used in the model. Specify the trip generation and distribution methods used by the model. Identify all socioeconomic variables as well as their sources. Be sure to document all calibration techniques used in the model. Define the future year DHV, K factor, D factors, and vehicle classification percentages. Comment on and include forecast year traffic flow maps for the PSA (24-hour average daily traffic volumes and design hour traffic volumes).

Output Phase

Step 3a: Document Forecast

Documentation is a very important step in the project-level traffic forecasting process. Long after the forecast is completed the documentation will serve as a chronicle of the analysis process. The documentation should clearly reveal the inputs, outputs, models, and assumptions used.

The documentation needed for project-level traffic forecasts is the following:

- Cover Page – List the project name, state and/or federal project number, the date that the forecast was completed, and who completed it.

- Table of Contents – Provide chapter and section numbers as well as location for all report sections.

- List of Tables – List the table number, a description of the table information, and the location within the report.

- List of Figures – List the figure number, a description of the figure information, and the location within the report.

- Introduction and Background – A brief introduction describing the project-level traffic forecast. Important information needed in the introduction includes state and/or federal project number, forecast year(s), specific variables forecast for each year.

- Study Area – Describe both the OSA and PSA in brief detail. Relevant information includes descriptions of the counties and municipalities containing the project (current population, development level, etc.), locations of interest in the area (airports, hospitals, universities, etc), description of the roadway network in the study area. Maps of both the OSA and PSA need to be included in this section.

- Project Description – Specify the focus of the project-level traffic forecast. Identify all scenarios that are examined and the roadway network changes proposed.

- Base Year Condition – Identify the base year and list the traffic data used to create the base year conditions. Data sources such as NCDOT historical counts and any new MTM, ATR, ATRVC, or other counts used will be described by the forecasting engineer and documented at the end of the report.

- Traffic Data Collection – List all historical and new traffic data collected by type (MTM, ATR, ATRVC, etc) and location. Include a map with all traffic data collection locations.

- Adjustment Factors – Describe any seasonal or daily adjustment factors used to convert new traffic data to base year volumes. Explain any growth factors used to convert historical data into base year volumes.

- Development of Traffic Flow Maps – Define the base year DHV, K factor, D factors, and vehicle classification percentages. Comment on and include base year traffic flow maps for the PSA (24-hour average daily traffic volumes and design hour traffic volumes).

- Future Year Forecast(s) – Describe the analysis tool (statistical method, computer model, etc) used to produce future year forecast(s), and summarize the steps associated with the tool.

- Model Network Development – Identify all roadways, intersections, and important driveways included in the model. Define the TAZs and external zones used in the model. Simplified models may not use explicit zones. Provide maps that detail the roadway network and socioeconomic zones used in the model.

- Trip Generation and Distribution – Specify the trip generation and distribution methods used by the model. Identify all socioeconomic variables as well as their sources.

- Model Calibration – Give a detailed account of all calibration techniques used in the model. Explicitly state all assumptions.

- Socioeconomic Data Development – Give a detailed account of all future socioeconomic data used in the model. Explicitly state all assumptions.

- Future Year Trip Table Development – Give a detailed account of all traffic growth factors used in the model. Explicitly state all assumptions.

- Future Year Traffic Volume Forecasts – Define the future year DHV, K factor, D factors, and vehicle classification percentages. Comment on and include forecast year traffic flow maps for the PSA (24-hour average daily traffic volumes and design hour traffic volumes).

- Appendices – Include all relevant data used in the forecast such as: historical traffic count data, new traffic count data, model input, and model output.

- Attachments – Include all computer files used in the forecast on a floppy disc or CD-ROM.

Step 3b: Review

All project-level traffic forecasts endorsed by the Traffic Forecasting Unit must undergo a review.

The purpose of the review is to determine that:

- The project-level traffic forecast is complete. There should be no missing data files, correct documentation, etc.

- The project-level traffic forecast is suitable for archiving. – It should be of sufficient quality, and have enough documentation to be useful and intelligible in the distant future.
- The Guidelines for NCDOT Project-Level Traffic Forecasting Procedures have been followed.

Any problems identified during the review must be resolved before the project-level traffic forecast is endorsed by the Traffic Forecasting Unit and accepted into the forecast archives.

The review panel will typically consist of the following people:

- The forecast requestor
- The Traffic Forecasting Unit Supervisor
- The person responsible for all Traffic Forecasting reviews

If possible the panel might also include:

- Division engineer or representative (for critical projects)
- City or county engineer or planner or representative
- MPO/RPO engineer

For small project-level traffic forecasts, it is possible to conduct peer reviews by phone conference or even email. Larger project-level traffic forecasts, though, tend to be best dealt with in face-to-face meetings. Prior to the review meeting, all people involved will receive copies of the forecasts, as well as any extra documentation or files being included. Distributing this information is the responsibility of the forecaster. During a typical review:

- Reviewers are asked to comment on the quality of the forecast.
- Specific problems and deficiencies are noted on a list of deficiencies, which is collected by the forecaster.
- A decision is made based on the recommendations of the reviewers to either:
  - Accept the forecast as is
  - Accept the forecast conditional on the resolution of identified liens
  - Reject the forecast

All issues regarding the forecast must be resolved before the forecast is endorsed and distributed by the Traffic Forecasting Unit.

Step 3c: Forecast Dissemination

The results of the review including any corrected deficiencies compiled, filed with the project-level traffic forecast, and distributed to interested parties.

Analysis Methods

Depending on the outcome of the analysis method decision tree, either the hand method or the TransCAD method is used for a particular project-level traffic forecast. Both methods follow Step 2b (Model Study Area) of the project-level traffic forecasting procedure but use different tools for analysis. While the TransCAD method utilizes a computer program, the hand method combines trend analysis, screenline traffic balancing, and turn movement tools to forecast future traffic.

Analysis Approach: Hand Method

The following steps outline the Hand Method. Subsequent sections describe the spreadsheets and give detailed examples.

1. Create a base year stick diagram that shows all the links in the PSA roadway network.

2. Examine historical and current traffic count data. Adjust count data for seasonal and daily factors.

3. Load the base year stick diagram with daily volumes based on the traffic count and turning movement data. Check for continuity and balanced flows at intersections and along roadways while allowing loss and gain at driveways.

4. Determine the base year DHV, ADT, vehicle classification percentages, K factor, and D factors. Create a base year ADT stick diagram.

5. Create a future year stick diagram that shows all the links in the roadway network including the project. Make sure to identify and show any new facilities or widened links compared to the base year.

6. Use the trend analysis spreadsheet with historical ADT data to create 25-year, 20-year, 10-year, and 5-year traffic growth trends. At least three historical traffic counts per link are desirable. Based on the growth trends and local input make a future year forecast for each link in the roadway network.

7. Use future year economic and land use data to modify future year forecast link volumes. Link volume additions or subtractions should be based on conversations with local officials, field trips, historical and projected trends, and engineering judgment. Any link volume modifications should be documented and explained. Link volume modifications due to a change in land use should be derived from the latest edition of the ITE Trip Generation Manual.

8. If a new facility is added or an existing facility is widened in the future year roadway network, use the screenline spreadsheet to balance volumes over competing facilities.

9. Use NCHRP 255 BTURNS to forecast future turning movements for all intersections and major driveways.

10. Determine the future year DHV, ADT, vehicle classification percentages, K factor, and D factors. Create a future year ADT stick diagram (Figure 3-1).

11. Document and explain all assumptions made in the project-level traffic forecast.

Trend Analysis Spreadsheet (TAS)[3]

This NCDOT spreadsheet uses historical ADT data as input to make forecasts for future year ADT. It requires at least three ADT entries to perform a trend analysis. An example best illustrates the use of the Trend Analysis Spreadsheet. The data used in this example comes from a corridor of US-501 near Roxboro. The project-level traffic forecast requires projecting the data out to the year 2025 using the long term and short-term trends. This example uses 16 years of data. There are two count stations with the following ADT data (Table 3-1). A discussion of the limitations of the Trend Analysis Spreadsheet follows the example

Table 3-1. TAS Example Count Data

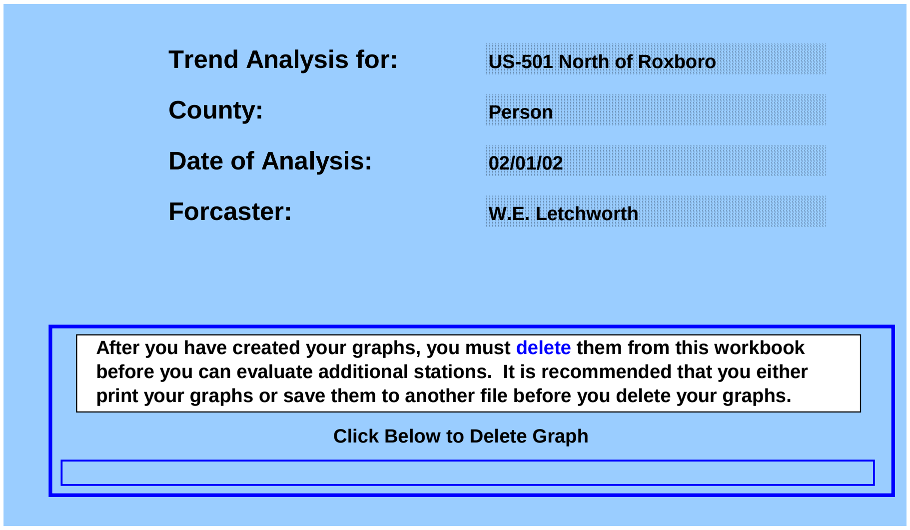
Year	Station 1	Station 2	**Year**	Station 1	Station 2
1985	3,900	4,600	**1993**	4,500	6,000
1986	3,400	4,600	**1994**	5,100	6,300
1987	3,400	5,900	**1995**	5,800	7,800
1988	3,500	6,000	**1996**	6,300	7,800
1989	4,000	5,000	**1997**	6,000	7,500
1990	4,400	5,700	**1998**	6,400	7,900
1991	4,200	5,700	**1999**	6,900	8,200
1992	4,100	5,700	**2000**	6,300	7,600

Step 1: Main Menu

1. Begin by entering basic information on the Main Menu page (Figure 3-4).

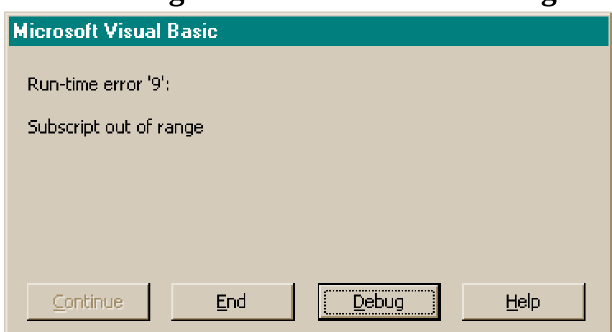
[3] NCDOT Traffic Forecasting Unit Trend Analysis Spreadsheet, 2000.

Figure 3-4. TAS Main Menu



2. Click on the graph buttons to delete all previous graphs. Click on "END" to remove all debug messages (Figure 3-5). Click on "OK" to remove all sheet deletion boxes.

Figure 3-5. TAS Error Message



3. Click on "Continue" to go to the ADT Input screen.

Step 2: ADT Input Screen

1. Input station descriptions and ADT counts for each station from 1985 to 2000 (Figure 3-6).

Figure 3-6. TAS Input Screen

Adt Data for Traffic Count Location

		Station Location Descriptions
US-501 Nor		
Person	Station 1	Between Woodsdale RD and SR1430
2/1/02	Station 2	Between Tonker Dr. and Cavel-Chub Lake Rd
W.E. Letchw	Station 3	

1. Enter adt counts for up to three stations

2. After data entry, go to "Begin Data Analysis"

Year	Station 1	Station 2	Station 3
1978			
1979			
1980			
1981			
1982			
1983			
1984			
1985	39	46	
1986	34	46	
1987	34	59	
1988	35	60	
1989	40	50	
1990	44	57	
1991	42	57	
1992	41	57	
1993	45	60	
1994	51	63	
1995	58	78	
1996	63	78	
1997	60	75	
1998	64	79	
1999	69	82	
2000	63	76	

2. Click “Print This Page” to print for documentation purposes and click “Begin Data Analysis” to go to Station Selection for Analysis page.

Step 3: Station Selection for Analysis

1. Click “Go to Station One” to analyze Station 1.

Step 4: Station 1 Analysis

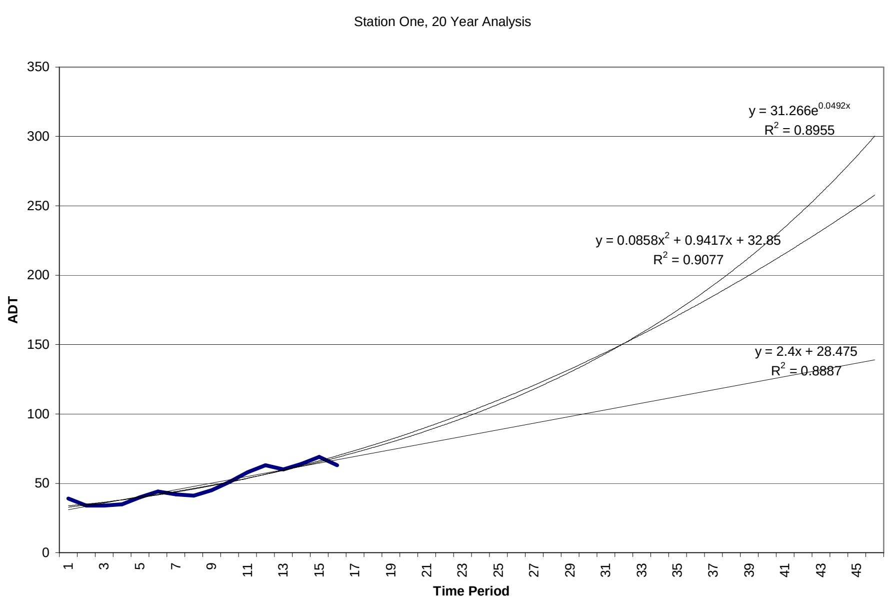
1. Follow the instructions in the box on the right hand side of the screen (Figure 3-7).
   - First year of data
   - ADT for first year
   - Last year of data
   - ADT for last year

Figure 3-7. TAS Station Analysis Input

Enter the first year you have data for		1985
Enter the adt for that year		39
Enter the last year you have data for		2000
Enter the adt for that year		63
Number of Years in Analysis		20
Average Yearly Increment	1.6	
Estimated 2025 ADT		103
Average Yearly Growth Rate	3.25%	
Estimated 2025 ADT		140

2. Click "Twenty Year Graph" to produce a forecast graph with three trendlines – linear, polynomial, and exponential (Figure 3-8). The equations that are calculated in this manner can be used for a forecast of any length (19 year, 20 year, 21 year, etc). Similarly the graph produced is not exclusively a 20 year forecast.
3. Go to File, Print to print this page for documentation.
4. Click on Station Analysis Tab at the bottom of the screen to return to Station Selection for Analysis screen.

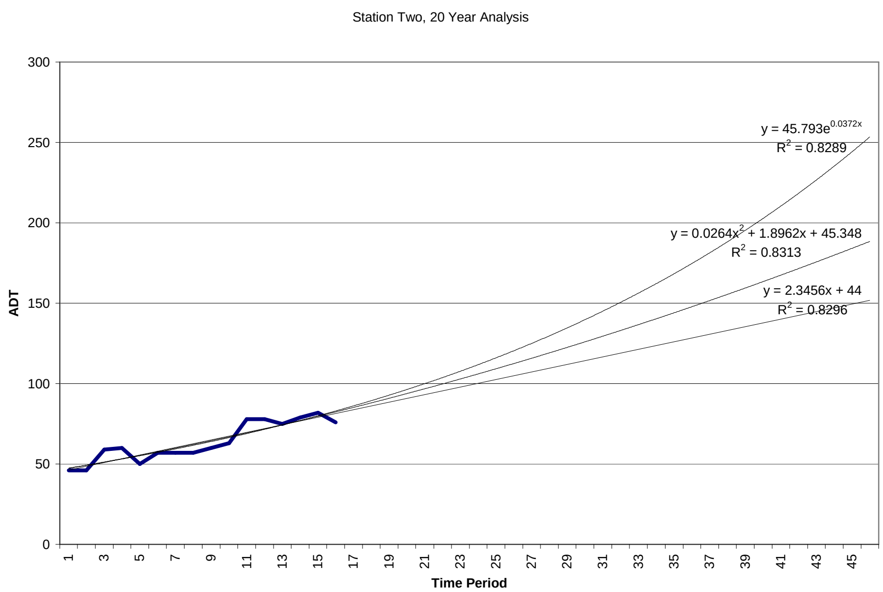
Figure 3-8. TAS Station 1 Long Term Graph



Step 5: Station 2 Analysis

1. Go to Station 2, input data, and make a 20-year graph, and print, as done for Station 1 (Figure 3-9).

Figure 3-9. TAS Station 2 Long Term Graph



2. Again click on the Station Analysis tab to return to the Station Selection for Analysis screen.
3. Click “Go to Estimate Sheet” to go to the Estimate Sheet.

Step 6: Estimate Sheet

1. Station 1 - By looking at the graph for Station 1, observe that the equation y = 0.0858x2 + 0.9417x + 32.85 has the highest R^2 value at 0.9077. This indicates that the polynomial equation fits the trend at Station 1 the best. Check to see if this is intuitively correct. Use the polynomial equation to estimate the 2025 ADT at Station 1 (Figure 3-10). This indicates that the ADT at station one in the year 2025 will be 20,800. Click “Print This Page” for documentation.

Figure 3-10. TAS Station 1 Long Term Estimate

Polynomial Equation: y = ax^2+bx+c			
	Enter the "y" value (future year)	**2025**	
	Enter the "a" value	**0.086**	
	Enter the "x" value	**40**	
	Enter the "b" value	**0.942**	
	Enter the "c" value (constant)	**32.850**	
Estimated ADT for year	**2025**	**equals**	**208**

2. Station 2 - As with Station 1, the polynomial equation best fits the data, as indicated by the highest R^2 value at 0.8313. Again, input the information from the graph into the polynomial equation section to determine the 2025 ADT (Figure 3-11). This indicates that the ADT at Station 2 in the year 2025 will be 16,300. Click "Print This Page" for documentation.

Figure 3-11. TAS Station 2 Long Term Estimate

Polynomial Equation: y = ax^2+bx+c			
Enter the "y" value (future year)		2025	
Enter the "a" value		0.026	
Enter the "x" value		40	
Enter the "b" value		1.896	
Enter the "c" value (constant)		45.348	
Estimated ADT for year	**2025**	**equals**	**163**

Step 7: Short Term Trends

1. Click on the "Main Menu" tab to return to the main menu.
2. Click on the "Station 1, 20yr" button and then on "OK" to delete the Station 1 graph. The equations that are calculated in this manner can be used for a forecast of any length (9 year, 10 year, 11 year, etc). Similarly the graph produced is not exclusively a 20 year forecast.
3. Delete the graph for Station 2 in the same manner.
4. Click "Continue" to go to the ADT Input Screen.
5. Delete all but the last five years of data from both Stations.
6. Click "Begin Data Analysis."
7. Create graphs, print, and determine 2025 ADT for both stations just as before.
8. Station 1 - Notice that the line with the highest R^2 value produces a negative ADT over time (Figure 3-12). This is impossible, so we use the value with the second highest R^2 (Figure 3-13). The explanation for a dramatic decrease in traffic may be due to a projection from insufficient historical data; a temporary short term traffic decline resulting from a plant closing; or a projection from declining traffic data when a new bypass or parallel route opens that competes with the project of interest. Discuss such situations with local officials.
9. Station 2 - Notice that the line with the highest R^2 value produces an unrealistic negative ADT over time (Figure 3-14). This is impossible, so we use the value with the second highest R^2 (Figure 3-15).

These examples generally indicate poor fit to the data ($R^2 \ll 1.0$). Furthermore, significant extrapolation beyond the data occurs by necessity, though undesirable. Such forecasts results should be treated with suspicion.

Figure 3-12. TAS Station 1 Short Term Graph

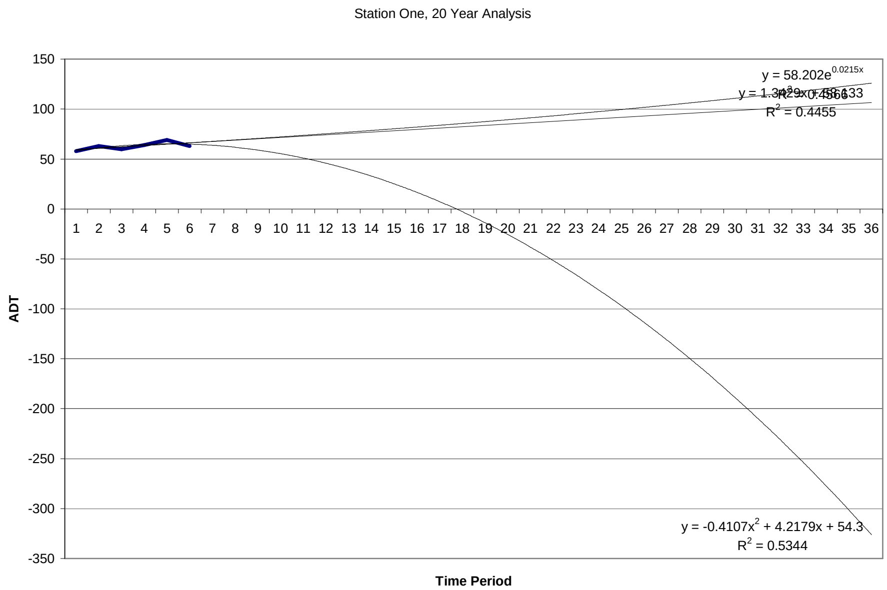


Figure 3-13. TAS Station 1 Short Term Estimate

Exponential Equation: y = ae^bx			
	Enter the "y" value (future year)	**2025**	
	Enter the "a" value	**58.2020**	
	Enter the "x" value	**30**	
	Enter the "b" value	**0.0215**	
Estimated ADT for year	**2025**	**equals**	**111**

Figure 3-14. TAS Station 2 Short Term Graph

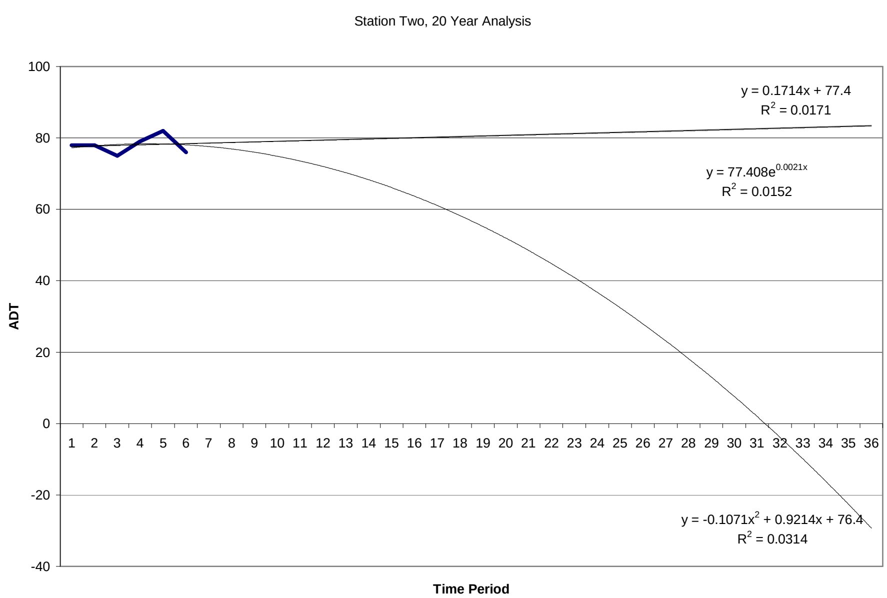


Figure 3-15. TAS Station 2 Short Term Estimate

Linear Equation: y = ax+b	
Enter the "y" value (future year)	2025
Enter the "a" value	0.1714
Enter the "x" value	30
Enter the "b" value (constant)	77.4000

Estimated ADT for year	2025	equals	83

Discussion and Critique of the Trendline Analysis Spreadsheet

The trendline spreadsheet uses historical data for three or more years to develop linear, exponential, or polynomial models of traffic data. While models may fit the historical data very closely ($R^2 \approx 1.0$), the forecast trend may be realistic or very unrealistic. In deed, R^2 shows data fit and not causality. Thus, R^2 does not necessarily assure a quality forecast. For example, short-term historical data and models may forecast conservative traffic growth, drastic decreases, or drastic increases. Engineering judgment tempered by information from local officials must be used to select the appropriate long-term model and traffic forecast. Clearly long-range forecasts, which are extrapolations from short-term historical data, are uncertain. The economic and other conditions, which occurred historically, may or may not occur in the future. Consequently long range forecasts are uncertain and must be used carefully in the project design process.

Screenline Spreadsheet (SS)[4]

The Screenline Spreadsheet derives from NCHRP Report 365 methods. The spreadsheet uses base year volumes and forecast volumes to balance future year traffic over parallel facilities. The mathematical basis of the Screenline Spreadsheet is simple proportionality. The spreadsheet allocates forecast volumes proportional to capacity.

Screenlines are only defined across facilities within the directional analysis area. For example, if only east/west highways are under investigation, only north/south screenlines are required. Screenlines need to cross facilities midway between major intersections or every two miles. An example best demonstrates the use of the Screenline Spreadsheet. The data in this example illustrates a hypothetical new north/south facility (link 50-51) in an area that has four existing north/south facilities (Table 3-2).

[4] NCHRP 365, Transportation Research Board, 1998.

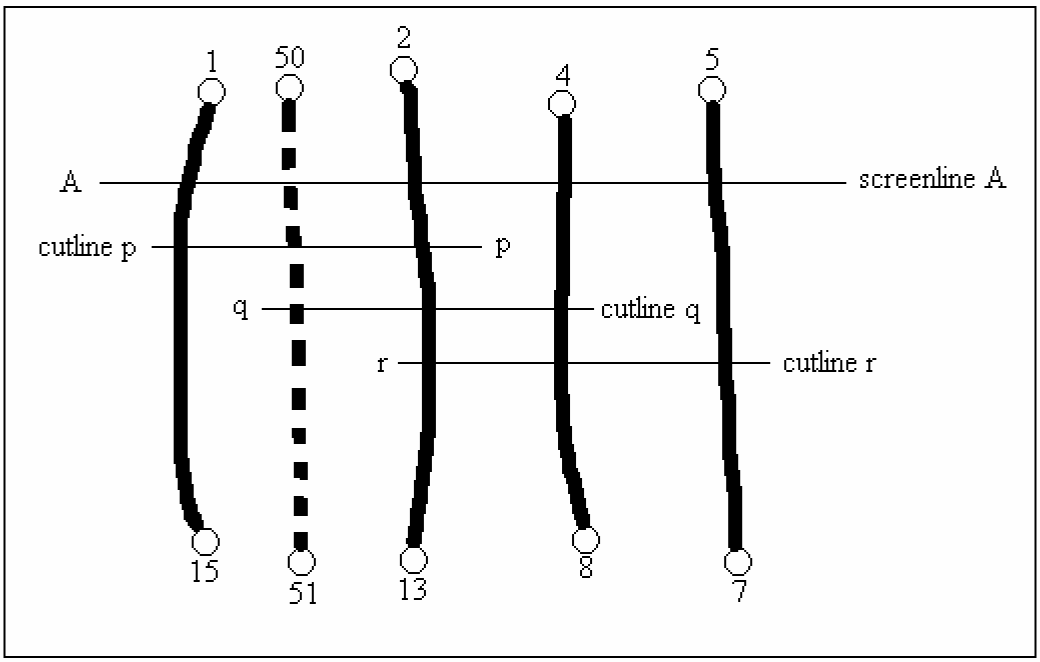
Table 3-2. SS Traffic Data

Link Descriptor		Base Year Traffic Count	Capacity	Forecast Year Assignment Volume
A Node	B Node	(ADT)	(ADT)	(ADT)
1	15	1,850	2,200	0
50	51	0	3,000	4,000
2	13	5,000	7,800	8,200
4	8	2,500	2,750	2,500
5	7	2,650	3,500	4,800

Step 1: Setup

1. Draw a stick diagram of the facilities for distributing assigned volumes. Assign node numbers to the ends of the links and define the screenline (Figure 3-16).
   - Screenline A crosses five links (1-15, 50-51, 2-13, 4-8, and 5-7)

Figure 3-16. SS Stick Diagram



2. Draw multiple overlapping cutlines that each cut three roads.
   - Cutline p, q, and r each cross over three roads

Step 2: First Cutline Analysis

1. Enter the cutline name in the "Cutline Name" cell.
   - The first cutline is named "p-p"
2. Enter the node names for each link crossed by the cutline in the "Link Descriptor" cells.
   - The first link is 1-15, the second is 50-51, and the last is 2-13.

3. Enter the number 1 in the "Enter 1 if New" cell for any links that are a new facility.
   - Link 50-51 is a new facility so 1 is entered for it
4. Enter the base year volumes (ADT) for each link in the "Base Year Volume" cell. Enter 0 base year volume for any links that are new facilities.
   - The base year volumes are entered:

Link 1-15	1,850
Link 50-51	0
Link 2-13	5,000

5. Enter the capacity for each link in the "Capacity" cell.
   - The capacities are entered:

Link 1-15	2,200
Link 50-51	3,000
Link 2-13	7,800

   If the capacity for a link is unknown, a complete list of default capacities by roadway type is provided in the TransCAD analysis method (Table 3-3).
6. Enter the forecast year assignment volumes (ADT) for each link in the "Forecast Year Assignment Volume" cell.
   - The forecast year assignment volumes are entered:

Link 1-15	0 – From the forecast year assignment volume
Link 50-51	4,000 – From the forecast year assignment volume
Link 2-13	8,200 – From the forecast year assignment volume

Step 3: Second Cutline Analysis

1. Enter the cutline name in the "Cutline Name" cell.
   - The first cutline is named "q-q"
2. Enter the node names for each link crossed by the cutline in the "Link Descriptor" cells.
   - The first link is 50-51, the second is 2-13, and the last is 4-8.
3. Enter the number 1 in the "Enter 1 if New" cell for any links that are a new facility.
   - Link 50-51 is a new facility so 1 is entered for it
4. Enter the base year volumes (ADT) for each link in the "Base Year Volume" cell. Enter 0 base year volume for any links that are new facilities.
   - The base year volumes are entered:

Link 50-51	0
Link 2-13	5,000
Link 4-8	2,500

5. Enter the capacity for each link in the "Capacity" cell.
   - The capacities are entered:

Link 50-51	3,000
Link 2-13	7,800
Link 4-8	2,750

6. Enter the forecast year assignment volumes (ADT) for each link in the "Forecast Year Assignment Volume" cell. Use the value from the "Total Assignment

Adjustment" cell as the forecast year assignment volume for links analyzed in previous cutlines.

- The forecast year assignment volumes are entered:

Link 50-51	2,815 – From the "Total Assignment Adjustment" cell in the previous cutline (p-p)
Link 2-13	6,850 – From the "Total Assignment Adjustment" cell in the previous cutline (p-p)
Link 4-8	2,500 – From the forecast year assignment volume

Step 4: Last Cutline Analysis

1. Enter the cutline name in the "Cutline Name" cell.
   - The first cutline is named "r-r"
2. Enter the node names for each link crossed by the cutline in the "Link Descriptor" cells.
   - The first link is 2-13, the second is 4-8, and the last is 5-7.
3. Enter the number 1 in the "Enter 1 if New" cell for any links that are a new facility.
   - None of the links are new facilities
4. Enter the base year volumes (ADT) for each link in the "Base Year Volume" cell. Enter 0 base year volume for any links that are new facilities.
   - The base year volumes are entered:

Link 2-13	5,000
Link 4-8	2,500
Link 5-7	2,650

5. Enter the capacity for each link in the "Capacity" cell.
   - The capacities are entered:

Link 2-13	7,800
Link 4-8	2,750
Link 5-7	3,500

6. Enter the forecast year assignment volumes (ADT) for each link in the "Forecast Year Assignment Volume" cell. Use the value from the "Total Assignment Adjustment" cell as the forecast year assignment volume for links analyzed in previous cutlines.
   - The forecast year assignment volumes are entered:

Link 2-13	6,850 – From the "Total Assignment Adjustment" cell in the previous cutline (q-q)
Link 4-8	2,500 – From the "Total Assignment Adjustment" cell in the previous cutline (q-q)
Link 5-7	4,800 – From the forecast year assignment volume

Step 5: Results

Record the final balanced volumes for each link. Use the "Total Assignment Adjustment" values for the links cut by the last cutline. Use the **bold** "Total Assignment Adjustment" values for all other links.

- The final balanced volumes are recorded:

Link 1-15	2,535 – From the **bold** "Total Assignment Adjustment" cell in the cutline (p-p) (Figure 3-17)
Link 50-51	2,693 – From the **bold** "Total Assignment Adjustment" cell in the cutline (q-q) (Figure 3-17)
Link 2-13	7,030 – From the **bold** "Total Assignment Adjustment" cell in the cutline (r-r) (Figure 3-18)
Link 4-8	3,515 – From the "Total Assignment Adjustment" cell in the cutline (r-r) (Figure 3-18)
Link 5-7	3,726 – From the "Total Assignment Adjustment" cell in the cutline (r-r) (Figure 3-18)

Figure 3-17. SS Output 1

Distribution of Assigned Volumes Among Available Facilities **Example**
NCHRP 365 Method

Cutline Name	Enter 1 if New	Link Descriptor A Node	B Node	Base Year Volume (ADT)	Percent Base Year Volume on Cutline	Capacity (pc/hr)	% of Total Capacity on Cutline
p-p		1	15	1850	27.0	2200	16.9
	1	50	51	0	0.0	3000	23.1
		2	13	5000	73.0	7800	60.0
Total				6850	100.0	13000	100.0

Link Descriptor A Node	B Node	Forecast Year Assignment Volume (ADT)	Capacity Assignment Adjustment	Volume Assignment Adjustment	Total Assignment Adjustment
1	15	0	0	2535	**2535**
50	51	4000	2815	0	2815
2	13	8200	0	6850	6850
Total		12200	2815	9385	12200

Cutline Name	Enter 1 if New	Link Descriptor A Node	B Node	Base Year Volume (ADT)	Percent Base Year Volume on Cutline	Capacity (pc/hr)	% of Total Capacity on Cutline
q-q	1	50	51	0	0.0	3000	22.1
		2	13	5000	66.7	7800	57.6
		4	8	2500	33.3	2750	20.3
Total				7500	100.0	13550	100.0

Link Descriptor A Node	B Node	Forecast Year Assignment Volume (ADT)	Capacity Assignment Adjustment	Volume Assignment Adjustment	Total Assignment Adjustment
50	51	2815	2693	0	**2693**
2	13	6850	0	6314	6314
4	8	2500	0	3157	3157
Total		12165	2693	9472	12165

Figure 3-18. SS Output 2

Distribution of Assigned Volumes Among Available Facilities **Example**
NCHRP 365 Method

Cutline Name	Enter 1 if New	Link Descriptor A Node	B Node	Base Year Volume (ADT)	Percent Base Year Volume on Cutline	Capacity (pc/hr)	% of Total Capacity on Cutline
r-r		2	13	5000	49.3	7800	55.5
		4	8	2500	24.6	2750	19.6
		5	7	2650	26.1	3500	24.9
Total				10150	100.0	14050	100.0

Link Descriptor A Node	B Node	Forecast Year Assignment Volume (ADT)	Capacity Assignment Adjustment	Volume Assignment Adjustment	Total Assignment Adjustment
2	13	6314	0	7030	**7030**
4	8	3157	0	3515	3515
5	7	4800	0	3726	3726
Total		14271	0	14271	14271

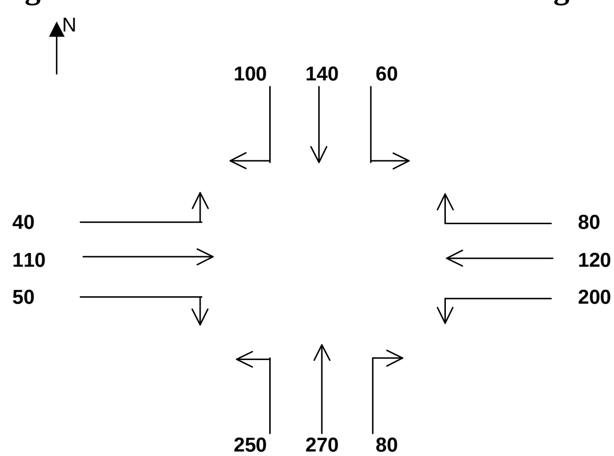
Discussion and Critique of the Screenline Spreadsheet

The Screenline Spreadsheet allocates forecast volumes to new and existing facilities proportional to their capacities. This approach implies that other factors that drivers use to choose routes (speed, travel time, potential attractiveness of origins and destinations, etc.) are difficult to predict and accommodate. Hence, the forecast allocation of traffic on the new project is uncertain. Appropriate care and engineering judgment must temper the forecasts as they are used in the project design process.

Balanced Turning Movement Spreadsheet (BTURNS)[5]

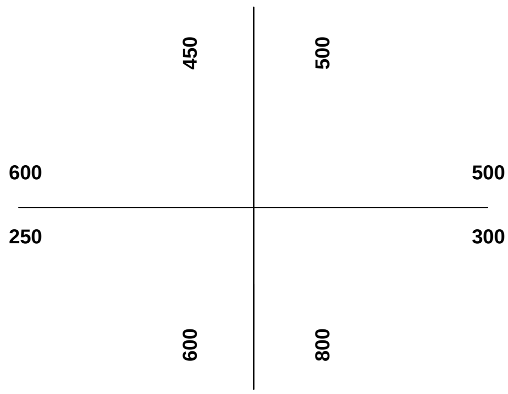
The basis for BTURNS derives from NCHRP Report 255 methods. This spreadsheet provides balanced future directional turning movement volumes for an intersection based on future year directional link volumes. Turning movements can be calculated with either base year actual turning movements, assigned directional turning movements, or an initial estimate of future year directional turning percentages. BTURNS may be used successively from intersection to intersection along a corridor to balance intersection-turning movements and maintain continuity of traffic. An example illustrates the BTURNS spreadsheet. The data used in this example is from a hypothetical standard intersection. The base year turning movements are shown in Figure 3-19. The future year directional link volumes are in Figure 3-20. It is assumed the flows entering the intersection have been checked for continuity from other intersections.

Figure 3-19. BTURNS Base Year Turning Movements



[5] NCHRP 255 Spreadsheets, Transportation Research Board, 1982.

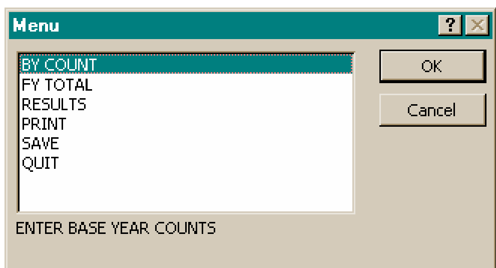
Figure 3-20. BTURNS Base Year Link Volumes



Step 1: Base Year

1. Select BY COUNT from the menu and click “OK” (Figure 3-21).

Figure 3-21. BTURNS Menu



2. Enter base year actual turning movements for each intersection approach (Figure 3-22). Make sure to press the ENTER key after each entry. If a movement does not exist leave the cell blank and press the ENTER.

Figure 3-22. BTURNS Base Year Counts

APPROAC	TURN MOVEMENT	BY COUNT
--------	--------	-----
NORTH	LEFT	250
BOUND	THRU	270
	RIGHT	80
SOUTH	LEFT	60
BOUND	THRU	140
	RIGHT	100
EAST	LEFT	40
BOUND	THRU	110
	RIGHT	50
WEST	LEFT	200
BOUND	THRU	120
	RIGHT	80

Step 2: Future Year

1. Select FY TOTAL from the menu and click "OK."
2. Enter future year directional link volumes for each intersection approach (Figure 3-23). Make sure to press the ENTER key after each entry. If a movement does not exist leave the cell blank and press the ENTER.

Figure 3-23. BTURNS Future Year Counts

APPROACH	FY TOTAL
--------	-----
NORTHBOUND	
IN ...	800
OUT ...	500
SOUTHBOUND	
IN ...	450
OUT ...	600
EASTBOUND	
IN ...	250
OUT ...	300
WESTBOUND	
IN ...	500
OUT ...	600

Step 3: Results

1. Select RESULTS from the menu and click "OK" (Figure 3-24).
2. Click "Cancel."
3. Go to File, Save to save for documentation.
4. Go to File, Print to print for documentation.

Figure 3-24. BTURNS Results

```
FUTURE DIRECTIONAL TURN VOLUMES FROM FUTURE DIRECTIONAL LINK VOLUM
    NCHRP 255, PAGE 105  Written by: FHWA (C. Fleet)
*** RESULTS ***         Modified by: COMSIS Corp. (M. Roskin)  2/1
```

APPROACH	TURN MOVEMENT	BY COUNT	FY FORECAST
--------	--------	-----	--------
NORTH	LEFT	250	153
BOUND	THRU	270	427
	RIGHT	80	222
SOUTH	LEFT	60	188
BOUND	THRU	140	197
	RIGHT	100	69
EAST	LEFT	40	39
BOUND	THRU	110	189
	RIGHT	50	39
WEST	LEFT	200	264
BOUND	THRU	120	78
	RIGHT	80	134

Discussion and Critique of BTURNS

BTURNS provides balanced future directional turning movement volumes for an intersection by means of proportional balancing after many iterations. While the future turning movements may fit the historical data, the forecasted turning movements may be very realistic or unrealistic. For example, intersection-turning movements can be greatly changed by the type of future development. Hence, the forecast turning movements on the new project are uncertain. Careful consideration and engineering judgment should be applied to the turning movements as they are used in the project design process.

Truck Forecasting

The NCDOT Traffic Survey Unit collects truck traffic data both mechanically and manually. Mechanical counts use tube type traffic counter with a minimum 48-hour duration and one hour count intervals. Data is collected using both the NCDOT classification system and the 13-vehicle class scheme recommended by FHWA (Table 3-3). Manual counts use observers to watch vehicle types at a location and then record them with an electronic counting board. The results of the Traffic Survey Unit's vehicle classification counts are usually published annually in the Highway Traffic Statistics report.

Truck percentages should be determined by forecasting truck traffic separate from vehicle traffic. The forecasting engineer should continuously consider facilities (terminals, truck stops, etc.). They relocate frequently and are rarely where they were 20 years in the past. Furthermore, the engineer should not "bump" estimates to account for the trend of Federal and State laws to allow heavier vehicles over time. The Bridge or Pavement designer makes that consideration.

Depending on the availability of data, one of the following truck forecasting methods should be used:

Table 3-3. NCDOT and FHWA Vehicle Classifications

NCDOT Classification	FHWA Classification
Passenger Vehicle	Class 1 - Motorcycle
	Class 2 - Passenger Car
	Class 3 - 2 Axle, 4 Tire Vehicle
Dual	Class 4 - Bus
	Class 5 - 2 Axle Single Unit Truck
	Class 6 - 3 Axle Single Unit Truck
	Class 7 - 4 plus Axle Single Unit Truck
Truck, Tractor with Semi-Trailer (TTST)	Class 8 - 4 Axle TTST with 1 Trailer
	Class 9 - 5 Axle TTST with 1 Trailer
	Class 10 - 6 Axle TTST with 1 Trailer
TTST with 2 Trailers (Twin)	Class 11 - 5 Axle TTST with 2 Trailers
	Class 12 - 6 Axle TTST with 2 Trailers
	Class 13 - 7 Axle TTST with 2 Trailers

Source: NCDOT Traffic Survey Unit, 2002.

1. Growth Factor Based on Historical Trends – This approach directly applies the growth factor of truck traffic, which is calculated based on historical traffic

trends. This method requires at least two years of truck traffic data. The annual growth factor (AGF) is calculated with following equation:

$$AGF = \left(\frac{T_B}{T_R}\right)^{\frac{1}{Y_R - Y_B}}$$

*Where T_B is truck volume in year Y_B and T_R is truck volume in base year Y_R.

The AGF can be applied to calculate future volume T_T of target year Y_T with the following equation:

$$T_T = T_R(1 + AGF)^{(Y_T - Y_R)}$$

2. Growth Factor Based on Economic Projections – This approach starts with an assumption that the truck traffic is derived from underlying socioeconomic factors such as population, income and employment. A growth factor for forecasting future truck traffic can be derived from economic forecasts, assuming that the demand for transport of a specific commodity is directly proportional to an economic indicator that measures demand for that commodity. The most desirable indicators are those that measure output or demand in physical units (tons, cubic feet, etc.). However, if these measures are not available indicator variables in terms of constant dollars are acceptable.

   Step 1: Separate freight traffic by commodity.

   Step 2: Determine annual growth factor for each commodity as follows:

   $$AGF = (I_2/I_1)^{1/(Y2-Y1)}$$

   *Where I_1 is the value of the economic indicator in year Y1 and I_2 is the value of the economic indicator in year Y2.

   Step 3: Calculate forecast-year traffic for each commodity as follows:

   $$T_f = T_b AGF^n$$

   *Where n is the number of years in the forecast period.

   Step 4: Aggregate the forecasts across commodity to produce the forecast of total freight demand.

3. Trend and Time Series Analysis – Trend and time series analysis involves the extrapolation of past historical trends in truck traffic. The basic time-series methods are complicated tools of extrapolation, which characterize the past behavior or a pattern of a variable and then forecast the future. It is appropriate for project level analysis because the method is simple to implement and not data intensive. Historic data are required only for the variable to be forecast.

Time-series models assume that the effects of all of the variable's significant influences can be captured by an analysis of the historic changes in the variable itself and that, during the forecast period, these influences will not change in character. Because of the presumption, time-series method is more appropriate for short-term forecasts than the long-term forecasts, which generate more prediction error.

When using a time-series method, care should be given to examine the data pattern and choose an appropriate method among various kinds of time-series methods. The most common time-series model is Auto Regressive Integrated Moving Average (ARIMA) model. The ARIMA model is available in many statistical software and spreadsheets.

4. Regression Analysis – Regression analysis is a statistical method that uses a least-square fit for a prediction. The main objective in regression analysis is to uncover the relationship between independent variables, (year, population, economic indicators, etc.) and dependent variables (truck traffic), which may be influenced by independent variables. The relationship between independent and dependent variables can be established using estimating parameters.

   In order to use regression analysis for forecasting purposes, independent variables need to be available to make a prediction. These forecasts may be projected from historic data or from other regression equations (provided that the system of equations is not circular), or the predictor using other appropriate techniques may develop them. Normally historic time-series data (an alternative is cross-section data) are used to estimate a relationship between the dependent variable and the independent variables for regression techniques. These sources are obtained for both variables over the trend of several time periods. The relationship from historic time-series data is applied to predictions that explain the independent variables for one or more future time periods to build forecasts of the dependent variable for the parallel time periods.

Discussion and Critique of Truck Forecasting

Truck forecasting methods use historical data for two or more years to develop different models of truck traffic data. While models may fit the historical truck data very closely, the forecast truck trend may be realistic or very unrealistic. For example, short-term historical data and models may forecast conservative truck traffic growth, drastic decreases, or drastic increases. Engineering judgment tempered by information from local officials must be used to select the appropriate long-term model and truck traffic forecast. Clearly long-range truck forecasts, which are extrapolations from short-term historical data, are uncertain. The economic and other conditions, which occurred historically, may or may not occur in the future. Consequently long-range truck forecasts are uncertain and must be used carefully in the project design process.

Common practical assumptions for design are: hold truck percentage (not volume) constant between base year and forecast year; and assume half the forecast daily truck percentage occurs in the peak hour of the future year. Issues of concern include: apparent increasing truck traffic volumes on major highways; increasing truck traffic percentage of total traffic; and over compensation for trucks and increased design cost.

Analysis Approach: TransCAD Method

The discussion now switches from the Hand Method to TransCAD. Steps are explained by subsequent paragraphs and a detailed example is given in Appendix E.

TransCAD represents an integrated package to perform a traffic forecast. It uses GIS-based land use data and a GIS-based highway network to predict balanced traffic flows at intersections and along links. Its use may be particularly advantageous if a regional travel demand model already exists. Detailed steps follow and a subsequent case study demonstrates this complicated though valuable method for large urban project-level traffic forecasts. Note that the forecasting engineer should have TransCAD training before applying these TransCAD guidelines.

1. Contact the SWP Engineer assigned to PSA and ask if a regional model containing the PSA exists. Explain all of the details of the project-level traffic forecast to the SWP Engineer and ask about the assumptions made in the regional model. Blend all information gathered from local planners, district engineers, and SWP Engineers to accurately describe the base year. Check on the status of any proposed projects in the regional model to ensure that they are still on schedule.

2. Have the SWP Engineer run the base year regional model for the area of interest.

3. Compare the flows assigned by the regional model to area traffic count data. If the flows are within accepted percent difference values based on roadway type, consider the model validated and continue to the next step. If the flows are outside of the accepted percent difference values the model may need to be recalibrated. To recalibrate the model, have the SWP Engineer change some of the IDS or other trip generation equations used for trip production. Adjust the IDS formulas until the model flows agree with the base year traffic count data if appropriate. However, be cautious of "over calibration." Experienced modelers accept variation in the link volumes versus counts for efficiency and future model forecasting robustness.

4. Determine the base year DHV, AADT, vehicle classification percentages, K factor, and D factors. Create a base year design hour stick diagram.

5. Create a future year regional model that shows all the links in the roadway network. Identify and show any new facilities or widened existing links.

6. Based on the historical traffic growth trends, local input, SWP Engineer judgment, and Forecasting Engineer judgment change TAZ production and attraction data. Any TAZ production or attraction modifications should be documented and explained. Have the SWP Engineer run the regional model for the future year.

7. Determine the future year DHV, AADT, vehicle classification percentages, K factor, and D factors. Create a future year design hour stick diagram.

8. Document and explain all assumptions made in the project-level traffic forecast.

Step 1: Set Up the TransCAD Base Year Network[6]

1. Assemble the following ArcView layers (.SHP) or TransCAD geographic files (.DBD):
   - County street network
   - County land parcel data
   - County orthographic photographs
   - Regional model TAZ's
   - Regional model land parcels
   - Regional model street network

2. Convert all ArcView layers (.SHP) into TransCAD geographic files (.DBD).

   Converting Geographic Files:
   1. Open the layer to be converted (File-Open). If the layer is open choose it from the drop down list.
   2. Choose Tools-Export to display the Export Geography dialog box.
   3. In the Export box choose what to export. TransCAD can export all features or those from a selection set.
   4. In the To box choose the file type to create.
   5. In the ID Field box choose the field containing the feature ID.
   6. Click OK, the Save As dialog box appears.
   7. Choose the folder and enter the file name.
   8. Click Save.

3. Create a PSA workspace. This workspace represents the project study area. The PSA workspace will be used to perform the TransCAD analysis and a number of maps can be made to document the forecast. Make sure to open all geographic files as "exclusive access."

4. Develop TAZ's if they do not already exist. Using the orthographic photographs, field trip findings, regional model TAZ's, and local input, identify parcels to be joined into a TAZ. Add a field to the parcel dataview labeled "Project TAZ" and

[6] *TransCAD User's Guide,* Caliper Corporation, 2001.

assign each parcel a TAZ number. Use the Merge-by-Value feature to group parcels by TAZ number. Save the project TAZ's as a geographic file (.DBD) to the PSA folder.

Merging Parcels into TAZ's:

1. Choose the parcels layer.
2. Choose Tools-Geographic Analysis-Merge by Value.
3. In the Merge box choose All Records.
4. In the Based on box choose Project TAZ.
5. In the Create Layer box type Project TAZ.
6. Check the Compute Attributes box and add "Productions and "Attractions."
7. Click OK to display the Save As box.
8. Name the new file Project TAZ.
9. Click OK.

5. Create external stations. At every intersection of the project study area boundary and a roadway link create an external station. Add a field to the roadway node dataview labeled "Node Type." Assign each node a node type value with the following node type codes:
   - Blank – intersection
   - 1 – centroid
   - 2 – external station

6. Add trip generation data. Use regional model windshield data, regional model regression equations, local input, and field trip findings to assess the number of daily trips a particular TAZ will produce. For most SWP regional models IDS (Internal Data Summary) is used to develop productions and attractions. SYNTH is also used to calculate "thru trips." In the TAZ dataview add fields labeled "Productions" and "Attractions" and assign each TAZ a production and attraction value.

   Editing Information in a Dataview:
   When opening a layer uncheck the "Open as read only:" box and check the "Open for exclusive access" box in order to edit the layer. There are several ways to edit information in a dataview:
   - Directly edit a single cell.
   - Fill a range of cells (this includes clearing cells).
   - Add and delete records.

   Directly Editing Data
   1. Click on the cell containing the data to edit.
   2. Type a new value.

   Filling a Range of Cells
   1. Select the range to fill.

2. Choose Edit-Fill to display the Fill dialog box.
3. Choose a method by clicking on the radio button.
    - Single Value fills in a single value in the selected fields.
    - Sequence fills the selected cells with a sequence of numbers.
    - Clear all values in the range deletes all values.
    - Formula fills the selected cells with the results of a formula.

In choosing the formula radio button the Formula dialog box appears.

1. Enter a formula in the Formula box. Use the formula builder for help.
2. Click Verify to check the formula.
3. Click OK.

Adding a New Field

1. Go to Dataview-Modify Table.
2. Click Add Field.
3. Type a name for the new field in the Name box.
4. Change the type to
    - Real (8 bytes) – if calculations need to be performed in field
    - Integer (4 bytes) – if calculations do not need to be performed in this field
    - Click "OK" to add your new field.

7. Add roadway link data. In the roadway link dataview add four fields to the roadway node dataview labeled: "Speed," "Time," "Link Type," and "Capacity." Assign each roadway link a speed value based on the posted speed limit (mph). Assign each roadway link a time value by filling the "Time" column with the following formula: length/speed*60. Assign each roadway a link type and a capacity with the following capacity codes[7] (Table 3-4):
    - R – rural (uninterrupted flow, 70 mph)
    - S – suburban (2 signals/mile, <10 intersections/mile, 50-60 mph)
    - B – urban (arterial with variations in signal spacing, access control)
    - F4 - 4-lane freeway
    - F6 - 6-lane freeway
    - F8 - 8-lane freeway
    - D4 - 4-lane divided
    - D6 - 6-lane divided
    - U3 - 3-lane divided
    - U4 - 4-lane undivided
    - U5 - 5-lane undivided
    - U6 - 6-lane undivided
    - U7 -7-lane undivided
    - T9 - 9' lane two-lane
    - T10 - 10' lane two-lane
    - T11 - 11' lane two-lane

[7] NCDOT Traffic Forecasting Unit Capacity at LOS "D" Table, 2000.

- T12 - 12’ lane two-lane
- O2 - one-way 2-lane
- O3 - one-way 3-lane
- O4 - one-way 4-lane

An urban 3 lane undivided facility would be coded as BU3 and have a capacity between 12,000 and 16,000 vehicles per day.

Table 3-4. NCDOT Level of Service “D” Roadway Capacities

Daily Capacity for LOS “D” (AADT)			
Section	R	S	U
F4	54,000	54,000	54,000
F6	81,000	81,000	81,000
F8	108,000	108,000	108,000
D4	50,000	37,700 - 41,700	18,000 – 22,000
D6	75,700	56,500 - 62,600	30,000 – 34,000
U3	23,200	20,300 - 21,400	12,000 – 16,000
U4	48,000	33,500 - 37,100	18,000 – 22,000
U5	49,000	35,600 - 39,400	24,000 – 28,000
U6	71,900	50,300 - 55,700	30,000 – 34,000
U7	73,400	53,400 - 59,200	36,000 – 40,000
T9	9,000	8,500	8,000
T10	11,000	10,500	9,500
T11	12,000	11,500	11,000
T12	13,000	12,500	12,000
O2	-	-	14,000
O3	-	-	22,000
O4	-	-	30,000

Note that as the GIS-based network is developed, some links on a GIS-based map may appear to connect to a node when only one of the roadways is actually connected in GIS. Also, some GIS applications use a great number of nodes and short links to represent curves. In these situations, creating the network “by hand” may be better than using GIS.

8. Attach the TAZ’s to the street file. When TAZ centroids are created, connect them to the network and edit the centroid connectors to mimic the ground conditions.

<u>Creating Centroids</u>

1. Choose the Project TAZ layer from the drop down box.
2. Click Tools-Export.
3. In the Export box choose all features.
4. In the To box choose the file type to create (usually Standard Geographic File).

5. In the ID Field box choose the field containing the feature ID.
6. In the Options box check Export as Centroid Points.
7. Click OK, the Save As dialog box appears.
8. Choose the folder and enter the file name.
9. Click Save.

Inserting Centroids into A Street File

This will connect all TAZ centroids to the network layer. It will add centriod connectors to the nearest node.

1. Select the layer containing the TAZ centroids from the drop-down box
2. Select Tools-Map Editing-Connect.
3. In the Using box select all records.
4. In the To line layer box choose the network layer.
5. Click the Nodes radio button.
6. Type 1 in the maximum connections box.
7. Click OK.

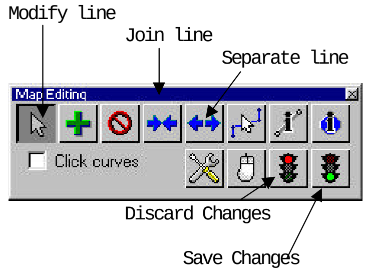
Centroid connectors run from the centriods to the nearest node. This may not realistically depict the network. Connect the centroid connectors to more realistic locations if necessary.

Editing Centroid Connectors

1. Open the network layer, unchecking the "Open as read only:" box and checking the "Open for exclusive access" box.
2. Select Tools-Map Editing-Toolbox to open the map editing toolbox (Figure 3-25).
3. Zoom in on the centroid connector you wish to edit.
4. Click on the end of the centroid connector using the "Split line" tool to separate the centroid connector from the link it is attached to.
5. Using the "Modify line" tool drag the end of the centroid connector over the link that you wish to connect it to.
6. Click on the end of the centroid connector using the "Join line" tool to join it with the link.
7. Use the "Modify line" tool to close the gap created when you split the lines. Drag one endpoint directly over the other.
8. Use the "Join line" tool to join the lines together.
9. Click on the "Save edits" button to save your changes.

In the event that a mistake is made click on the "Cancel edits" button to cancel all changes.

Figure 3-25. TransCAD Editing Toolbox



Step 2: Run the TransCAD Regional Model[8]

1. Assemble all of the street and TAZ layers.

2. Make a TransCAD network based on time.

   Creating a Network File
   1. Choose the layer from which the network will be built from the drop-down list on the toolbar. This is generally the street layer.
   2. Choose Networks/Paths – Create to display the Create Network dialog box.
   3. In the Create links from box choose Entire line layer.
   4. In the Read time from box choose the field containing the link times.
   5. You can include a description in the Description box.
   6. Check the Include Turn Information box.
   7. Choose all fields in the Optional Fields boxes.
   8. Check the Drop Duplicate Links box.
   9. Click OK to display the Save As dialog box.
   10. Type a file name in the box and click Save.

3. Create a multiple shortest path matrix that minimizes time. (The network is open).

   Creating a Multiple Shortest Path Matrix
   1. Networks/Paths – Multiple Paths.
   2. Multiple shortest path dialog box appears.
   3. Under Setting-Minimize select time.
   4. Click OK.
   5. The Save as Dialog box appears.
   6. Type a file name in the box and click Save.

4. Make three copies of the shortest path matrix, naming them HBW, HBO, and NHB.

---

[8] *Travel Demand Modeling with TransCAD*, Caliper Corporation, 2001.

Copying a Matrix

1. Matrix – Copy.
2. Select OK.
3. The Save as Dialog box appears.
4. Name the file (HBW, HBO, or NHB) making sure to change the label to match the file name and click Save.
5. Create synthetic friction factors for the three trip types (HBW, HBO, NHB).

Creating Synthetic Friction Factor Matrices

1. Planning – Trip Distribution – Synthetic Friction Factors.
2. Create Friction Factor Matrix box will appear.
3. Select the Matrix (HBW, HBO, or NHB) to fill with the friction factor data from the Matrix name drop down list.
4. Check the Use this matrix box.
5. Fill in the appropriate gamma parameters with recommended values[9] such as Table 3-5. These values may help, but reasonableness checks must be applied throughout the process.

Table 3-5. NCHRP 365 Gamma Parameters

Trip Purpose	a	b	c
HBW	28507	0.02	0.123
HBO	139173	1.285	0.094
NHB	219113	1.332	0.01

6. Select the Shortest Path matrix as the impedance matrix.
7. Click OK.

6. Apply the Gravity Model.

Applying the Gravity Model

1. Open the dataview containing the TAZ productions and attractions.
2. Planning – Trip Distribution – Gravity Evaluation.
3. The Gravity Evaluation box will appear.
4. For each trip purpose (HBW, HBO, NHB, and EXT) identify the location of productions and attractions from the productions and attractions drop down list.
5. Set the Constraint Type to Production by clicking on the radio button.
6. Click the Friction Factors Tab.
7. Click the Matrix Radio button.
8. Select the corresponding Friction Factor Matrix from the Matrix File drop down list. (For EXT use the HBW Friction Factor Matrix).
9. Click OK.
10. The Save As dialog box will appear.

[9] Travel Estimation Techniques for Urban Planning, NCHRP 365, Transportation Research Board, 1998.

    11. Type a file name in the box and click save.

7. Quicksum the P's and A's by trip type into one P's and A's matrix.

   Quicksuming a Matrix
    1. Open the P's and A's matrix.
    2. Matrix – QuickSum.

8. Convert the total P and A matrix into an O and D matrix.

   Converting Ps and As to Os and Ds
    1. Planning – P-A to O-D.
    2. Convert P-A matrix to O-D Matrix dialog box will appear.
    3. Uncheck the Report "each hour separately" box.
    4. Select the QuickSum matrix for use in the Change information box.
    5. Click OK.
    6. Type a file name in the box and click Save.

9. Combine the O and D matrix with the thru trips matrix (from SYNTH).

   Combining Matrices
    1. Open the O and D matrix and the thru trips matrix.
    2. Matrix – Combine.
    3. The Combine Matrix Files box will appear.
    4. Select the O and D matrix and the thru trips matrix.
    5. Click OK.
    6. Type a file name in the box and click Save.
    7. QuickSum the combined matrix to produce a total O and D matrix for the network.

10. Run traffic assignment using total Os and Ds.

   Assigning Traffic Over the Network
    1. Planning – Traffic Assignment
    2. The Traffic Assignment box appears
    3. From the Method drop down list select All or Nothing (small town) or User Equilibrium (large town) or Capacity Restraint (for operational purposes)
    4. Under the Matrix File drop down list select the Total O and D matrix
    5. Under the matrix drop down list select QuickSum
    6. Click OK
    7. Type a File name in the box and click Save.

11. Label the links with the assigned flows.

   Labeling Links
    1. Click on the Automatic Labels button.

2. From the Field drop down box select Tot_Flow.
3. Click OK.

Step 3: Create a Future Year Model

1. Open the calibrated base year regional model.
2. Create new TAZs if needed.
3. Add any new facilities to the roadway layer.
4. Change roadway link capacities to account for any future widening.
5. Run IDS and SYNTH with future year population and socioeconomic data.
6. Add IDS production and attraction data to the existing TAZs.
7. Save the future year regional model.
8. Run the model.

Discussion and Critique of TransCAD Method

Compared with the Hand Method, TransCAD offers:

- A zone-level model for the future commercial and residential development that generates the traffic. A parcel-level model is desirable.
- An integrated tool to show the sensitivity of traffic to alternative assumptions regarding land use type, intensity, and trip generation models. Indeed, the Hand Method only accepts "ad hoc" trip generation data.
- An internal turning movement balancing mechanism.
- Equilibrium algorithms that automatically allocate travel between proposed and existing highways.
- A systematic, reproducible, documentable approach to forecasting project-level traffic.

However, the TransCAD Method most often is appropriate for large urban projects. For use in traffic forecasting it should already exist for the region since it is time consuming to develop and calibrate. It is not appropriate as a "quick-response" tool for small projects. Also, the turning movement results from the TransCAD model may not be reasonable (this may be obvious to the investigator or the forecast requestor). The whole process should be reviewed to look for other unreasonable results and/or errors. If this does not uncover an improvement, the investigator ma have to adjust the results to be more reasonable.

While TransCAD is becoming institutionalized at NCDOT and a number of engineers are proficient with it, others must be trained on TransCAD in general and more specifically in project-level traffic forecasting.

Chapter Summary

This chapter demonstrates procedures for applying traffic forecasting tools and methodologies for projects in urban and rural settings. The guidelines address data collection, analysis methods and tools, as well as required documentation. For non-urban projects without regional models trend analysis, screenline analysis, and turning movement spreadsheets form the framework for traffic forecasting. Examples are provided for each hand method tool within the guidelines. For urban projects simplified methods using TransCAD form the framework for traffic forecasting. Three case studies that show detailed use of the analysis methods described in the guidelines are located in Appendix C, D, and E. The next chapter of this report discusses the findings of this project and the recommendations for NCDOT.

CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS

Project Review

This project documents a methodology and related procedures to accomplish project-level traffic forecasting for NCDOT. While the methodology is general and can guide an engineer or planner through various steps including field visits, local discussions, data collection, analysis and documentation, the procedures provide explicit analytical tools appropriate for the forecasting task.

The methodology structures and systematizes the forecasting process using two general methods: (1) the hand method which utilizes spreadsheet procedures to address smaller, rather isolated projects, and (2) TransCAD which can evaluate larger projects that are part of complicated networks. Given Base Year traffic volumes, turning movements, land use and transportation network information, both methods provide estimates of future facility volumes and turning movements assuming alternative development scenarios. The methodology implicitly recognizes uncertainty in the forecasting process regarding development (trip generation) and the importance of truck traffic estimates for design.

The project report provides guidelines to NCDOT staff and consultants as they prepare and document project traffic forecasts. In addition, the report, which includes detailed examples, can serve as a tutorial or manual to engineers and planners. Furthermore, the report serves as an informative reference to the citizens and public officials of towns and cities that are most affected by traffic forecasts and resulting projects.

The first chapter introduces the issues related to forecasting traffic for urban and rural highway projects. The project objectives are:

1. To identify procedures to integrate systems level and project level traffic forecasts in urban areas.
2. To identify appropriate systematic procedures for non-urban project traffic forecasts.
3. To demonstrate and document the proposed urban and rural traffic forecasting procedures with case study examples.
4. To discuss issues inherent in truck traffic forecasts.
5. To discuss the uncertainty inherent in the forecasting process.

As the report develops in subsequent chapters a simplified, yet systematic, methodology and tool set are developed.

The second chapter reviews sources for framing the forecast methodology and various software tools. NCDOT is transitioning from Tranplan to TransCAD, which can provide link volumes and turning movements directly for a project level traffic forecast. However, the traffic estimates are based on a regional model with Traffic Analysis Zones and land use descriptions that may be too aggregate for site-specific and corridor level traffic forecasts. Often parcel-level and intersection-level information is needed for detailed forecasts of automobile and truck traffic that is used in the design process. Thus, hand methods and spreadsheets can be used for more localized forecasts.

The third chapter of this report presents the detailed methodology for project-level traffic forecasts. It gives guidelines for data collection, selection of analysis methods and tools, and documentation. For non-urban projects without regional models simplified hand methods are used. They include trend analysis, screenline analysis, and turning movement spreadsheets. Examples demonstrate each hand method tool within the guidelines of the methodology. For small, isolated urban projects hand methods may be used. As projects become larger and have a wider network impact, methods using TransCAD can be used alone or integrated with hand methods. Of particular interest in this chapter are three case studies that show detailed use of the methodology and the analysis methods. Details of the cases are in appendices.

Conclusions

Overall this project provides guidance on data collection, analysis methods, documentation styles, and training recommendations to bring about an improvement in the project-level traffic forecasts prepared by NCDOT.

During the course of this project the researchers concluded the following:

- NCDOT uses a variety of quantitative and qualitative methods to perform project-level traffic forecasts. The variety of analysis methods used is attributed to the different types (urban vs. rural, large vs. small, etc.) of forecasting projects received by the Traffic Forecasting Unit.
- The selection of which method to use often depends on the engineer's preference and expertise.
- Systematic guidelines for selecting methods by project type are needed and were developed.
- The quality of traffic forecasts varies in terms of methods used and thoroughness of documentation.
- Systematic guidelines for traffic forecasting should also serve as a manual to guide the development and documentation of a forecast to ensure accuracy and repeatability.
- TransCAD is the state-of-the-art regional modeling tool used by NCDOT and it has the capability to develop turning movements, as well as link volumes, that are important in traffic forecasts. It should be used for project-level traffic forecasting when a regional model already exists.
- While TransCAD depends on aggregate traffic analysis zones, a transition toward GIS-based parcel level models will provide the finer focus that many traffic forecasts need.
- TransCAD is not the software to use for all traffic forecasts. Creating a TransCAD model is too time-consuming and data intensive for small projects.
- A synthesis of hand methods augmented by spreadsheet applications can quickly produce an accurate forecast for small projects.

- The result of a traffic forecast is a diagram showing explicit values for average daily link volumes and turning movements. The anticipated range of uncertainty in the future estimates is not known or indicated.

Recommendations

Data

The accuracy of a project level forecast increases in direct proportion to the amount of accurate data available. NCDOT should:

1. Coordinate with local agencies to collect and archive parcel level GIS data using standardized reporting formats such as those currently available for property tax and census data. Currently, regional model forecasts are based on the TAZ. Parcel and street level forecasting will eventually be more common with TransCAD and other tools. Such models created using parcel level data would allow extremely accurate network loading and allow investigation into the sensitivity of trip generation rates to project level forecasting. GIS-based models would also allow different assumptions about future build-out scenarios to be tested efficiently and show their effects on the traffic forecast.

2. Make full use of the Linear Referencing System (LSR) when constructing forecasting models. Capacities and speed limits are of great concern to modeling, specifically in the area of network loading.

3. Coordinate traffic counts with GIS and LRS, allowing traffic count data and the exact locations to be easily retrieved. Hand sketches of traffic counts should be eliminated and all count information should be available on the Internet.

4. Reconsider the use of quarter turns on traffic forecast “stick” diagrams. Where possible display all turning movement counts at each intersection including ramps. Aggregate the turning movements to show directional link volumes.

5. Add permanent staff to the Traffic Survey Unit. More staff will provide better coverage of AADT data for use by forecasters. Use temporary staff if there is a significant increase in demand for TM’s.

6. Collect more frequent truck data. Current truck data is limited in terms of years (one or two days every three to five years) and duration (18 or 48 hours). Additional permanent staff will expand the Weigh in Motion system of continuous monitoring stations. As a result the Traffic Survey Unit will be able to develop seasonal groups for vehicle class data and to factor short-term vehicle class counts to annualized values similar to AADT’s. Improved truck data will support more accurate modeling techniques.

7. Develop a TransCAD-based statewide truck traffic database and model for Notrh Carolina to test alternative highway improvement for truck route diversion, truck traffic growth and other issues related to truck movements. More staff will improve coverage of vehicle class stations to provide a statewide estimate of truck flows on the National Highway System, provide consistency between forecasts, and support statewide truck modeling.

8. Archive primary data sets and make them available over the Internet.

9. Examine the anticipated range of uncertainty in traffic forecasts resulting from alternative development scenarios and variability in such parameters as base year traffic data, truck data, and trip generation rates.

TransCAD

TransCAD represents the state-of-the-art in transportation planning tools, both at the regional and project levels. NCDOT should:

1. Perform forecasts at the parcel level when data is available. This will greatly increase the realism of traffic assignment and allow small changes in land use to affect network loading. TransCAD development and use are moving in the direction of parcel-level analysis.

2. Promote ongoing development of TransCAD's travel demand modeling capabilities, especially the development of a sub-area modeling tool that can quickly address site and project-level traffic forecasts.

3. Convert Tranplan models into TransCAD as local plans require updating. This will facilitate the development of project level forecasts and allow NCDOT planners to both focus on a specific area and to retrieve better turning movement data than TransPlan can provide.

4. Incorporate trip generation within TransCAD, eliminating the need for a separate model in IDS, to allow testing of alternative land use and trip generation scenarios and assumed values for trip rates.

Hand Method

The hand method is excellent for performing forecasts on smaller areas. NCDOT should:

1. Refine prototype spreadsheets to produce a spreadsheet that can balance turning movements at multiple intersections along a corridor. This will take less time and yield more accurate results than treating each intersection individually with an iterative balancing spreadsheet and balancing subsequent intersections by hand.

2. Continue to automate hand methods by developing new spreadsheets and packaging hand methods into one integrated toolset for both consultant and in-house use.

3. Continue to explore simplified network models for projects that fall outside of urban regions. Such models could improve the efficiency and accuracy of project level forecasts, specifically those that are somewhat large for the hand method, but too small for modeling in TransCAD.

4. Incorporate the use of time series models for traffic forecasts, especially truck traffic forecasts, as improved seasonal and yearly data become available.

5. Make the methodology and software of the hand method available over the Internet and the office intranet so that NCDOT staff and consultants can work towards standardizing analysis procedures and reports.

Training

It is important that forecasters know how to operate TransCAD and that all parties involved understand the input, output and archival requirements of a forecast. NCDOT should:

1. Continue the current NCDOT TransCAD training program, and add a one- or two-day unit on project-level traffic forecasting. Formal training will facilitate the learning process. It will build upon the tutorial format of the project report, the manual, and the example cases.

2. Hold a seminar with users of traffic forecasts to discuss their needs, the forecasting process, documentation, data archiving and possible shortcomings and uncertainty in the process. Participants should include NCDOT, MPO, county and city officials and consultants who work with NCDOT to produce traffic forecasts for projects. A seminar can educate officials on what information to supply to forecasters, inform officials on the output of a forecast, and develop a rapport between officials and forecasters.

Technology Transfer

Technology transfer regarding this project can occur in several ways:

- Distribute this final report and manual in traditional bound documents.
- Distribute the report on CD.
- Provide access to an electronic version of the report, manual and spreadsheets. Three spreadsheets are available for use when performing forecasts using the hand method (These spreadsheets will be provided on CD and will be accessible through the electronic version of the report).
- Document the project, report, manual, and methods on an NCDOT webpage.
- Present Traffic forecasting conference presentations, workshops and seminars.

- Transfer the case study traffic forecast results of the proposed US 15-501 Bypass for Pittsboro to NCDOT for their use (Extensive network, socioeconomic and parcel level data were collected during the development of the Pittsboro TransCAD model. All data and TransCAD models will be provided in electronic form on CD. Discussions with the NCDOT Statewide Planning engineer responsible for Pittsboro have begun.).
- Provide the truck traffic methods and estimated growth factor techniques to the staff maintaining the bridge management system model.

Other

Traffic forecasts for transportation project are extremely important documents, both to members of NCDOT and the public. NCDOT should:

1. Promote and enforce the idea that a project level traffic forecast should be reproducible. All data and assumptions must be documented and data sets archived to justify the forecaster's results. This will allow others to easily update or reproduce the forecast as necessary.

2. Ensure that all updates to forecasts are performed using new data and traffic counts. Otherwise, the forecast makes no correction for highway and land use changes between the base year of the original forecast and the update.

3. Formalize relationships between Statewide Planning forecasters and engineers in charge of specific cities. This will ensure that the needs of project level forecasters are met when citywide models are created. It will also make forecasters more aware of the assumptions and limitations of regional models.

4. Work toward a standardized software toolset, including both TransCAD and the hand methods, for consultants and NCDOT staff to use. A standard set of software procedures will allow standard datasets to be transferred easily from consultants to NCDOT and among NCDOT staff, and the standard software and datasets will simplify the review and approval process. Standard software and datasets will also support the important concepts of reproducible, "transparent" forecasts that can be more easily updated and tested for sensitivity to assumptions regarding land use, truck traffic, and transportation network

Summary

This final chapter of the report reviews the project, lists and discusses conclusions that derive from the project, and makes recommendations regarding various issues regarding forecasting traffic for highway projects. The recommendations address data collection, the use of hand methods and TransCAD, training, and other topics such as documentation, standardized software, and NCDOT institutional relationships regarding traffic forecasting.

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A list of geographical locations, the most recent study for an area, and the assigned SWP engineer is located on the NCDOT webpage at: http://www.dot.state.nc.us/planning/statewide/smallurban/status.html

A list of the Division Engineers is located on the NCDOT webpage at: http://apps01.dot.state.nc.us/apps/directory/toc.html

A list of the MPOs is located on the NCDOT webpage at: http://apps01.dot.state.nc.us/apps/directory/4651.html

A list of the Bicycle and Pedestrian Division engineers is located on the NCDOT webpage at: http://apps01.dot.state.nc.us/apps/directory/3367.html

A list of the Division of Aviation engineers is located on the NCDOT webpage at:
http://apps01.dot.state.nc.us/apps/directory/3364.html

A list of the Ferry Division engineers is located on the NCDOT webpage at:
http://apps01.dot.state.nc.us/apps/directory/3365.html

A list of the Bridge Maintenance Unit engineers is located on the NCDOT webpage at:
http://apps01.dot.state.nc.us/apps/directory/2820.html

A list of the Rail Division engineers is located on the NCDOT webpage at:
http://apps01.dot.state.nc.us/apps/directory/3393.html

A list of the Structural Design Unit engineers is located on the NCDOT webpage at:
http://apps01.dot.state.nc.us/apps/directory/682.html

Digital maps for each county in North Carolina are available in metric and English units along with downloading directions on the NCDOT webpage at:
http://www.dot.state.nc.us/planning/statewide/gis/DataDist/DD_CtyMps.html

A list of the GIS Unit engineers is located on the NCDOT webpage at:
http://apps01.dot.state.nc.us/apps/directory/3240.html

Traffic volume maps for each county in North Carolina are located on the NCDOT webpage at: http://www.dot.state.nc.us/planning/statewide/traffic.survey

A list of the Traffic Survey Unit engineers is located on the NCDOT webpage at:
http://apps01.dot.state.nc.us/apps/directory/3265.html

Population data for each county in North Carolina is located on the Demographic Office webpage at: http://demog.state.nc.us/

A list of local Demographic Office data center contacts is located on the Demographic Office webpage at: http://sdc.state.nc.us/frame_start_contacts.html

Employment data for each county in North Carolina is located on the Employment Security Commission webpage at: http://eslmi12.esc.state.nc.us/websaras/

A list of Employment Security Commission contacts is located on the Employment Security Commission webpage at: http://www.esc.state.nc.us/Default.asp?openitem=5

The Traffic Survey Unit conducts all field data collection for the NCDOT and all traffic count requests will be made through this webpage:
http://www.dot.state.nc.us/planning/statewide/traffic_survey/traffic.html

A list of the Traffic Survey Unit engineers is located on the NCDOT webpage at:
http://apps01.dot.state.nc.us/apps/directory/3265.html

APPENDIX A: TURN MOVEMENT SOFTWARE EVALUATION

An Evaluation of Methods for Estimating Turning Movements for Project Level Traffic Forecasts Utilizing Data Obtained from a Travel Demand Model

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Disclaimer
Illustrative purposes only. Not an example to aspire to.

Abstract
Intersection turning movement volumes associated with the project-level forecast are necessary for planning and designing the intersections and interchanges along a roadway project. Travel demand models provide output that is critical for the completion of a project-level traffic forecast, yet sometimes do not provide turning movement data that is sufficient for direct use in traffic forecasts. A comparison of various methods for estimating turning movement data given the output from a travel demand model illustrates that the traffic forecaster has a wide choice of methods that yield sufficient results.

Introduction

An important application of data provided by a travel demand model is the project-level traffic forecast. The calibrated travel demand model is used to forecast the amount of traffic anticipated to utilize a particular facility for which improvements are being planned, be it a widened facility or a new facility. A critical element of the project-level forecast is the determination of turning movements associated with intersecting roadways along the subject facility. Turning movement data are necessary for the planning and design of the intersections and interchanges along a roadway facility.

Early travel models typically provided data that could not be used directly in project-level forecasts or did not provide turning movement data at all (1). Advances in travel demand modeling packages, however, have resulted in some models that do provide turning movements. This study involved applying various methods for estimating turning movements to data taken from the travel demand model for the Town of Plymouth, North Carolina and comparing the resulting calculations. The methods analyzed in this study include two calculation procedures included in the NCHRP Report 255 and simulations using TMOVES, a post-analysis computer program and two travel demand modeling software packages, Tranplan and TransCAD. This analysis determined turning movement volumes for the 2025 design year utilizing all five of these methods. In addition, calculations of the turning movements at the subject intersection in the 1996 base year were made using Tranplan and TransCAD; these estimations were then compared to the original ground counts taken at the intersection.

NCHRP 255 Calculation Procedures

The National Cooperative Highway Research Program (NCHRP) Report 255, *Highway Traffic Data for Urbanized Area Project Planning and Design*, compiles techniques used in urban areas to bridge the gap between system-level and project-level analyses. Among these are two techniques for estimating turning movements, the ratio factoring method and the directional volume iteration method. Both of these procedures employ known base year data along with future year projections to estimate future year turning movements.

Ratio Factoring Method

The ratio factoring method estimates turning movements based on the relationships between base year assignments and actual base year counts (1). The analyst assumes that the ratio between a base year count and a base year assignment is of comparable magnitude to the future year values. The future year turning movements are then estimated by comparing the ratios between base year turning movements, as follows:

$$V_{ri} = Fi * \frac{B_{ci}}{B_{ai}}$$

where V_{ri} = ratio adjusted future year turning movement volume i;
Fi = future year forecasted volume for turning movement i;
B_{ci} = base year traffic count for turning movement i; and
B_{ai} = base year assigned volume for turning movement i.

Directional Volume Iteration Method

The directional volume iteration method derives future year turning movements from specified link volumes and initial turning movement percentages taken from the field data. This iterative balancing method involves five steps, which are diagramed in Figure 1. The volume of traffic entering and leaving the analysis intersection is determined based on an iterative balancing of inflows and outflows of a turning movement matrix until an acceptable set of turning volumes result (1). Typically, this procedure requires six to ten iterations for convergence to an acceptable threshold.

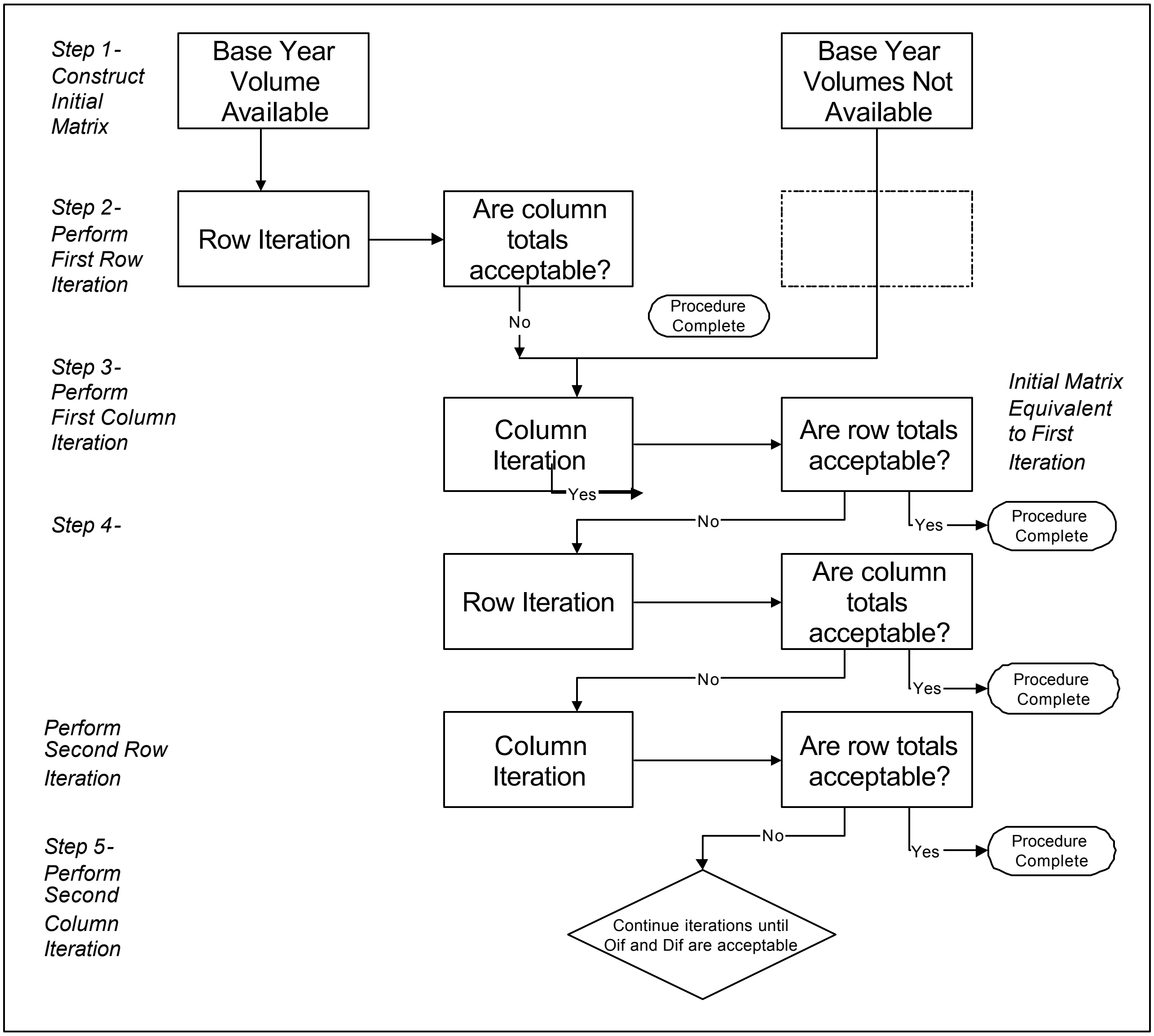
TMOVES Simulation

TMOVES is a computer program that estimates turning movements to match user-specified approach volumes based on a seed matrix of turning movement data (2). TMOVES is capable of utilizing data provided from actual counts or local knowledge or is able to generate the seed data based on information such as approach angles and land development density.

Tranplan Simulation

Tranplan in an integrated suite of programs used to forecast the impacts of alternative land use scenarios and transportation networks on transportation systems (3). Tranplan has been widely used by many entities for travel demand modeling in past years. This software uses a set of batch files to run the four-step travel demand process. The Tranplan file for network assignment allows the user to include as output the turning movement volumes for up to fifty ranges of nodes and up to four entry links and five exit links at each selected node.

Figure 1 – Directional Volume Iteration Method for Computing Turning Volumes



TransCAD Simulation

TransCAD is a GIS-based system for transportation data management and analysis (4), including the analysis of the traditional four-step travel demand model. TransCAD estimates turning movements using a balancing technique that makes initial estimates of movements based on default percentages mixed with the results of the traffic assignment. This approach allows the user to obtain turning movements for any intersection without having to pre-select the intersection prior to assignment.

Case Study in Plymouth, NC

The Statewide Planning Branch of the North Carolina Department of Transportation (NCDOT) recently developed a travel demand model to replicate travel in the Plymouth planning area for the development of an updated thoroughfare plan. The Town of Plymouth is the seat of Washington County, located in the eastern portion of North Carolina. Plymouth is located along the Roanoke River, approximately 70 miles west of Manteo, North Carolina (5). The geographical location of Plymouth is shown in Figure 2.

The Plymouth model applied the traditional four-step planning process (trip generation, trip distribution, mode choice, and trip assignment) to both the 1999 base and the 2025 design years. Prior to application of the four-step process, the planning area was delineated and the 1999 base year network was developed. Next, socioeconomic data and traffic data were applied to the four-step process, simulating the 1999 traffic patterns of the planning area. Once the traffic model accurately reflected the traffic counts, the socioeconomic data was projected to the 2025 design year and the four-step process was repeated. The existing street system was then loaded with the projected traffic volumes and the resulting loaded network was analyzed for deficiencies. Once solutions for these anticipated capacity deficiencies were determined, the future year model was run again, incorporating these network improvements, resulting in the final future year model.

The intersection utilized for this comparative analysis is the intersection of US 64 and Washington Street (SR 1357)/NC 32. This intersection is the most heavily traveled in the Plymouth planning area. The NCDOT Traffic Surveys Unit assessed the traffic at this intersection in February 1999. The data resulting from this 24-hour traffic count are summarized in Figure 3.

Results

Turning movements for the intersection of US 64 and Washington Street/NC 32 were calculated using the five previously discussed methods. Table 1 presents the estimated 1999 turning movement volumes resulting from the Tranplan and TransCAD analyses, along with the actual ground count data which are presented as a basis of comparison. The estimated 2025 turning movement volumes resulting from all five methods are summarized in Table 2. The assumptions and calculations required for each of these analyses are included in Appendices A through D.

For the base year calculations, neither the Tranplan nor the TransCAD turning movements were very representative of the actual ground counts. The Tranplan values differed from the counts 5% to 93%. Overall, Tranplan estimated turning movements that were closer to the actual turning movements.

For the future year calculations, the results from the ratio factoring method, the directional volume iteration method, and the TMOVES simulation were all comparable. The closest comparison can be made between the directional volume iteration method and the TMOVES simulation, however. The Tranplan simulation seemed to produce through movements much higher than those resulting from the other methods, while the left and right turning volumes were lower than those resulting from the other methods. The TransCAD simulation results did not really seem to compare to any of the other results. While a few of the TransCAD turning movement estimates were about the same as the estimates from the other methods (for example, the westbound left turn), the majority of the estimates varied greatly from other method estimates (for example, the eastbound right turn movement).

Figure 2 – Geographic Location for the Town of Plymouth *Source: MapQuest.com, 2001.*

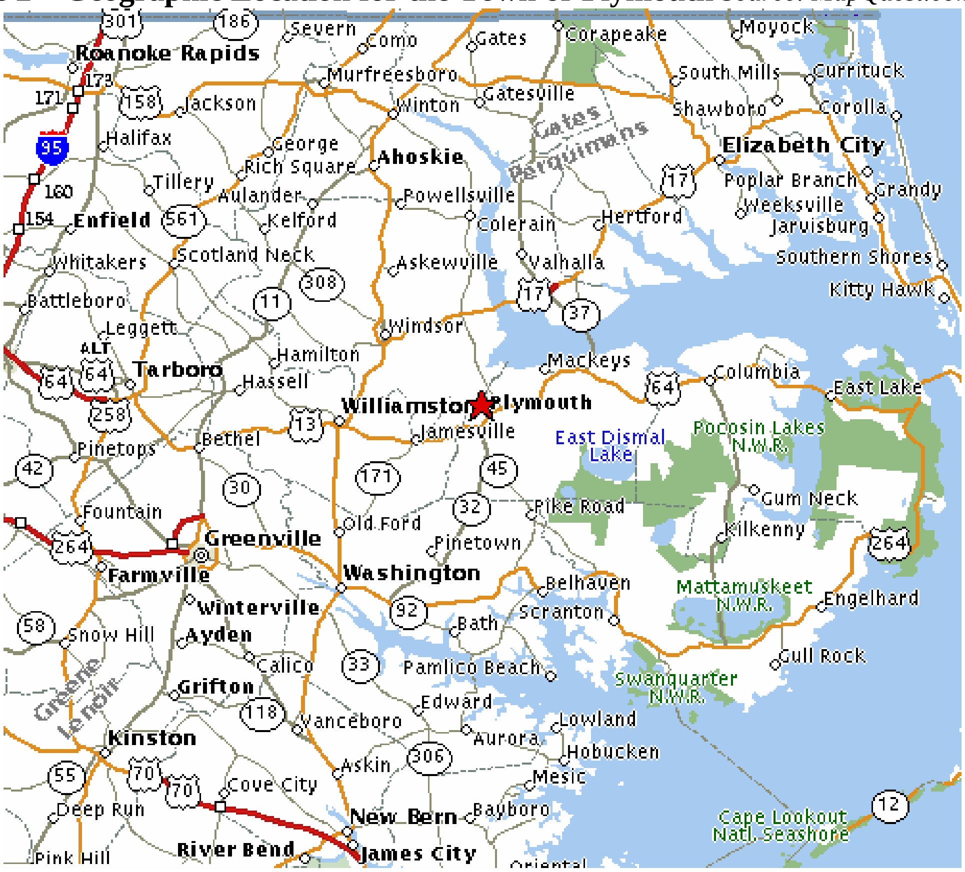


Figure 3 – Intersection of US 64 and Washington Street/NC 32 24-Hour Counts (Feb 99)

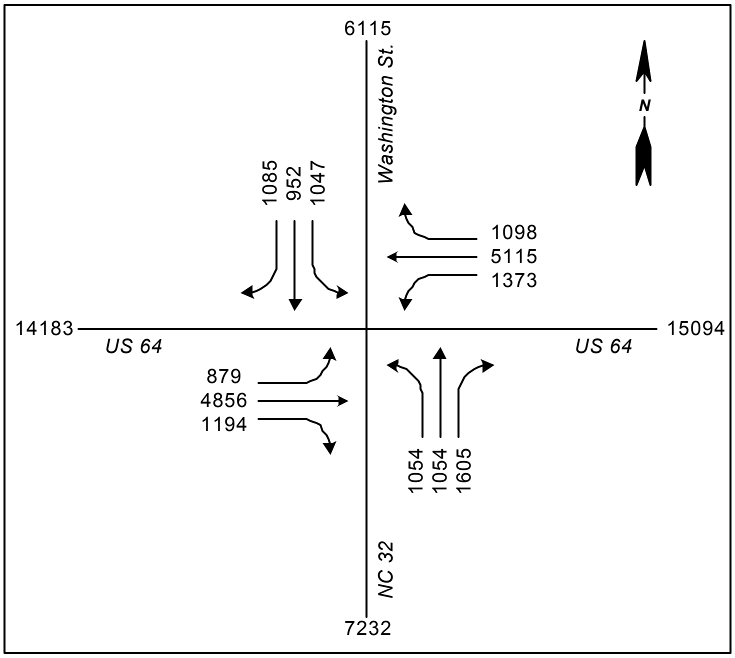


Table 1 – Estimated 1999 Turning Movements

Approach & Movement		1999 Ground Counts	Tranplan Simulation Method	TransCAD Simulation Method
Westbound	Left	1098	867	1041
	Through	5115	5352	5747
	Right	1098	1875	1305
Southbound	Left	1047	1876	1993
	Through	952	611	747
	Right	1085	361	168
Eastbound	Left	879	364	441
	Through	4856	5350	5583
	Right	1194	398	88
Northbound	Left	1054	401	199
	Through	1054	612	1105
	Right	1605	861	571

Table 2 – Estimated 2025 Turning Movements

Approach & Movement		Ratio Factoring Method	Directional Vol. Iteration Method	TMOVES Simulation Method	Tranplan Simulation Method	TransCAD Simulation Method
Westbound	Left	2459	2055	2228	1553	2140
	Through	8471	8061	8284	8863	9412
	Right	1213	1798	1976	2072	935
Southbound	Left	1155	1707	1848	2070	1780
	Through	3068	1296	1295	1973	2405
	Right	1725	1555	1474	574	432
Eastbound	Left	1391	1385	1263	576	919
	Through	8036	8375	8163	8853	9530
	Right	4730	1720	1548	1545	526
Northbound	Left	4111	1385	1246	1554	1137
	Through	3041	1440	1385	1975	2768
	Right	2904	2399	2466	1558	1172

Conclusions

The subjective comparison of the turning movement volumes estimated by each method results in no concise determination of which method yields the best results. However, some general conclusions can be made from the results of these analyses.

Since the first three methods (ratio factoring, directional volume iteration, and TMOVES) produced similar results and incorporate both base year turning movement counts and future year link volume estimates, I feel that these methods would be sufficient to use when completing a project-level traffic forecast. Conversely, since neither the Tranplan or TransCAD analyses made use of the actual turning movement ground counts (only the two-way volumes on each leg of the intersection were used for initial model calibration), I do not feel that the turning movement estimates resulting from these two programs should be applied directly to a project-level forecast.

If, however, I had no choice but to use data from a travel demand model (such as in the case where no ground counts are available), I would choose the Tranplan estimates over the TransCAD estimates. It should be noted, however, that the version of TransCAD used for this analysis is Version 3.61. Caliper Corporation has indicated that the updated Version 4.0 will produce turning movement output as an option for traffic assignment. These turning movements will be the actual movements produced by the traffic assignment and obey all network restrictions and penalties. This should produce turning movement estimates that are more comparable to the Tranplan estimates.

References

1. *Highway Traffic Data for Urbanized Area Project Planning and Design*, NCHRP Report 255. Transportation Research Board. December 1982.
2. Purth, Peter G. *TMOVES, A Model of Turning Movement Propensity*. Northeastern University. January 1990.
3. *User Manual for TRANPLAN, Version 8.0.* The Urban Analysis Group. April 1995.

4. *TransCAD User's Guide, Version 3.0 for Windows.* Caliper Corporation. 1996.
5. *Thoroughfare Plan Study Report for the Town of Plymouth.* North Carolina Department of Transportation Statewide Planning Branch. February 2001.

NCHRP 255 Calculations

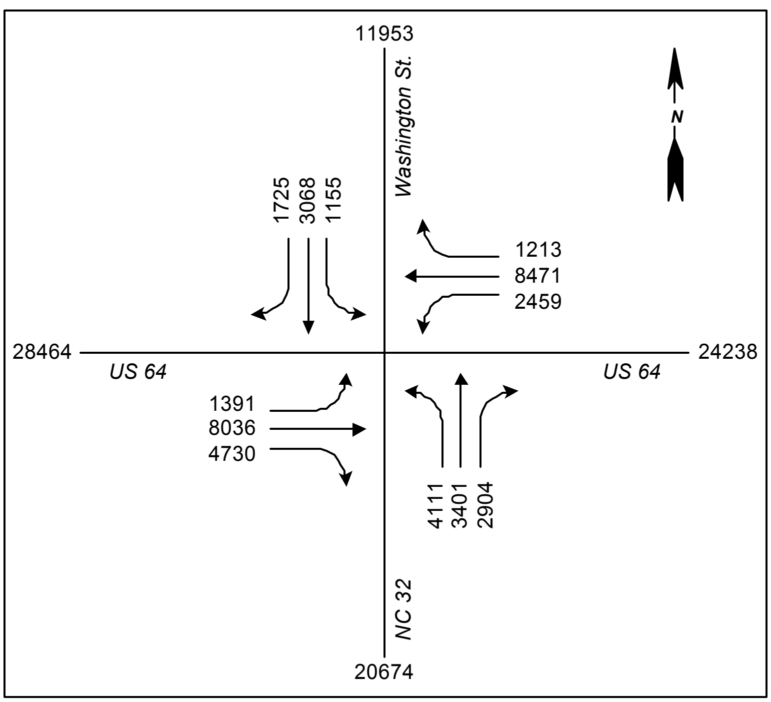
Ratio Factoring Method

The following output was obtained from the 1999 base and 2025 design year loadings of the Plymouth model:

- Simulated 1999 base year turning movements at intersection of US 64 and Washington Street/NC 32; and
- Simulated 2025 design year turning movements at intersection of US 64 and Washington Street/NC 32.

The ratio factoring method was then completed for the subject intersection using these data, along with the ground counts taken in February 1999, as shown on the following page. Figure 4 presents a summary of the resulting estimated turning movements.

Figure 4 – Intersection of US 64 and Washington Street/NC 32 Summary of Ratio Factoring Method estimation of 2025 future year turning movement volumes



$V_{ri} = F_i * (B_{ci}/B_{ai})$

V_{ri}= ratio adjusted future year volumes turning movement i

F_i= future year forecasted volume for turning movement i

(taken from calibrated Tranplan model)

B_{ci}= base year traffic count for turning movement i

(taken from February 1999 counts)

B_{ai}= base year assigned volume for turning movement i

(taken from calibrated Tranplan model)

Approach/Movement		F_i	B_{ci}	B_{ai}	V_{ri}
Westbound Approach	Left (1)	1553	1373	867	2459
	Through (2)	8863	5115	5352	8471
	Right (3)	2072	1098	1875	1213
Southbound Approach	Left (4)	2070	1047	1876	1155
	Through (5)	1973	950	611	3068
	Right (6)	574	1085	361	1725
Eastbound Approach	Left (7)	576	879	364	1391
	Through (8)	8853	4856	5350	8036
	Right (9)	1545	1194	390	4730
Northtbound Approach	Left (10)	1564	1054	401	4111
	Through (11)	1975	1054	612	3401
	Right (12)	1558	1605	861	2904

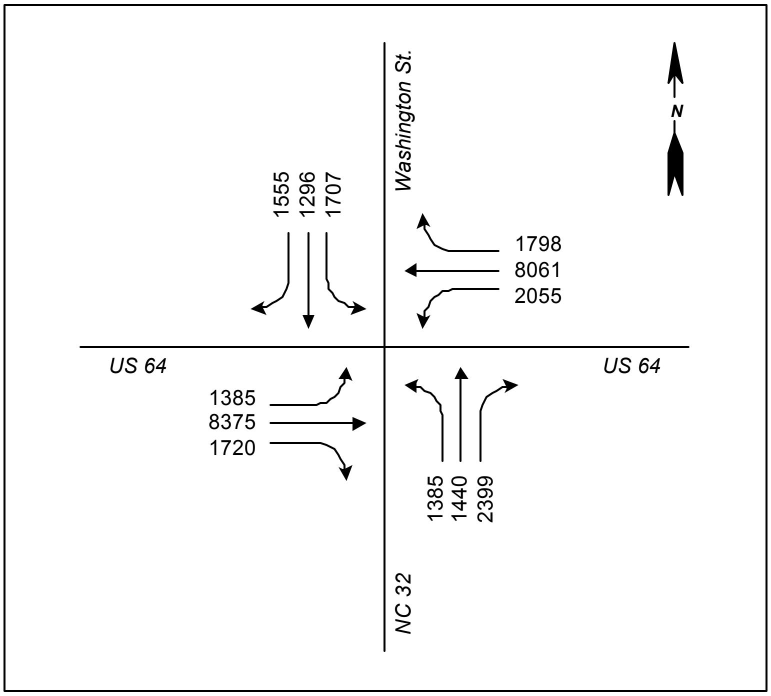
Directional Volume Iteration Method

The following data was required in order to complete the directional volume iteration method for the Plymouth intersection case study:

- Simulated 2025 future year directional link volumes at intersection of US 64 and Washington Street/NC 32; and
- Actual 1999 surveyed turning movements at intersection of US 64 and Washington Street/NC 32.

The following pages are taken from the Excel spreadsheet set up to perfrom the five steps comprising the directional volume iteration method. The first page presents the formulas used and the second page presents the actual calculations for the intersection of US 64 and Washington Street/NC 32. Figure 5 presents a summary of the resulting estimated turning movements.

Figure 5 – Intersection of US 64 and Washington Street/NC 32 Summary of Directional Volume Iteration Method estimation of 2025 future year turning movement volumes



Directional Volume Iteration Method - Formulas

Step 1: Construct initial turning movement matrix

		D_{1f} / D_{1b}	D_{2f} / D_{2b}	D_{3f} / D_{3b}	D_{4f} / D_{4b}
O_{1f}	O_{1b}	T_{11b}	T_{12b}	T_{13b}	T_{14b}
O_{2f}	O_{2b}	T_{21b}	T_{22b}	$T2_{3b}$	T_{24b}
O_{3f}	O_{3b}	T_{31b}	T_{32b}	T_{33b}	T_{34b}
O_{4f}	O_{4b}	T_{41b}	T_{42b}	T_{43b}	T_{44b}

Oib = base year inflow to the intersection on link i
Oif = future year inflow to the intersection on link i
D_{jb} = base year outflow from the intersection on link j
D_{jf} = future year outflow from the intersection on link j
Tijb = base year traffic flow entering through link i an d leaving through link j
Tijf = future year traffic flow entering through link i an d leaving through link j
* = represents adjusted values in each iteration

Step 2: Perform first row iteration

Replace O_{ib} with O_{if}
$T_{ijf}* = (O_{if}/O_{ib}) * T_{ijb}$
$D_{jf}* = S (T_{ij}f*)$

	$D_{1f}*$	$D_{2f}*$	$D_{3f}*$	$D_{4f}*$
O_{1f}	$T_{11f}*$	$T_{12f}*$	$T_{13f}*$	$T_{14f}*$
O_{2f}	$T_{21f}*$	$T_{22f}*$	$T_{23f}*$	$T_{24f}*$
O_{3f}	$T_{31f}*$	$T_{32f}*$	$T_{33f}*$	$T_{34f}*$
O_{4f}	$T_{41f}*$	$T_{42f}*$	$T_{43f}*$	$T_{44f}*$

Compare	**$D_{jf}*$**	**D_{jf}**	**? (%)**
j=1	D_{1f*}	D_{1f}	
j=2	D_{2f*}	D_{2f}	
j=3	D_{3f*}	D_{3f}	
j=4	D_{4f*}	D_{4f}	
Sum			

Step 3: Perform first column iteration

Replace $D_{jf}*$ with D_{jf}
$T_{ijf}*^{New} = (D_{jf}/D_{jf}*) * T_{ijf}*$
$O_{ijf}* = S (T_{ijf}*^{New})$

	D_{1f}	D_{2f}	D_{3f}	D_{4f}
$O_{1f}*$	$T_{11f}*^{New}$	$T_{12f}*^{New}$	$T_{13f}*^{New}$	$T_{14f}*^{New}$
$O_{2f}*$	$T_{21f}*^{New}$	$T_{22f}*^{New}$	$T_{23f}*^{New}$	$T_{24f}*^{New}$
$O_{3f}*$	$T_{31f}*^{New}$	$T_{32f}*^{New}$	$T_{33f}*^{New}$	$T_{34f}*^{New}$
$O_{4f}*$	$T_{41f}*^{New}$	$T_{42f}*^{New}$	$T_{43f}*^{New}$	$T_{44f}*^{New}$

Compare	**Oif***	**Oif**	**? (%)**
i=1	$O_{1f}*$	O_{1f}	
i=2	$O_{2f}*$	O_{2f}	
i=3	$O_{3f}*$	O_{3f}	
i=4	$O_{4f}*$	O_{4f}	
Sum			

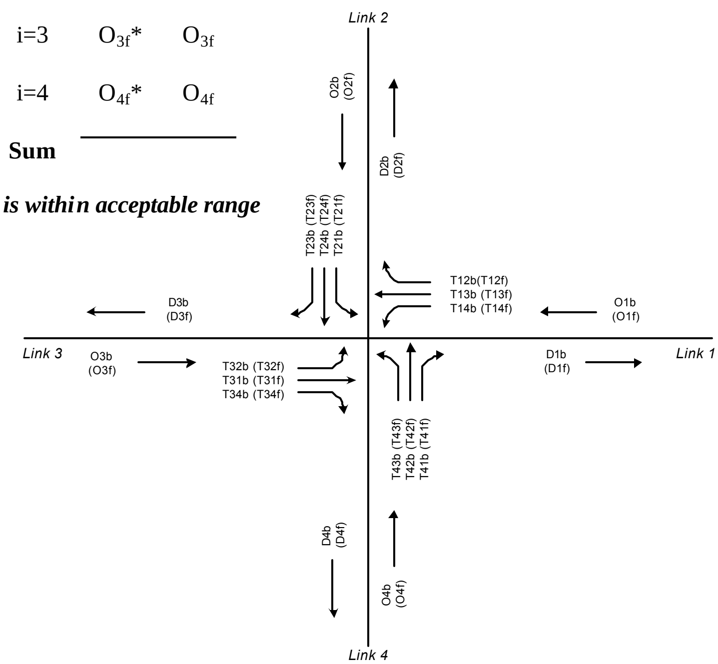
Perform additional iterations of Steps 2 & 3 until %D is within acceptable range

Step 4: Repeat row iteration if needed

Calculate new values for $T_{ij}*^{New}$ and $D_{jf}*$
Compare $D_{jf}*$ and D_{jf}

Step 5: Repeat column iteration if needed

Calculate new values for $T_{ij}*^{New}$ and $O_{if}*$
Compare $O_{if}*$ and O_{if}



Directional Volume Iteration Method - Plymouth Run

Step 1: Construct initial turning movement matrix

		12481	4623	11001	5071
		7508	3031	7254	3519
12488	7586	0	1098	5115	1373
4617	3084	1047	0	1085	952
10974	6929	4856	879	0	1194
5097	3713	1605	1054	1054	0

Step 2: Perform first row iteration

Replace Oijb with Oijf
Tijf* = (Oif/Oib) * Tifb
Djf* = S (Tijf*)

	11462	4647	11491	5576
12488	0	1808	8420	2260
4617	1567	0	1624	1425
10974	7691	1392	0	1891
5097	2203	1447	1447	0

Compare	**Djf***	**Djf**	**? (%)**
j=1	11462	12481	-8
j=2	4647	4623	1
j=3	11491	11001	4
j=4	5576	5071	10
Sum	33176	33176	

Step 3: Perform first column iteration

Replace Djf* with Djf
Tijf** = (Djf/Djf*) * Tijf*
Oijf* = S (Tijf**)

	12481	4623	11001	5071
11915	0	1798	8061	2055
4558	1707	0	1555	1296
11480	8375	1385	0	1720
5224	2399	1440	1385	0

Compare	**Oif***	**Oif**	**? (%)**
i=1	11915	12488	-5
i=2	4558	4617	-1
i=3	11480	10974	5
i=4	5224	5097	2
S um	33176	33176	

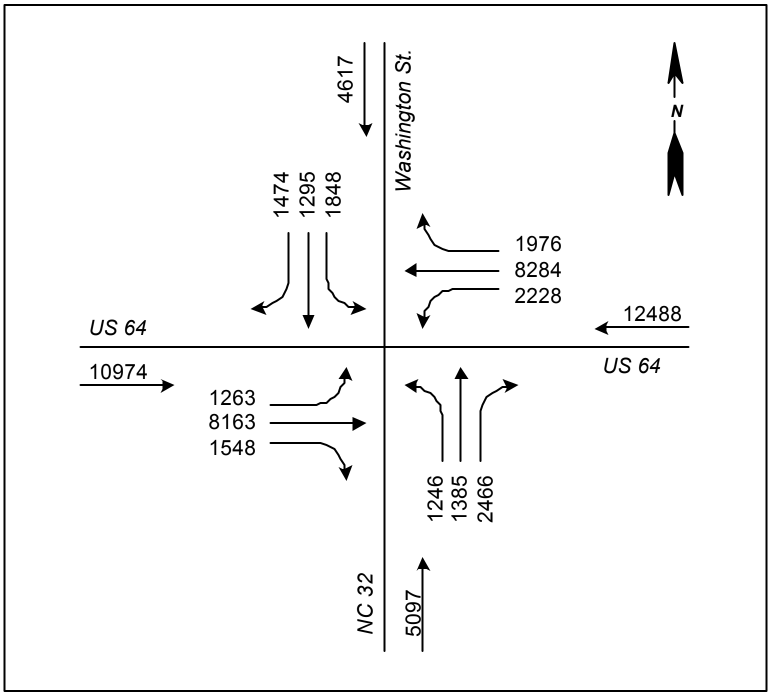
Perform additional iterations of Steps 2 & 3 until %D is within acceptable range

? within 5%, therefore no additional iterations needed

TMOVES Simulation

The input required to run the TMOVES program included the actual ground counts taken at the intersection of US 64 and Washington Street/NC 32 and the inflows and outflows on each approach from travel demand model. The output file generated by TMOVES is included on the following page. Figure 6 presents a summary of the resulting turning movements.

Figure 6 – Intersection of US 64 and Washington Street/NC 32 Summary of TMOVES Simulation 2025 future year turning movement volumes



c:\tmv_plymouth.out

US 64 @ WASHINGTON ST/NC 32 IN PLYMOUTH, NC
2025 ESTIMATED TURNING VOLUME MOVEMENTS
APPROACHES ARE NUMBERED COUNTERCLOCKWISE. APPROACH 1 IS:
WB APPROACH ON US 64
SEED (INPUT DIRECTLY):

ENTERING VIA	LEFT	STRAIGHT	RIGHT
1	1373.00	5115.00	1098.00
2	1047.000	952.000	1085.000
3	879.00	4856.00	1194.00
4	1054.000	1054.000	1605.000

APPROACH:	1	2	3	4
ENTERING VOLUMES:	12488.00	4617.00	10974.00	5097.00
LEAVING VOLUMES:	12481.00	4623.00	11001.00	5071.00

BIPROPORTIONAL ESTIMATES:

ENTERING VIA	LEFT	STRAIGHT	RIGHT	TOTAL	LEFT	STRAIGHT	RIGHT
1	2228.153	8284.317	1975.531	12488.000	.178	.663	.158
2	1847.918	1295.512	1473.571	4617.000	.400	.281	.319
3	1263.135	8163.268	1547.598	10974.000	.115	.744	.141
4	1246.267	1384.464	2466.269	5097.000	.245	.272	.484

LEAVING VIA	LEFT	STRAIGHT	RIGHT	TOTAL	LEFT	STRAIGHT	RIGHT
1	1847.918	8163.268	2466.269	12477.450	.148	.654	.198
2	1263.135	1384.464	1975.531	4623.130	.273	.299	.427
3	1246.267	8284.317	1473.571	11004.160	.113	.753	.134
4	2228.153	1295.512	1547.598	5071.262	.246	.273	.486

Tranplan Simulation

As stated previously, the Plymouth model applied the traditional four-step planning process (trip generation, trip distribution, mode choice, and trip assignment) to both the 1999 base and the 2025 design years. This was accomplished using the Tranplan suite of travel demand programs with an all-or-nothing loading. In order to determine the turning movement volumes in the design year, the previously developed future year model was run again, saving turns at node 65, which represents the intersection of US 64 and Washington Street/NC 32. This enabled HNIS, the graphics package used in conjunction with Tranplan, to show the actual turn movements at the subject intersection based on the future year loading. Figure 7 presents a summary of the resulting turn movements, while Figures 8 and 9 are actual print-outs from the HNIS package of the turn movements at this intersection in the base year and design year, respectively.

Figure 7 – Intersection of US 64 and Washington Street/NC 32 Summary of Tranplan simulation of 1999 and 2025 turning movement volumes

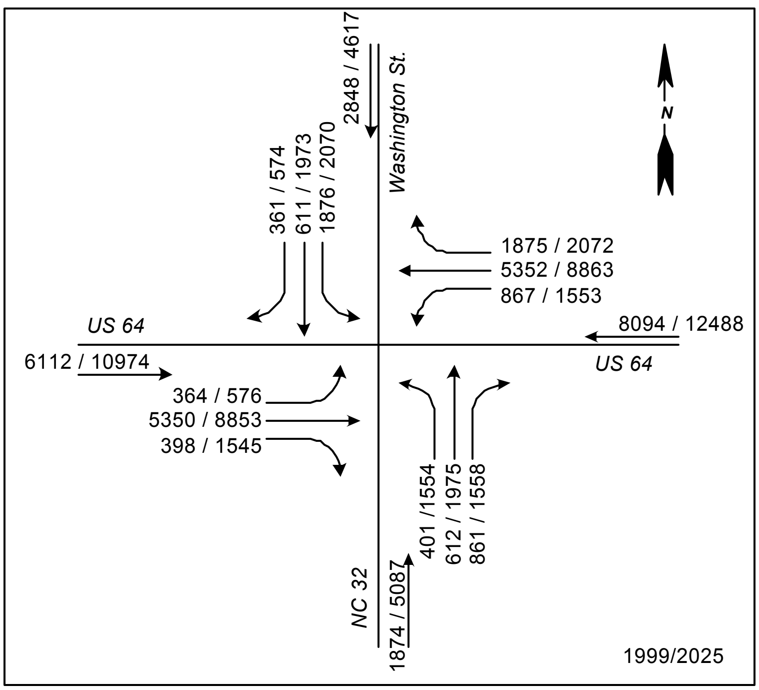


Figure 8 – 1999 Base Year Turn Moves from Tranplan
Intersection of US 64 and Washington Street/NC 32

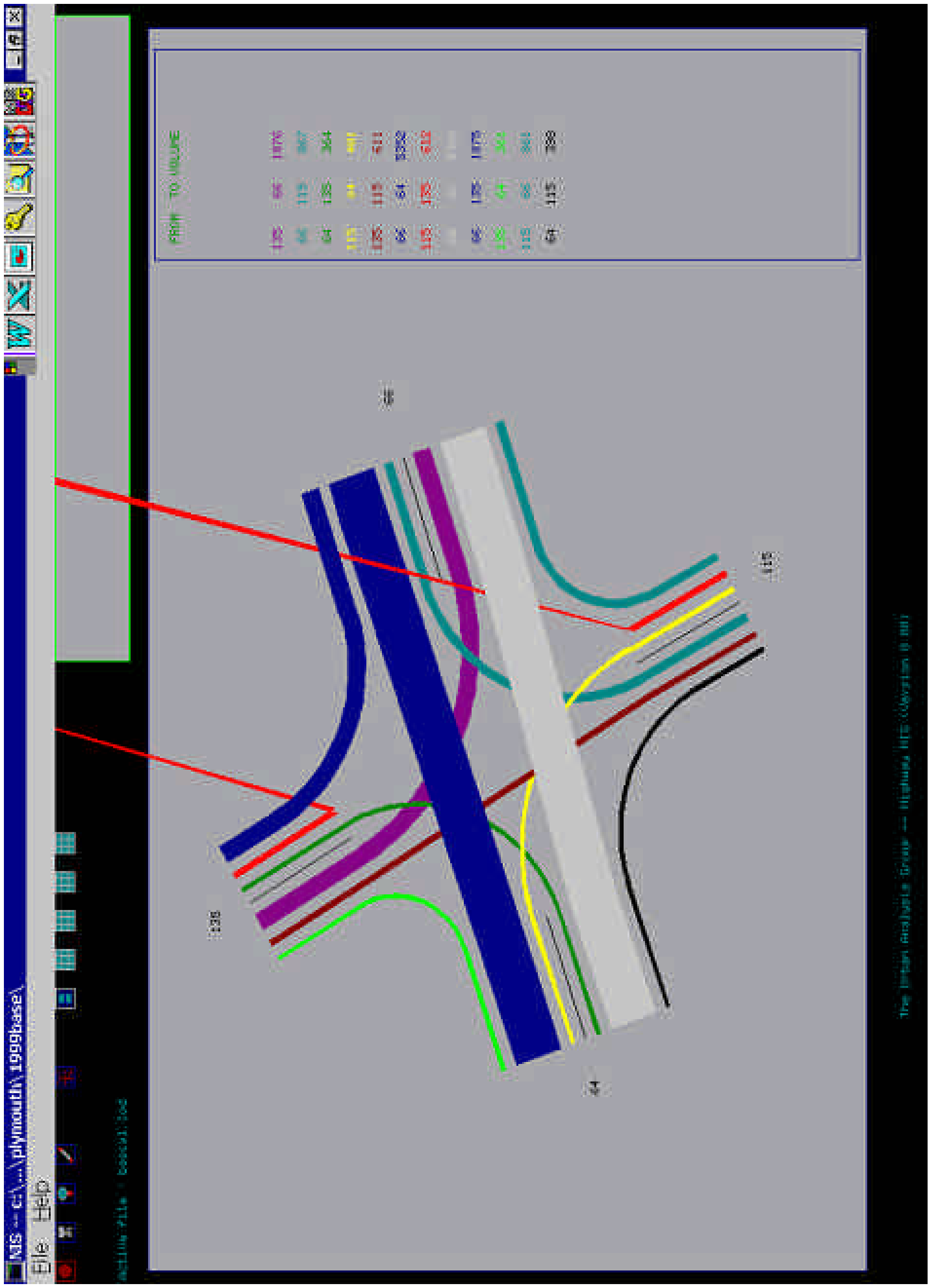
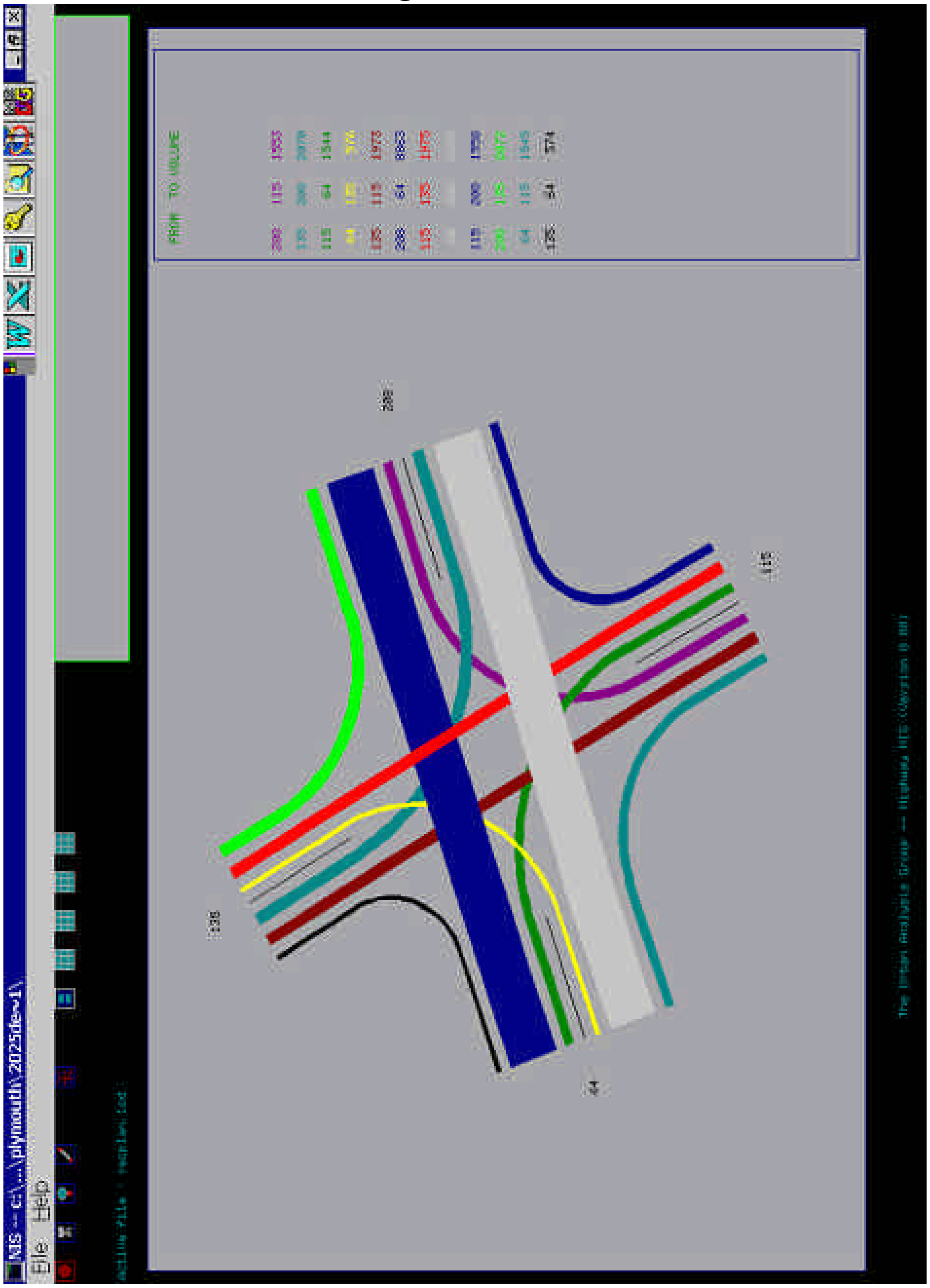


Figure 9 – 2025 Design Year Turn Moves from Tranplan Intersection of US 64 and Washington Street/NC 32



<u>TransCAD Simulation</u>

In order to simulate turning movements at the intersection of US 64 and Washington Street/NC 32 using TransCAD, the original model had to be imported into TransCAD. This was accomplished using the "Import Planning Networks" function. This function allows the user to import a network created with another software package, such as Tranplan, into TransCAD. Once the future year network was imported into TransCAD, the "Intersection

Diagram" tool was used to find the turning movements at the desired intersection. Figure 10 presents a summary of the resulting turn movements, while Figures 11 and 12 are actual print-outs from TransCAD of the turn movements at this intersection in the base and design years, respectively.

Figure 10 – Intersection of US 64 and Washington Street/NC 32 Summary of TransCAD Simulation 1999 and 2025 turning movement volumes

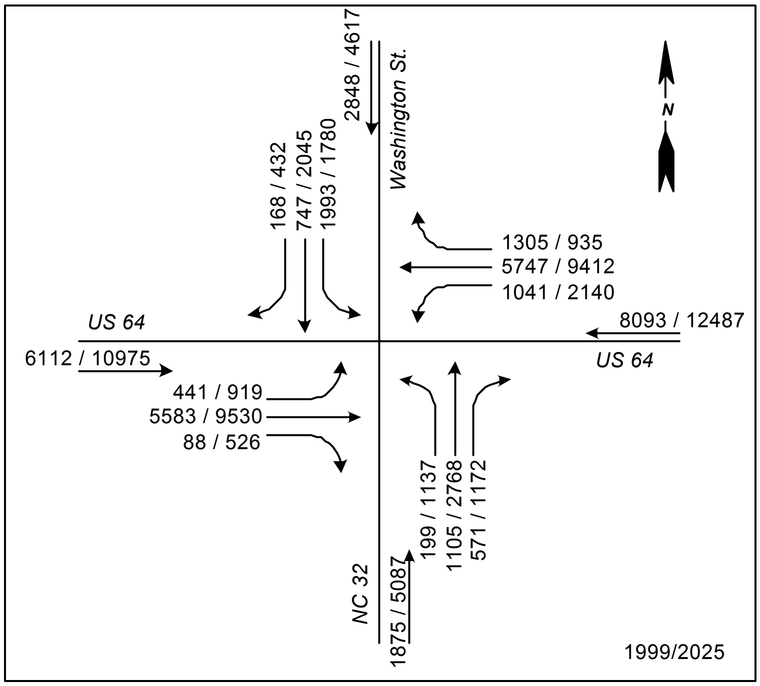


Figure 11 – Intersection of US 64 and Washington Street/NC 32 1999 Base Year

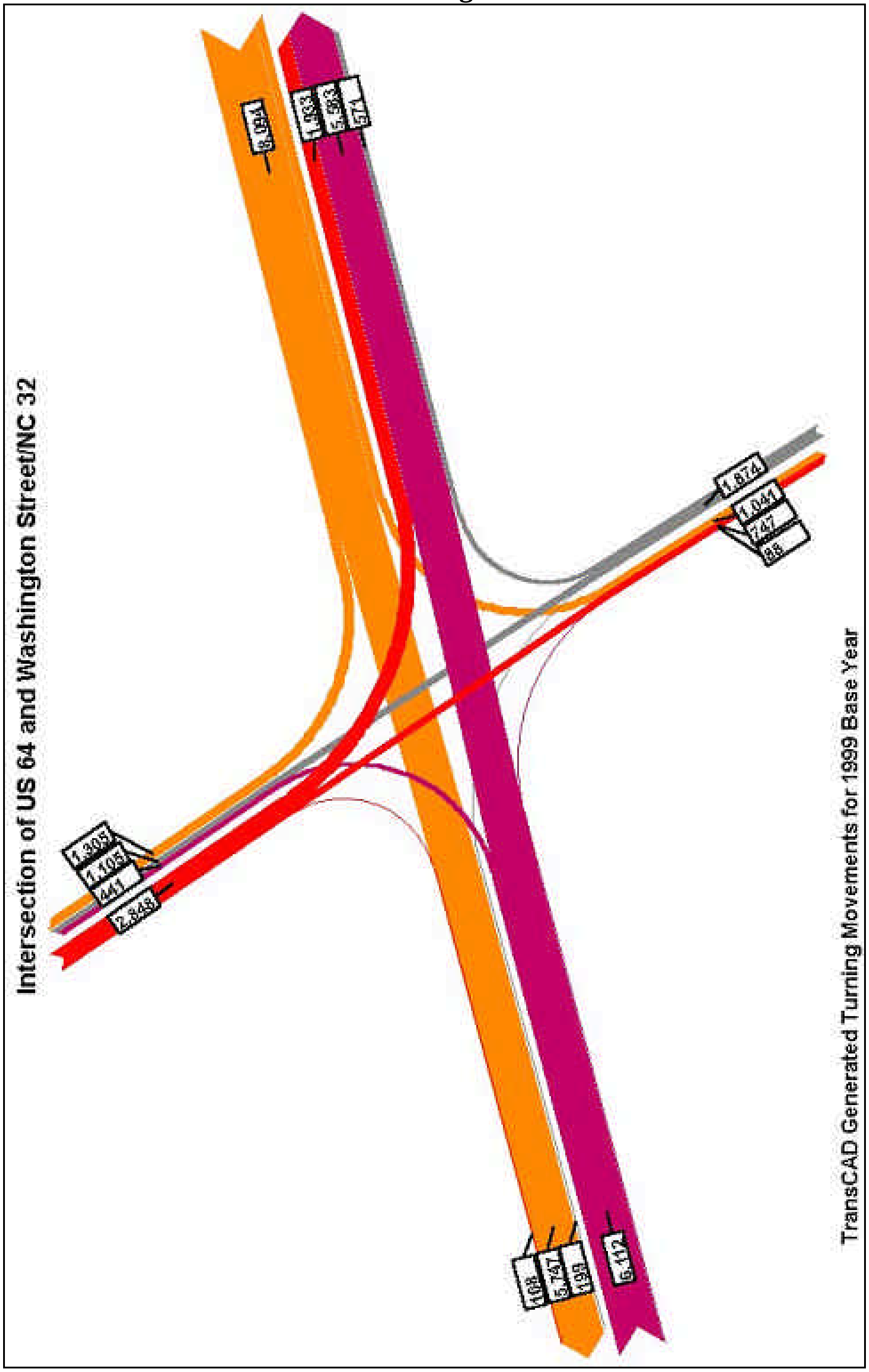
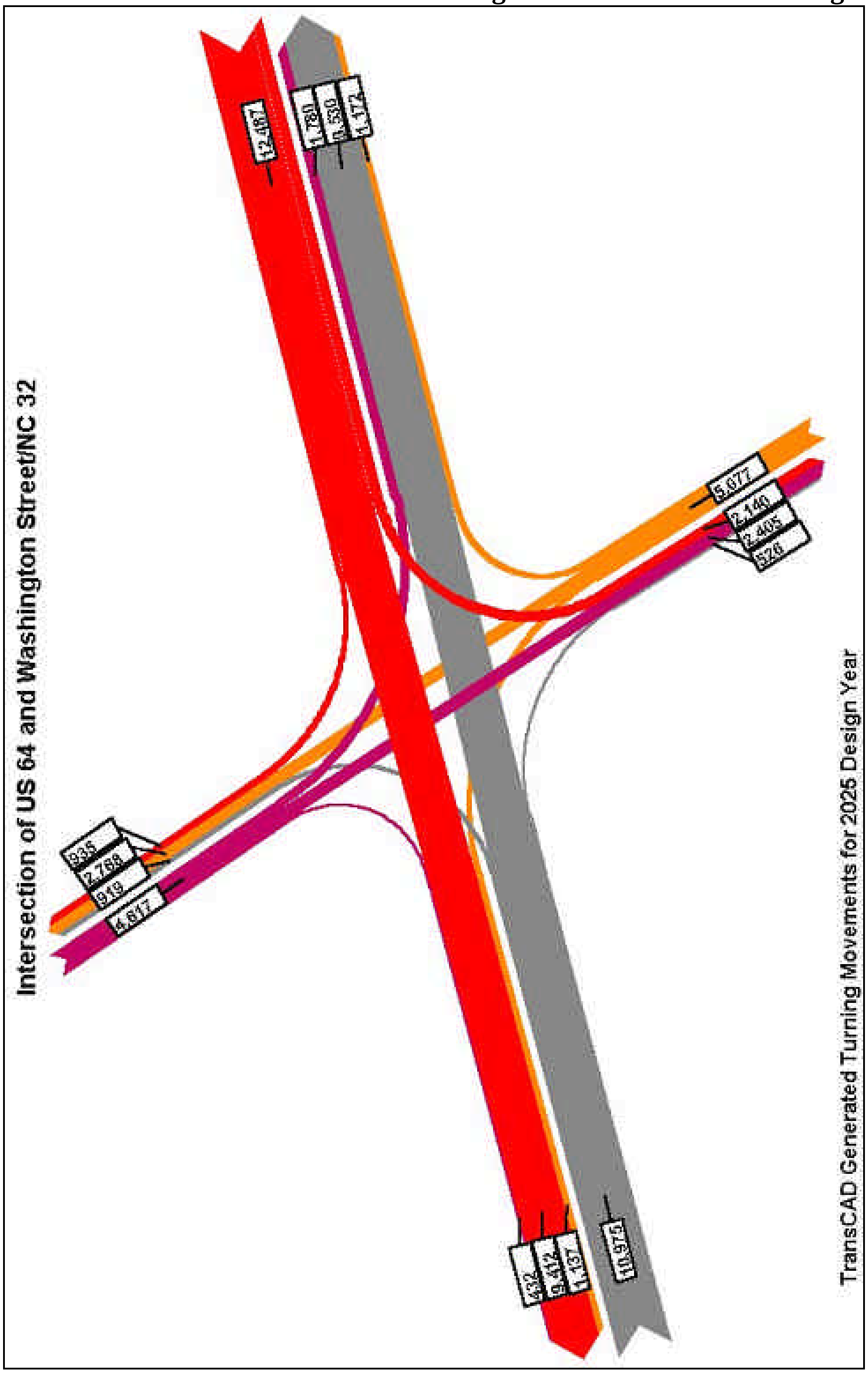


Figure 12 – Intersection of US 64 and Washington Street/NC 32 2025 Design Year



APPENDIX B – TRAFFIC FORECASTING SOFTWARE

The following software summaries derive from software descriptions and products available from PCTRANS[1] and McTrans[2]. NCHRP 255 spreadsheets are also included.

TransCAD

Requirements: Win 95/98/ME/NT/2000

Cost: $2,995-$9,995

Developer's Comments: TransCAD, developed by Caliper Corporation, is a PC-based GIS system for planning, managing and analyzing the characteristics and performance of transportation systems and capabilities. It has applications at the international, national, regional, and local levels, and can be used for any or all modes of transportation. Information on transportation networks, freight flows, routes, schedules, transportation analysis zones, passenger demand, and transportation system performance can be stored, displayed, and analyzed at any spatial scale. TransCAD provides: easy access to transportation and related geographic data; extended data model to support transportation planning, logistics, routing, operations research, and marketing applications; tools for presenting and visualizing transportation data; a complete toolbox of transportation analysis methods and models; a powerful applications development capability; and multimedia capabilities. TransCAD requires significant user input, including GIS maps and census data files.

Reviewer's Comments: TransCAD basically does it all, from national and regional planning all the way down to local planning. However, for a simple project, TransCAD may be overkill. The major hurdle to using TransCAD is the extensive training required, generally learned through a course taught by TransCAD personnel.

UfosNet[3]

Requirements: Win 95/NT

Cost: $9,500

Developer's Comments: UfosNET is a GIS-based travel demand forecasting system, which presents GIS mapping, integrated highway traffic simulation, and powerful editing and importing/exporting capabilities. The program offers an integrated transportation and land-use simulation system in a user-friendly environment. UFOS has built in tools for calculating intrazonal times based on nearest neighbor and weighted centroid methods, inter-zonal times, gravity trip distribution, and a balanced trip table using the Fratar model. Minimum paths can be built. Requires extensive training.

[1] PCTRANS, Kansas University Transportation Center, 2001.
[2] McTrans, University of Florida, 2001.
[3] UfosNet, RST International, Inc, 2001.

Reviewer's Comments: UFOSNET works much like TransCAD, but with fewer features.

Quick Response System II (QRSII)

Requirements: Win 95/NT

Cost: $195

Developer's Comments: QRS II, developed by AJH Associates, is a program for forecasting the impacts of urban developments on highway traffic and the impacts of highway projects on travel patterns. Intended for small area analysis either small cities or smaller parts of large cities the program uses interactive graphics for data input and retrieval of results and includes a comprehensive set of default parameters. QRS II can be used as a sketch-planning tool when time for more careful planning is unavailable or rigorous analysis of urban highway systems. QRS II is an entirely new implementation of the theory and philosophy of the original QRS manual techniques published in NCHRP Report #187.

Reviewer's Comments: QRS II is relatively easy to use and good for inexperienced users because of its comprehensive default parameters, calculation formulas, procedures and the embedded four-step travel demand forecasting process. QRS II is intended for small area analysis either small cities or smaller parts of large cities so it could be helpful in project-level planning. Results are summarized in 33 different standard text reports. GNE is also simple and easy to use.

TMODEL2 (TM2)[4]

Requirements: DOS 2.0

Cost: $3,800

Developer's Comments: TMODEL2, developed by TModel Corporation, is a user-friendly and efficient, menu-driven transportation modeling system using state-of-the-art modeling techniques. The program enables transportation planners to simulate and analyze a wide variety of transportation studies including: regional, municipal, cumulative impact, alternative scenario and site impact. Using TMODEL2TM, planners can easily build and calibrate models to forecast the impacts of alternative network or land-use scenarios. The main features of the program include many features:

- Node modeling of intersections for effective simulation of stop, yield and signal controls, including dynamic turn penalties based upon entering volumes
- Built-in network calculator that incorporates user-input or default formulas to compute V/C, VMT, VHT, delay and pollution indices
- Turning movements can be preloaded

[4] TMODEL2, TModel Corporation, 2001.

- Volumes can be presented in graphic form and transferred directly into NCAP, the Intersection Capacity Analysis Package (#TE-32), which is included in the TMODEL2 program for level of service analysis.

Version 2.54 is faster and many features have been added, including: The TMODEL3 Willumsen's Method, Distribution and Assignment Editors and Run modules; Implementation of Multi-Point Assignment (MPA);Implementation of Upstream Queuing Propagation (UQP); The Willumsen's method for estimation of a trip table from traffic counts now operates much faster, includes turning movements, and is not limited by model size; Plotting capabilities have been enhanced with the ability to control shading densities with either one global setting or in conjunction with your choice of pen width; The Graphic Editor has been expanded in numbers of links and nodes. Approximately 3000 additional link entries (totaling 6000 more links) can be used with the same amount of memory; Level of Service (LOS) Analysis; Revisions to make LAN use and multiple setups easier, node capacity using V/C rations, turn movement merging and adjusting tools, extensive land use file manipulation enhancements, easier trip length frequency analysis, street names in the network graphic editor and plots, scattergrams and regressions curves.

Reviewer's Comments: TMODEL is very similar to QRSII but has a number of added features. TMODEL is not as straight forward as QRS II and workshops are periodically held to train users.

TP/4-in-1

Requirements: MS-DOS 3.1+

Cost: $900

Developer's Comments: TP/4-in-1 runs the 4-step travel forecasting process, all in one execution on a PC. It is structured to execute the model for any size area. Once a region's MPO model is streamlined to fit within the structure of TP/4-in-1, any suburban jurisdiction planner could execute it or it could be built from scratch for any new unurbanized area. Running the model frequently or for only a few times per year is feasible for those unfamiliar with transportation modeling. Limitations are 2,250 zones; 16,400 nodes; and 128,000 links.

Some of the features include: Trip generation for 4 trip purposes + F-curves and K-factors, Matrix compression and reporting by purpose, Mode split for work trips on y using a matrix of percents, Capacity restraint assignment, multi-load assignment: loading another trip table over the same paths as the total trip table in capacity restraint, select link assignment and/or select link trip table compression, screenline analysis, turns.

Reviewer's Comments: This program is designed for novice transportation planners and can be run with a number of defaults. The major flaw of this program is the data input, which is not GIS based data.

TRAFFIX

Requirements: Pentium, Win95/98 or higher

Cost: $1,840

Developer's Comments: TRAFFIX is an interactive computer program that enables planners and engineers to efficiently: Conduct traffic impact and medium size city-wide traffic forecasting studies; Rapidly forecast the traffic impacts of new developments; Calculate level of service at critical signalized and unsignalized intersections and on arterials; Interactively test different mitigation measures, and Determine traffic impact fees for individual development projects. The program allows level of service (LOS) to be calculated simultaneously for both baseline and future (with project) scenarios at signalized and unsignalized intersections and on urban and suburban arterials. In addition, user-defined analysis scenarios can be created and level of service scenario comparison reports can be generated. Output reports are suitable for inclusion in project reports.

The network is drawn using cursor operated drawing tools. This road network consists of development zones, critical intersections, and gateways. The land uses, trip generation rates, and trip distribution percentages are then entered for each development zone. Then the paths that traffic will take moving from each development zone to each gateway are drawn on the network. A special "interactive screen" is provided in the program that allows users to quickly test various street improvements and signal timing changes for mitigating the impacts at an intersection.

Reviewer's Comments: Traffix is designed for smaller areas, specifically site impact work. The program computes turning movements and using the mitigation screen allows users to quickly test various street improvements and signal timing changes. However, all trip generation data, including rates must be entered. Users must also choose paths that traffic will take and the percentage of the productions of a zone that will take this path. This makes it very hard to simulate a new roadway and correctly determine the traffic on that roadway. This program seems to be excellent for LOS at intersections and for determining mitigation fees, but is limited in terms of the 4-step process.

Simplified Project Forecasting Model (SPF)

Requirements: DOS 2.0

Cost: $60

Developer's Comments: SPF is a simplified travel demand forecasting system, which captures the impact of changes in land use and the transportation network, and produces a growth factor to be applied to a base traffic volume estimate. The SPF develops facility specific travel demand forecasts without requiring extensive resources in the development of inputs or in the application of the procedure. The procedure is designed to produce a growth factor to be applied to an estimated base traffic volume rather than producing the absolute traffic volume as its primary output.

Reviewer's Comments: Older program. Surpassed by others.

Rural Forecasting Model (RFM)

Requirements: DOS 2.1, GW-BASIC or BASICA

Cost: $45

Developer's Comments: This program is designed to estimate future traffic volumes on rural state highways. RFM is capable of modeling three types of roadways, which were derived based on various socio-economic data and historical AADT information. The three models are: NINTERSTATES, representing interurban travel; NPRINCIPAL ARTERIALS, representing urban to rural travel; and NMINOR ARTERIALS AND MAJOR COLLECTORS, representing rural to rural travel. Projections of town and county household information, county automobile registrations, and town and county populations are required input.

Reviewer's Comments: The functions of this software are easily handled by other, more inclusive, programs.

The Highway Emulator Model (THE)

Requirements: MS-DOS 2.1+

Cost: $60

Developer's Comments: THE performs highway travel demand forecasting using a traditional four-step modeling approach. This menu-driven package allows the user to create a highway network, generate and distribute trips using either capacity restrained or equilibrium algorithms. It can accommodate networks with up to 300 zones, 2,000 nodes and 3,000 links. The program is best suited to corridor, subarea and site impact projects. The unique feature of THE Model is its ability to estimate a trip table from traffic counts, which can be coded in the network.

Other Comments: THE does not have its own graphical editor but other network editors such as GNE can be used. THE is best suited for corridor analysis, subarea analysis, and site impact projects. THE is a good forecasting program, however, other, more current programs, have surpassed it.

Trip Generation[5]

Requirements: Win3.1

Cost: $400

Developer's Comments: Trip Generation is a software program that uses the data from the sixth edition of ITE's Trip Generation Report and can calculate traffic generated by many different land uses or building types for traffic impact analyses, transportation corridor analyses, traffic circulation systems, and quick response planning techniques. The program can be used for single or mixed-use developments. It allows for addition of trip adjustment factors for each type of trip and is compatible with most commercial spreadsheets for incorporating the results into documents and/or graphics. Users have the option of using ITE rate, ITE equations or their own rates. Socioeconomic and land use data are required for input.

Reviewer's Comments: The Trip Generation program only does trip generation. Features of this program are currently incorporated into the newer, more sophisticated programs.

Traffic Estimation for Impact Studies (SITE/TEAPAC)

Requirements: MS-DOS 2.0+

Cost: $495

Developer's Comments: SITE is an on-screen, graphic technique for performing site traffic generation, distribution and assignment needed for typical traffic impact studies. The traffic assignment paths are user-specified, not computer-generated, thus allowing professional judgment to determine how traffic will approach and depart a development at the microscopic turning movement level. Assignment paths can be entered manually as a list of intersections, or the program can display shortest-route travel paths to which percentages can be assigned by the user. An option allows the selected paths to be automatically reversed for outbound flows. Assignment paths are displayed graphically on the screen, overlaid on the traffic network.

Traffic generation rates, distribution percentages and development size are entered and maintained independently of each other, allowing quick testing of changes for any of these parameters. SITE provides the capability of quickly and accurately assigning traffic volumes in a repeatable manner. The results of several runs can be combined to analyze larger multi-use developments or alternative land-use plans using a built-in cumulating process. Re-running the program for changing scenario conditions or sensitivity analysis is simple and quick due to the independence of the input variables and the interactive nature of the program.

[5] Trip Generation, MicroTrans, 2001.

Reviewer's Comments: The program is user friendly and helpful for site impact work but is outdated. SITE appears to be the precursor to Traffix.

Traffic Assignment Spreadsheet System for Windows (WINTASS)

Requirements: Win 95/NT

Cost: $295

Developer's Comments: WINTASS is a Window-based program that helps transportation planners or engineers estimate the relative impacts of land use changes on nearby roadway networks. It automates the traffic assignment process, provides a clear audit trail of assumptions and computations, delineates the relative impacts of site, existing, and growth components of future traffic projections and provides an intuitive method of distributing site-generated traffic throughout a roadway network.

Reviewer's Comments: WINTASS is specifically designed for site impact work and is not setup for corridor analysis. As with SITE, all the functions of WINTASS are available in the newer Traffix.

Traffic Interpolation & Extrapolation (TIES)

Requirements: MS-DOS 3.0 or higher

Cost: $150

Developer's Comments: TIES is developed for conducting interpolation and extrapolation of traffic volumes needed for numerous transportation planning and traffic engineering applications. TIES is based on guidelines provided in the Chapter Seven of the National Council of Highway Research Program (NCHRP) report 255, published by the TRB, with augmented procedures for extrapolation. Typical transportation planning applications of TIES include: 1) interpolation of traffic volumes when base and future model year traffic volumes are available but interim year traffic volumes are desired; 2) extrapolation of traffic volumes beyond a model year; and 3) projection of historical traffic volume in absence of a regional transportation model. In this program, traffic interpolation and extrapolation are conducted by choosing among various models such as linear, non-linear increasing, and non-linear decreasing, also must enter known traffic information.

Reviewer's Comments: TIES is a very specialized program specifically designed around NCHRP 255 methods. Features of this program are currently incorporated into the newer, more sophisticated programs.

VisualTraffic[6]

Requirements: Windows 3.0+, Excel 5.0

Cost: $150

Developer's Comments: This unique traffic assignment program that works with EXCEL 5.0 for Windows and is based on manual methods of forecasting that help the user visualize the network. It allows diversity and relieves the user from designing spreadsheets. The network can be drawn quickly with the mouse on a matrix of nodes. This network then becomes the interface to input distribution, route selection and assignments, making it as simple to understand as manual techniques with the advantage of spreadsheets. Vehicle trips can be posted onto networks selectively. The user can itemize the networks to leave a clear record of the forecast assumptions. You can quickly generate report tables from one or more network sheets. Printouts are report quality. Networks are developed in Excel worksheets by clicking on pre-drawn circles. Clicking on the nodes also does distribution and route selection.

Reviewer's Comments: VisualTraffic is a good tool for small networks. The program is especially good if time or data is not available for more complex modeling software. The program documents the forecasting steps and outputs report quality spreadsheets. The main problem of the program, however, is the distribution, which has to be done manually.

Planning and Project Development Spreadsheets (PPDS)

Requirements: MS-DOS 2.0+, Lotus 1-2-3.

Cost: $50

Developer's Comments: PPDS was developed by FHWA as part of NHI course #15251-Using the Urban Transportation Planning Process for Project Planning Process for Project Development and Design. It is a collection of Lotus 1-2-3 spreadsheets that automate the methods presented in NCHRP Report 255, Highway Traffic Data for Urbanized Area Project Planning and Design. These procedures are divided into the following five topical areas: refining system output; estimating traffic for different forecast years; quick response capacity analysis; future turning movement calculations; and traffic loadings for pavement design (ESALs).

Reviewer's Comments: PPDS is designed for use in conjunction with NCHRP 255. The five procedures included are very specific and have limited wide range use.

[6] Visual Traffic, Visual Software Company, 2001.

EZ-Turn [7]

Requirements: Win 95/NT

Cost: $490

Developer's Comments: EZ-Turn is Windows-based computer software, which can create error-free turning movement diagrams directly from a turning movement data file (in ASCII format) of the most popular transportation planning software packages. It posts the turning movement volumes for user-specified intersections for the following travel demand forecast models: EMME/2, MinUTP, Tmodel2, Tranplan, and TRIPS. EZ-Turn can process turning movement data for intersections of up to 8 legs/approaches. EZ-Turn can create a HCS (Highway Capacity Software) traffic volume input file (a TMC file) from a travel demand forecast models peak hour turning movement data file. The TMC file can be directly merged into HCS signal operational analysis. This is convenient when the intersection capacity analysis needs to be done for a number of runs and for a large number of intersections. The intersection node number, the entry and exit node numbers to/from the intersection and a turning movement data file from another software program are needed as input.

Reviewer's Comments: This software is very good for visually representing turning movements.

TMOVES

Requirements: MS-DOS 2.1+

Cost: $40

Developer's Comments: TMOVES estimates turning movements at intersections to match user-supplied approach inflows and outflows based on a "seed matrix" of turning flows. This program offers an effective method to convert AADT volumes into turning movement estimates, allowing users to conduct turning movement surveys less frequently and to apply travel forecasts to the turning movement level.

Reviewer's Comments: TMOVES is similar to EZ-Turns and provides nice turning movement graphics. TMOVES relies on a seed matrix of turning movements, and as a result, is not useful for estimating turning movements for new intersections.

NCHRP 255 Spreadsheets

Requirements: Excel 5.0+

Cost: Free

[7] EZ-Turn, Lee, Stephen, 2001.

Developer's Comments:

ATURNS Provides future directional turns from future and base assignments as well as base counts. Requires future year turning movement forecast, base year turning movement assignment, and base year turning movement counts. Assumes that the discrepancy between a base year count and a base year assignment is likely to be of the same magnitude in the future year. Given this assumption the future year turning movements can be modified by comparing the relative ratios or differences between base year link and turning volumes.

BTURNS Provides future directional turns from future directional link volumes. Starting with user-estimated turning percentages the directional volume method produces a final set of future year turning volumes. Requires future year directional link volumes and either base year actual or assigned directional turning movements or an initial estimate of future year directional turning percentages.

TTURNS Provides directional turns at "T" intersections. To determine the directional turning movements at a "T" intersection this program requires directional volumes on all links and one turning movement volume, be it known or estimated.

INTERP Performs traffic forecast interpolation. Interpolation requires two sets of known values between which data can be generated. Therefore, it is a suitable method for estimating traffic between two future year forecasts or between the base year and a future year assignment.

EXTRAP Performs traffic forecast extrapolation. The extrapolation method uses known or estimated growth trends to forecast traffic for a year situated either before or after an available computer assignment or base year count.

REFSL A screenline refinement procedure. The purpose of the screenline refinement procedure is to improve upon the link-by-link traffic forecasts produced by computer models. Future year link volumes are adjusted by the procedure across a screenline based on relationships between base year traffic counts, base year assignments, and future year link capacities. Requires base year traffic counts, base year assignment, base year link capacities, future year forecast, and future year link capacities.

UDELAY Calculates stopped delay based on the 1985 HCM procedures. The assumed lane group capacities are based on medial saturation flow rates for fair-to-good geometrics and traffic conditions.

ODELAY Calculates arterial speeds, delays, and queues for over-capacity conditions, includes a mid-block speed forecast and an intersection delay forecast. Requires intersection directional approach volumes (peak hour and immediately following off-peak hour), approach capacity, time duration of peak volume, signal cycle length during peak period, effective green time of signal during peak period, number of approach lanes.

DESIGN Determines ESALs for a new, upgraded or existing facility.

Reviewer's Comments: NCHRP 255 Spreadsheets include a number of simple spreadsheets for a wide variety of tasks. The REFSL and BTURNS spreadsheets are very good and easy to use.

APPENDIX C: US 19 CASE STUDY

-Example-
-For Illustrative Purposes Only-

Traffic Forecast
For
TIP Project R-2519-A

Prepared For:

THE NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION
STATEWIDE PLANNING BRANCH

Prepared By:

North Carolina State University Civil Engineering Department

June 2002

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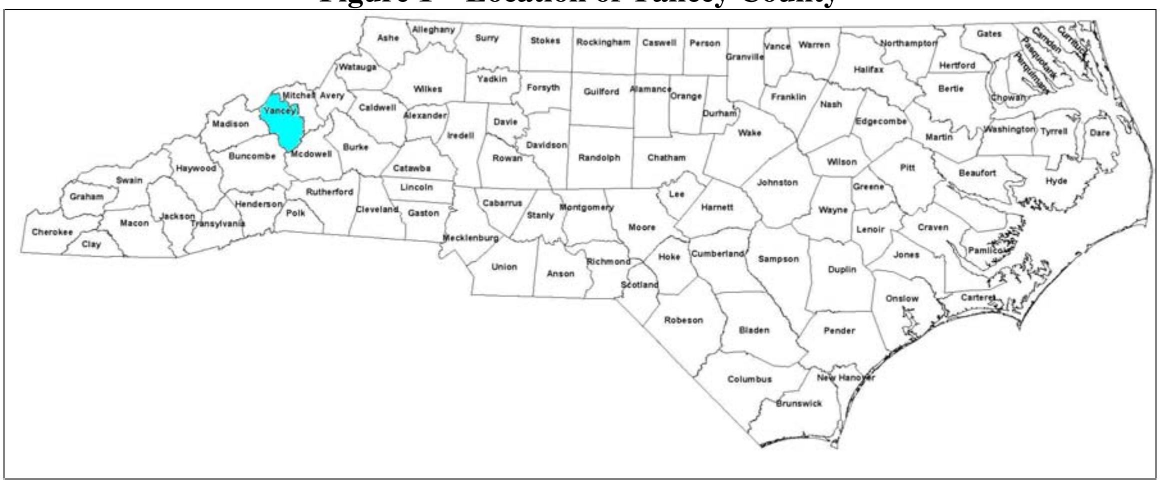
Appendices

1.0 INTRODUCTION

1.1 Project Description

Project R2519-A is a proposed widening of US-19E through Burnsville. NC. The case study project limits begin east of Burnsville, just beyond the intersection of US 19E and SR 197, and it extends west, just beyond SR 1139. This section of road will be widened from a two lane to a four-lane facility. The base year for this project is 1997 and the design year is 2025.

Figure 1 – Location of Yancey County



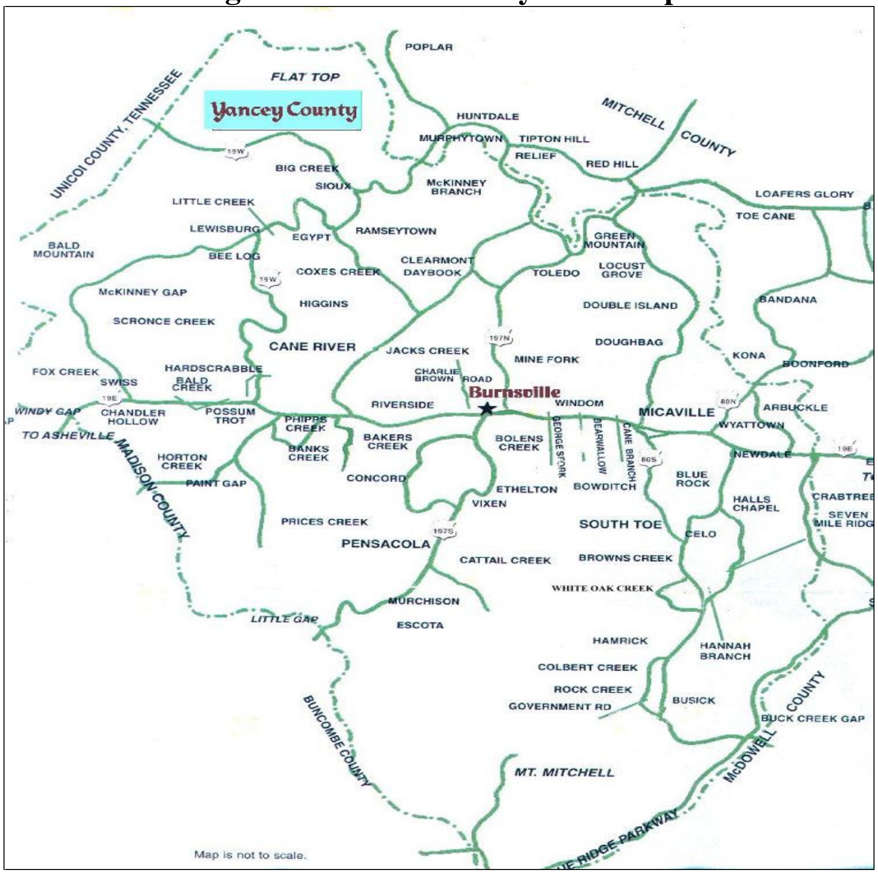
Source: NCDOT GIS Mapping Unit, 2002

1.2 Project Study Area

Yancey County is located in the mountains of western North Carolina and is bordered by Madison County on the west, Buncombe County on the southwest, McDowell County on the southeast, Mitchell County on the northeast, and Tennessee on the northwest (Figure 1). Most of the land use east and west of Burnsville is rural, with its major uses being for farmland and residential development. Almost all of the county's businesses and industries are within the city limits of Burnsville or nearby. A retirement community is developing in the area and business leaders are interested in improving the main street in Burnsville so that it is more attractive to tourists and retirees.

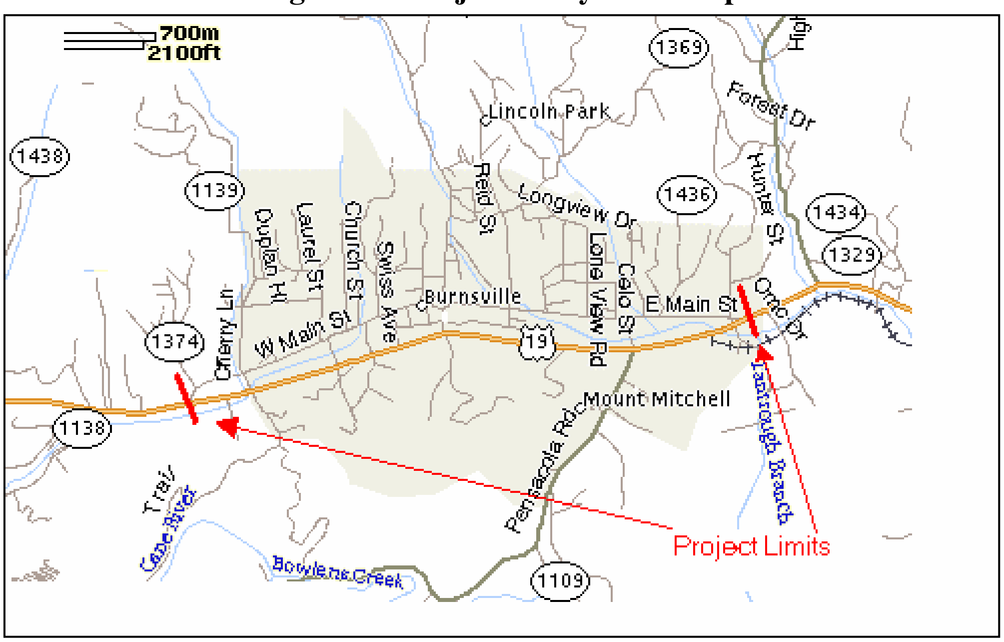
The Overall Study Area (OSA) is defined by the borders of Yancey County (Figure 2). This geographic area contains all of the roads and land parcels that determine the traffic levels within the Primary Study Area (PSA). The PSA is defined by the city limits of Burnsville (Figure 3). This study area includes all intersections and areas of special interest to the project.

Figure 2 – Overall Study Area Map



Source: Yancey County Chamber of Commerce, 2002.

Figure 3 – Project Study Area Map



Source: MapQuest.com, 2002.

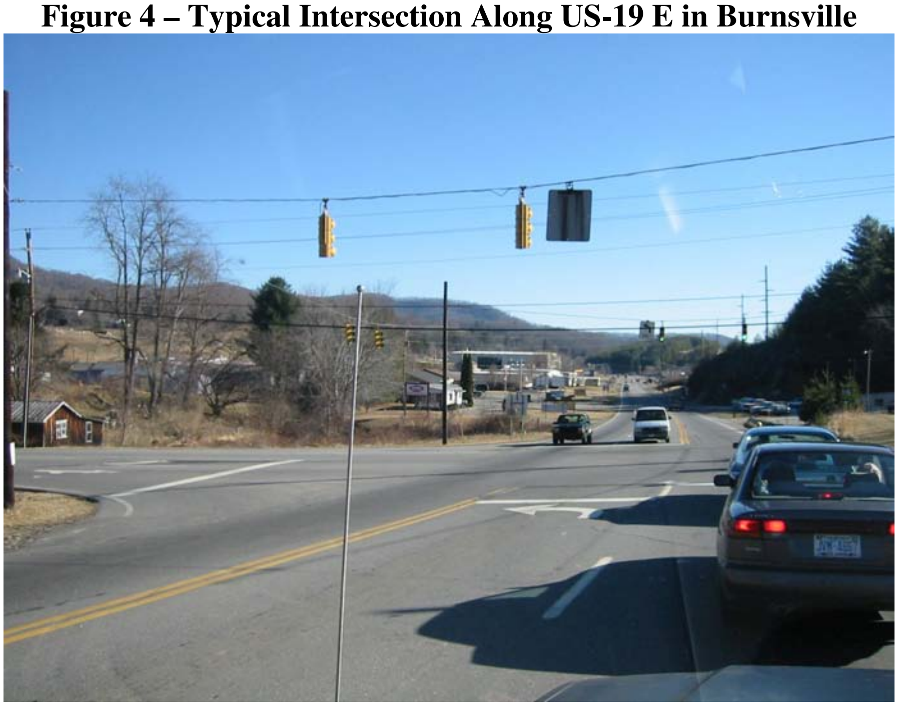
2.0 EXISTING CONDITIONS

2.1 Base Year Condition

Currently US-19E is a two-lane road (Figure 4) with a center turning lane through the Town of Burnsville. US-19E is the only east-west corridor through Yancey County. As a result it is the quickest and easiest route for commuters traveling to Burnsville and out of the county It carries the majority of Yancey County's traffic. With such a large volume of traffic traveling on a single, two-lane road, major congestion is experienced all along US-19E during peak hours of the day, and inside the city limits of Burnsville throughout the day.

Several field trips were made to the project area. The land use was found to be much different in the OSA than in the PSA. The rural OSA land uses include undeveloped woodlands, small farms, single-family homes, a mobile home park, schools, and churches. In the PSA the majority of the land use is commercial, including all town and county offices, a senior center, the county health department, and a Department of Social Services office. Within Burnsville the land is zoned C2, which allows retail uses and shopping centers, but requires setbacks and off-street parking.

Figure 4 – Typical Intersection Along US-19 E in Burnsville



2.2 Traffic Data Collection

The NCDOT Traffic Survey Unit provided historical ADT counts at three locations within the PSA (Appendix A). Counts were available for every year from 1995 through 2000 (Appendix B). The NCDOT Traffic Survey Unit also provided turning movement counts for 1997 for all major intersections in the study area along US-19E (Figure 5).

2.3 Adjustments to Base Year Data

Traffic in Burnsville does not experience seasonal fluctuation to the extent that other Western North Carolina counties do. No seasonal data is available and no adjustments were made.

2.4 Base Year Traffic Flow Maps

A 1997 base year traffic flow map was obtained from the NCDOT (Figure 5).

3.0 FUTURE YEAR FORECAST

3.1 Analysis Selection

The analysis used for this project was the Hand Method. The Hand Method contains three programs: Trend Analysis to analyze past data to find a trend in the traffic growth of an area, BTURNS to determine future turning movements, and Screenline Analysis to calculate diversion to parallel facilities. The Hand Method was selected because of the size of the study area and the relative simplicity of a widening project.

3.2 Expected Future Condition

While visiting Burnsville, several proposed developments were identified just outside of the city limits that could increase traffic through Burnsville. There are also sites inside of the city limits that could become commercial sites in the future. A new fast food restaurant is planning to move to Burnsville and a large industrial building is for sale within the city limits.

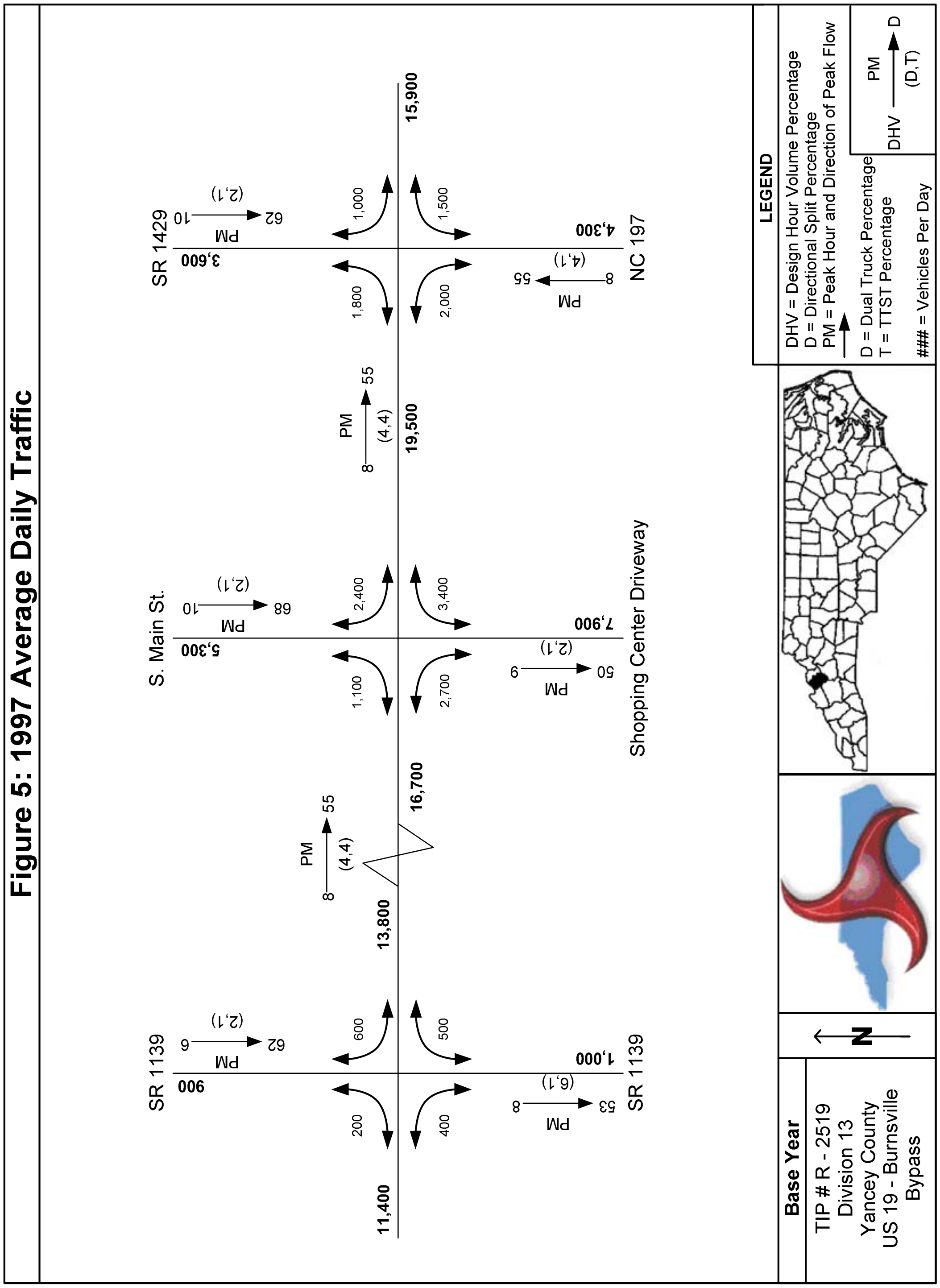
During the field investigations, local professionals, county commissioners and State Highway Patrol officers provided information. The NCDOT division engineer and his assistants helped to give insight about future projects that will be completed in the area, and how they might bring more traffic into the corridor. Additionally, Interstate 26 will soon be completed through Sam's Gap in Madison County. This Interstate is only a few miles away from the Burnsville study area and, once completed, could cause an increase to traffic through the area.

The county planner and the county manager were also helpful in giving information about future land use and development in, and around, the study area. This helped in accounting for the future growth of this unique area.

3.3 Adjustments to the Forecast

After discussing current trends and future plans with the local officials, several adjustments to the mathematical predictions were made. Using the trendline that best fit the historical data; a negative ADT was predicted for the future year (Appendix A of this forecast).

Figure 5 – Base Year Stick Diagram



Note: This figure is not in the preferred format. See Figure 6

This unrealistic long-term prediction results from extrapolating short term declining ADTs for recent years. However, according to local officials, the area is just experiencing a temporary decline in traffic due to closings of numerous textile, furniture, hosiery, and mechanical industries in the area. There are signs that other companies will replace those industries in the future. The county manager said many industries are interested in the study area as a location for their manufacturing plants. The new industry will increase jobs, and bring more people in to the area to live and work.

To accommodate the expected future population, more service-oriented work will also be needed, bringing further traffic into the area. There are also areas being considered for housing just outside of the Burnsville city limits. Local officials expect that the increase in attractive housing will be taken advantage of by retirees moving into the area and middle-aged professionals looking for summer homes, as other housing developments in the area have exhibited similar trends

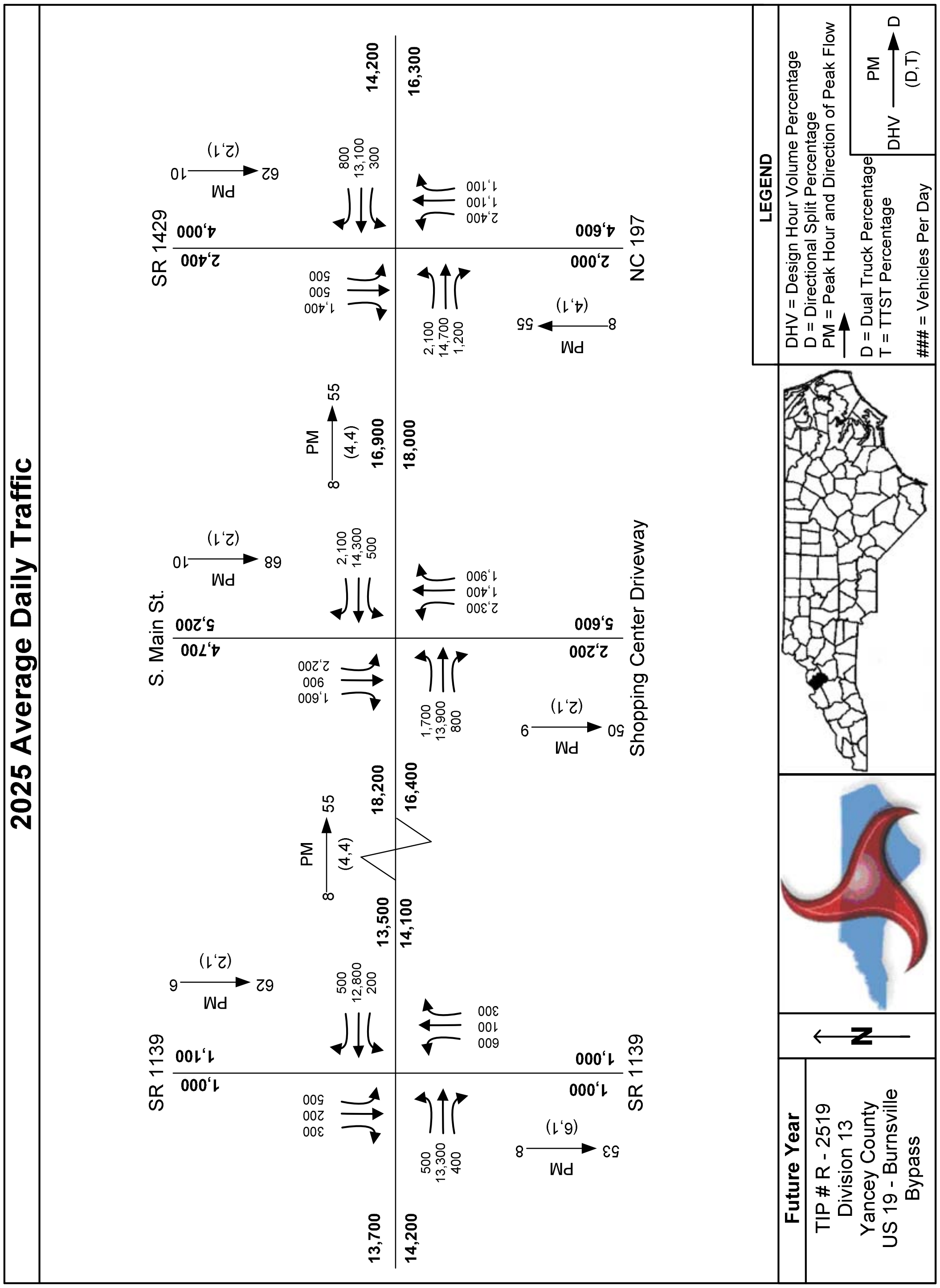
There has also been an increase in the number of commuters who live in or nearby Burnsville and commute to Asheville. Additionally, Interstate 26 will be completed in the near future and will most likely increase the traffic flow through Burnsville. The Interstate will become a major route to and from Asheville and the Tri-Cities in Tennessee. An interchange between US-19E and I-26 will be located just a few miles form Burnsville. When the four-lane project from the interchange through the Burnsville city limits is finished, more commercial and tourist traffic will travel through the Burnsville area.

Due to these factors, the projected negative ADTs are discounted. At each of the three count stations an exponential equation was used that fit the data and that produced higher ADTs in the year 2025 (Appendix B of this example).

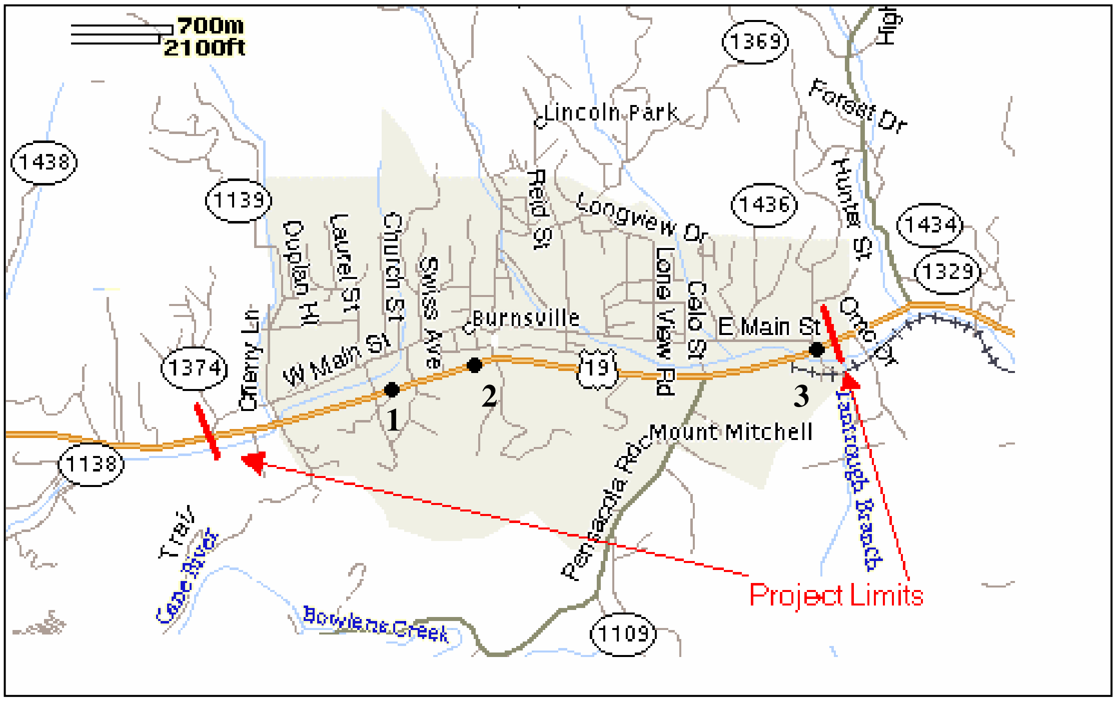
3.4 2025 Traffic Forecast

Based on the historical ADT counts and discussions with local officials, traffic is expected to grow at approximately 2.9% a year in the town of Burnsville. This growth percentage, based on engineering judgment, will cause traffic to double on US-19E over the next 23 years. Turning movements are expected to stay at the same percentages, barring any unforeseeable development outside of town. Finally, in the absence of information about specific developments, truck percentages and directional split are expected to remain the same. Future turning movements and ADTs in the study area are shown in Figure 6.

Figure 6 – Future Year Stick Diagram



Appendix A – ADT Count Station Locations



Source: MapQuest.com, 2002.

Appendix B – Trend Analysis Data

Trend Analysis Input Data

Adt Data for Traffic Count Location

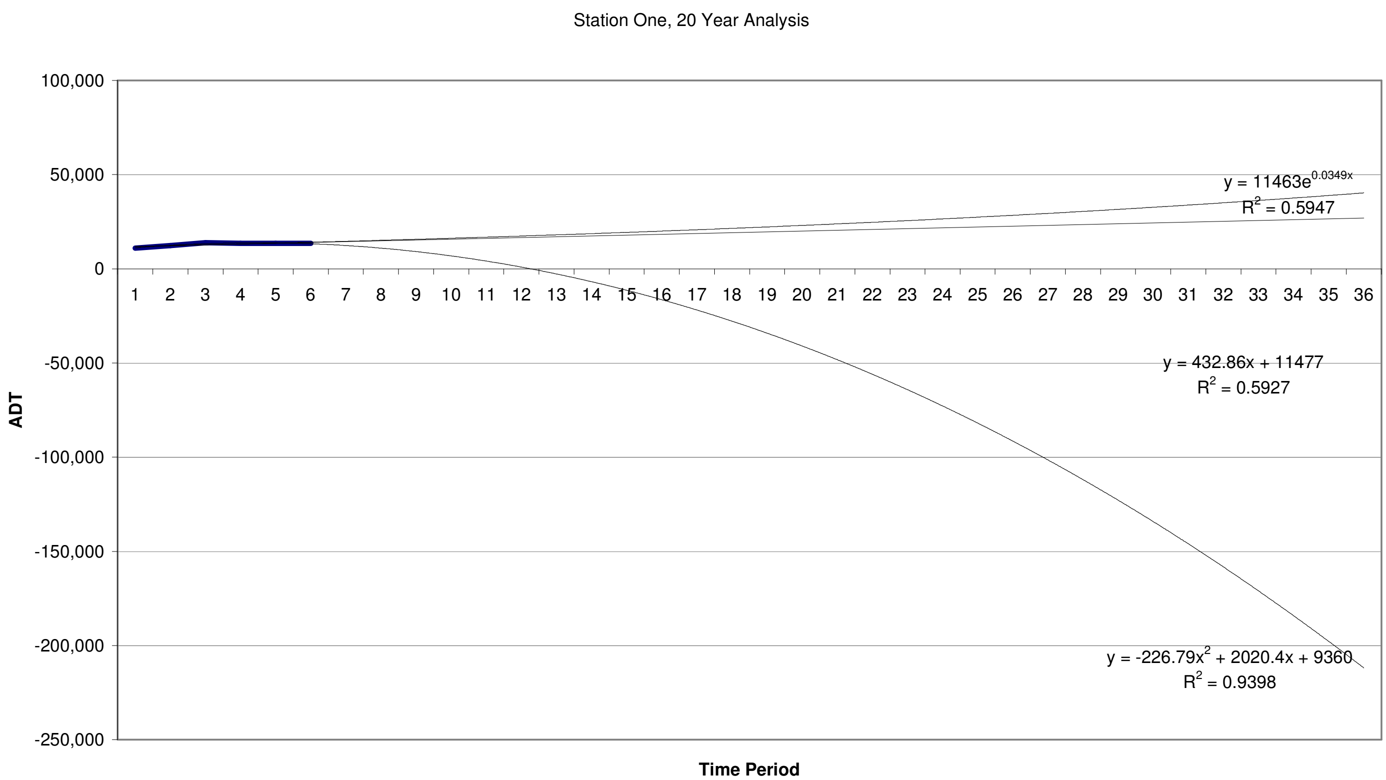
Dr. John Sto	Station Location Descriptions	
Yancey	Station 1	Between South Main Street and SR 1139
2/20/2002	Station 2	west of Main Street 100 meters
J. A. Bailey	Station 3	Between NC 197 and SR 1428

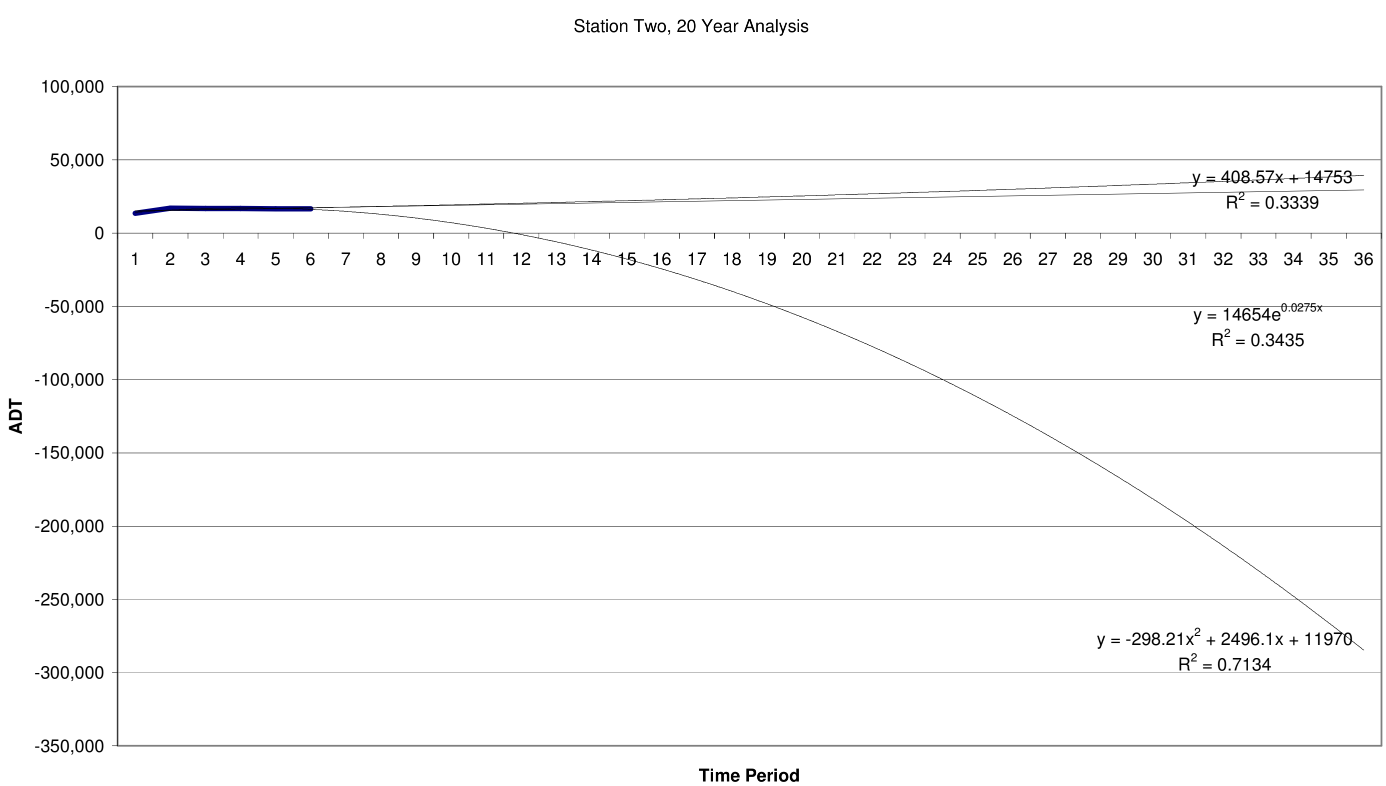
1. Enter adt counts for up to three stations

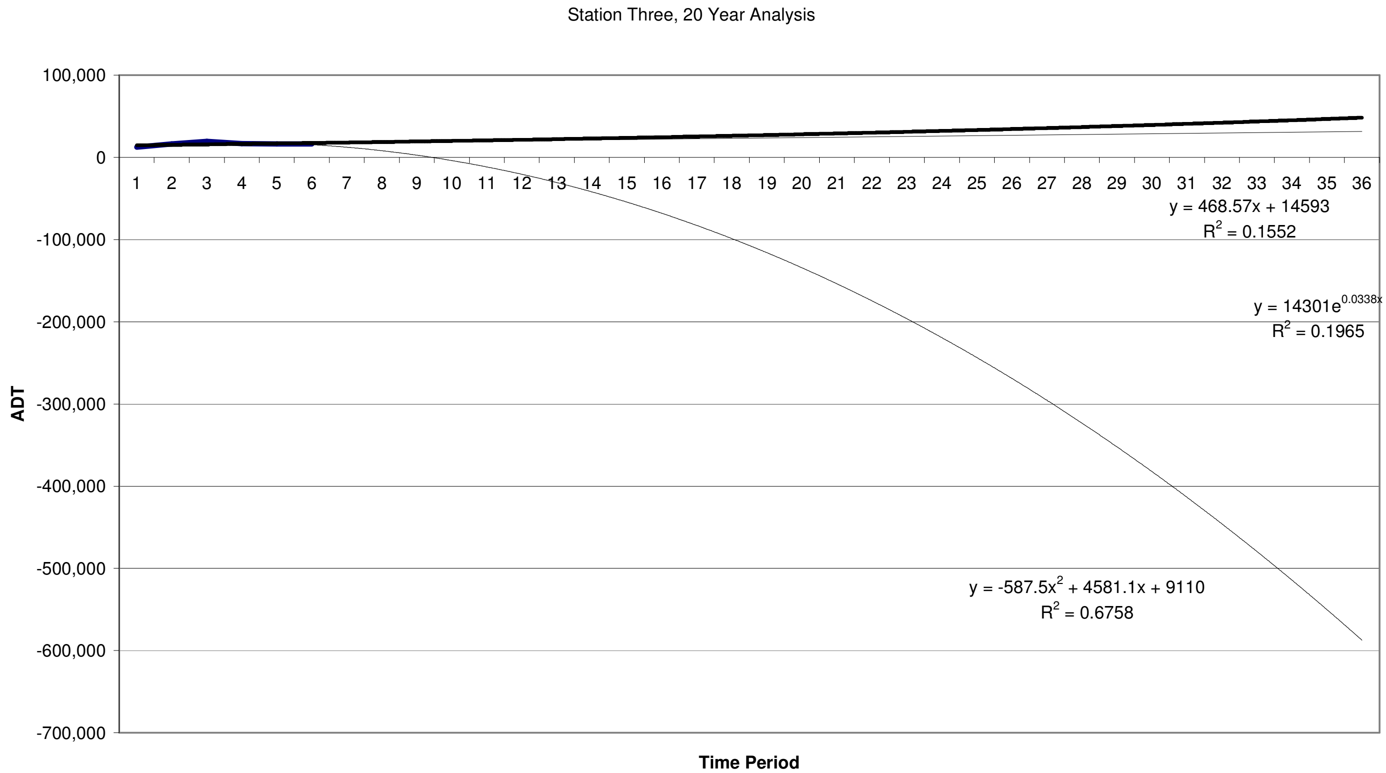
2. After data entry, go to "Begin Data Analysis"

Year	Station 1	Station 2	Station 3
1978			
1979			
1980			
1981			
1982			
1983			
1984			
1985			
1986			
1987			
1988			
1989			
1990			
1991			
1992			
1993			
1994			
1995	11,100	13,500	12,500
1996	12,400	17,000	16,200
1997	13,800	16,700	19,500
1998	13,650	16,700	16,600
1999	13,500	16,600	16,300
2000	13,500	16,600	16,300

Trend Analysis Output






Station Three, 20 Year Analysis
100,000
0
-100,000
-200,000
-300,000
-400,000
-500,000
-600,000
-700,000
ADT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
y = 468.57x + 14593
R2 = 0.1552
y = 14301e0.0338x
R2 = 0.1965
y = -587.5x2 + 4581.1x + 9110
R2 = 0.6758
Time Period

APPENDIX D: US 64 CASE STUDY

-Example-
-For Illustrative Purposes Only-

Traffic Forecast For Feasibility Study of Converting US 64 to an Expressway

Prepared For:

THE NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION
STATEWIDE PLANNING BRANCH

Prepared By:

North Carolina State University Civil Engineering Department

June 2002

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Appendices

1.0 INTRODUCTION

1.1 Project Description

The purpose of this forecast is to determine the future turning movements, ADTs and truck percentages on US-64 in western Wake County if the existing facility is converted to an expressway. This project extends from the US-64, US-1 split in the Town of Cary and extends to the Chatham county line. The base year for this project is 2002 for passenger cars, and 1996 for trucks, with a future year of 2025. This difference in base years is due to the lack of available truck traffic data. This project falls under the "Special" (S) category and will be performed using a synthesis of the Hand and TransCAD methods. Trucks will be forecasted using the growth factor method.

Figure 1: Location of Wake County

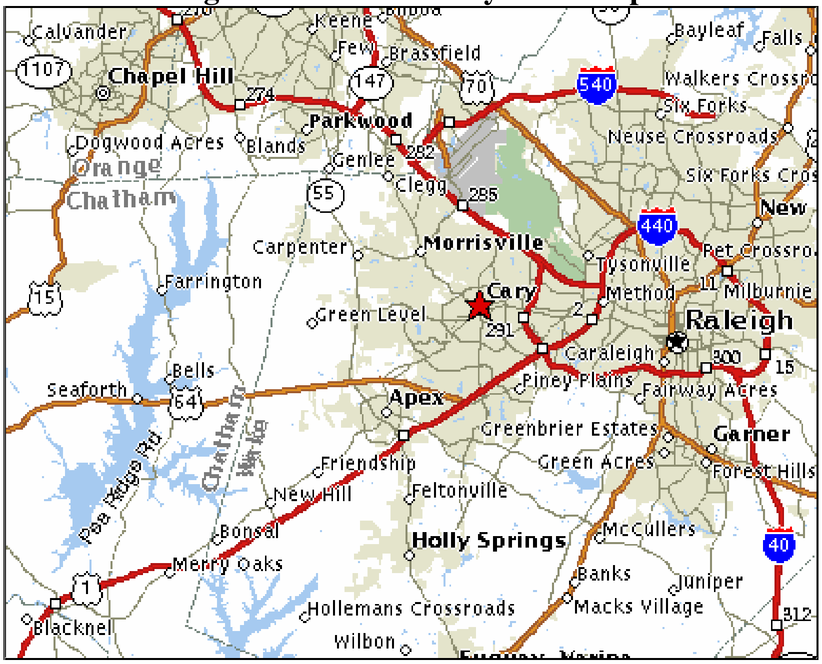
Source: NCDOT GIS Mapping Unit, 2002.

1.2 Study Area

Wake County is located in central North Carolina (Figure 1). Wake County is bordered by Chatham County on the west, Durham on the northwest, Granville on the north, Franklin on the northeast, Nash on the east, Johnston on the southeast, and Harnett on the south. It contains Raleigh, the capital of North Carolina, and several other smaller towns such as Cary, Knightdale, Wake Forest, and Fuquay-Varina. The county's land use is very diverse, ranging from dense urban, to rural farmland.

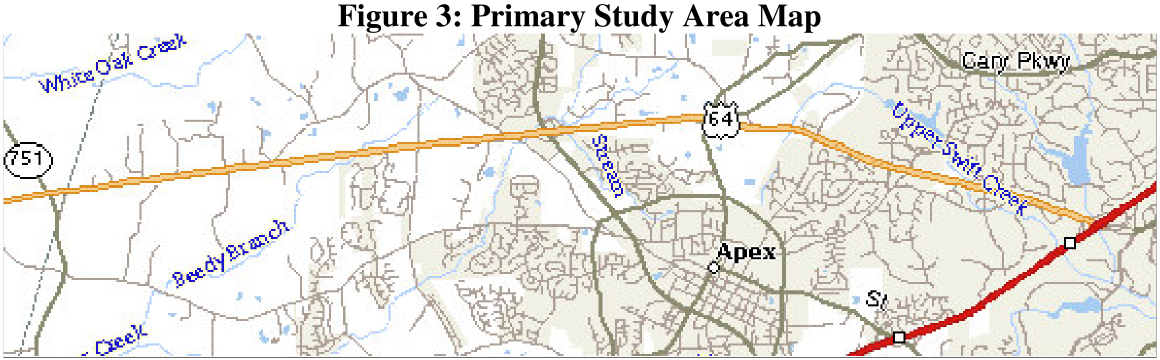
The Overall Study Area (OSA) is defined as western Wake County (Figure 2). The OSA contains all major developments and parallel facilities that affect traffic on US-64. The Primary Study Area (PSA), extends westward along US-64 from the US-64, US-1 split to the Wake county line (Figure 3). This area contains all properties adjacent to US-64 as well as surrounding residential and commercial developments.

Figure 2: Overall Study Area Map



Source: MapQuest.com, 2002.

Figure 3: Primary Study Area Map



Source: MapQuest.com, 2002.

2.0 EXISTING CONDITIONS

2.1 Base Year Condition

US-64 runs from Murphy to Manteo in North Carolina, serving as a major corridor in which to go from the coast to the mountains. Although US-64 is a longer route to Charlotte, it is becoming an increasingly attractive alternative to the slow moving traffic that occurs during the peak times of I-40. However, increased traffic on US-64 means the delay associated with the traffic signals and unregulated driveways is becoming more pronounced.

US-64 through the PSA is currently a four-lane section, with mainly at-grade intersections. Only the intersections with US-1, NC-55 and North Salem Street are grade separated. All others are stop sign or signal controlled. Additionally, in the western portion of the PSA there are numerous private residences and commercial properties that have direct access to US-64.

Land use varies throughout the PSA. Along the eastern part of the PSA in the Town of Cary the land use is primarily residential, commercial, and office. In this area, high-end residences occupy the land to the north of US-64 and various retail and commercial developments, including McGregor Village and the Cary Auto Park, occupy the land to the south. The land in this area is fairly built-out leaving little land available for further development. However, in the western portions of the PSA including the Town of Apex and beyond, much of the land is undeveloped. The portion that is developed is primarily residential with some commercial and industrial development.

2.2 Traffic Data Collection

The NCDOT Statewide Planning Branch provided turning movement counts for the majority of the major intersections in the PSA. Other turning movements were provided by local consulting firms and The Towns of Apex and Cary.

The NCDOT Statewide Planning Branch has been collecting ADT data as well as truck traffic data by truck type throughout North Carolina. The NCDOT branch collects data mechanically and manually. Mechanical counts use tube-type traffic counters with minimum 48-hour duration and one hour count intervals. Data is collected using 13-vehicle classification schemes recommended by FHWA. Manual counts are collected by observing vehicle types, and they are recorded manually on an electronic counting board. The collected data for US 64 are available from 1992 to 1996.

2.3 Base Year Traffic Flow Maps

A Base year traffic flow map (Figure 4) was constructed using the turning movement counts. Due to the differences in count dates and the need for continuity across the corridor, the counts had to be balanced, requiring minor adjustments to through volumes.

Figure 4a: Base Year Stick Diagram

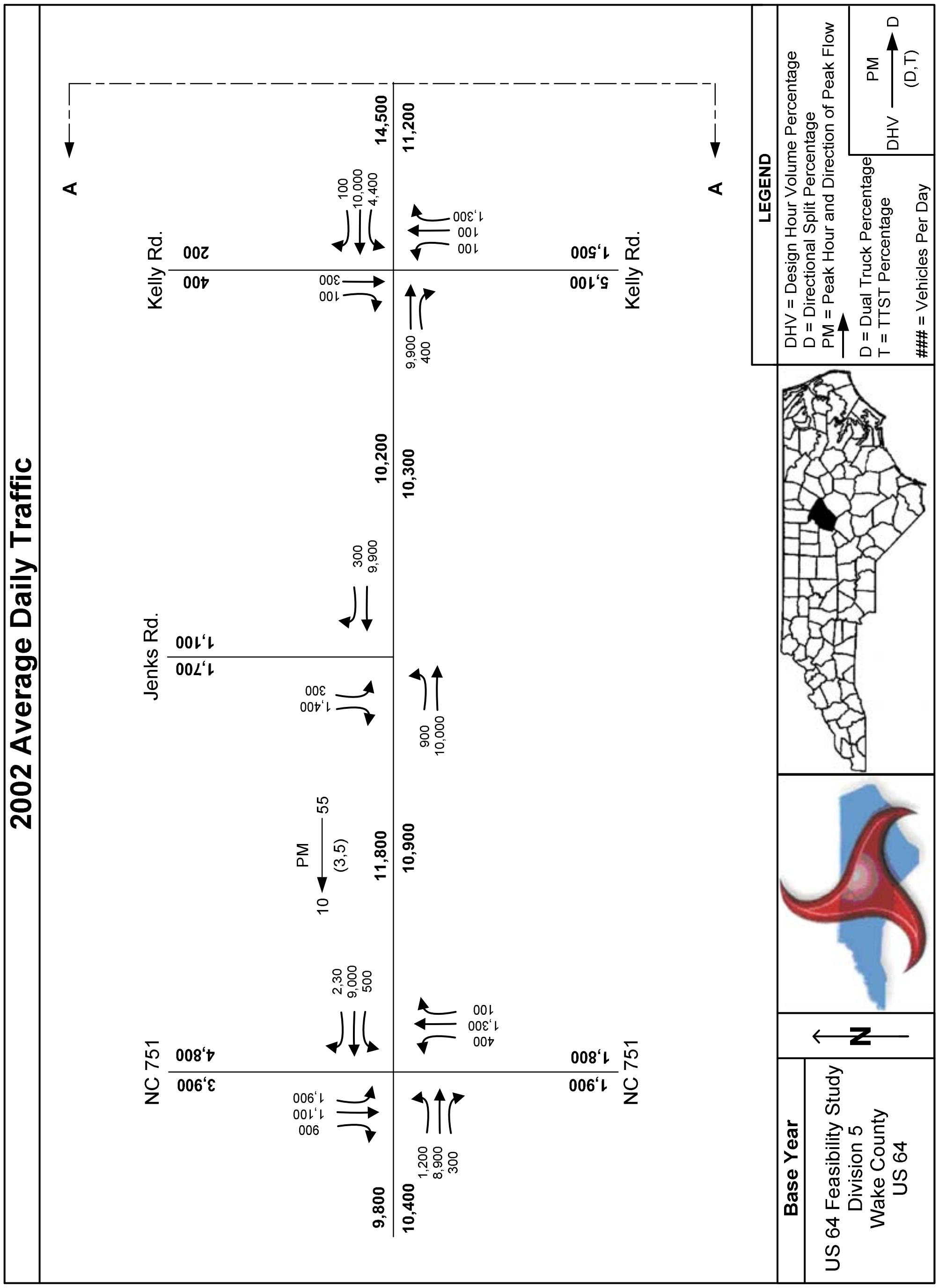
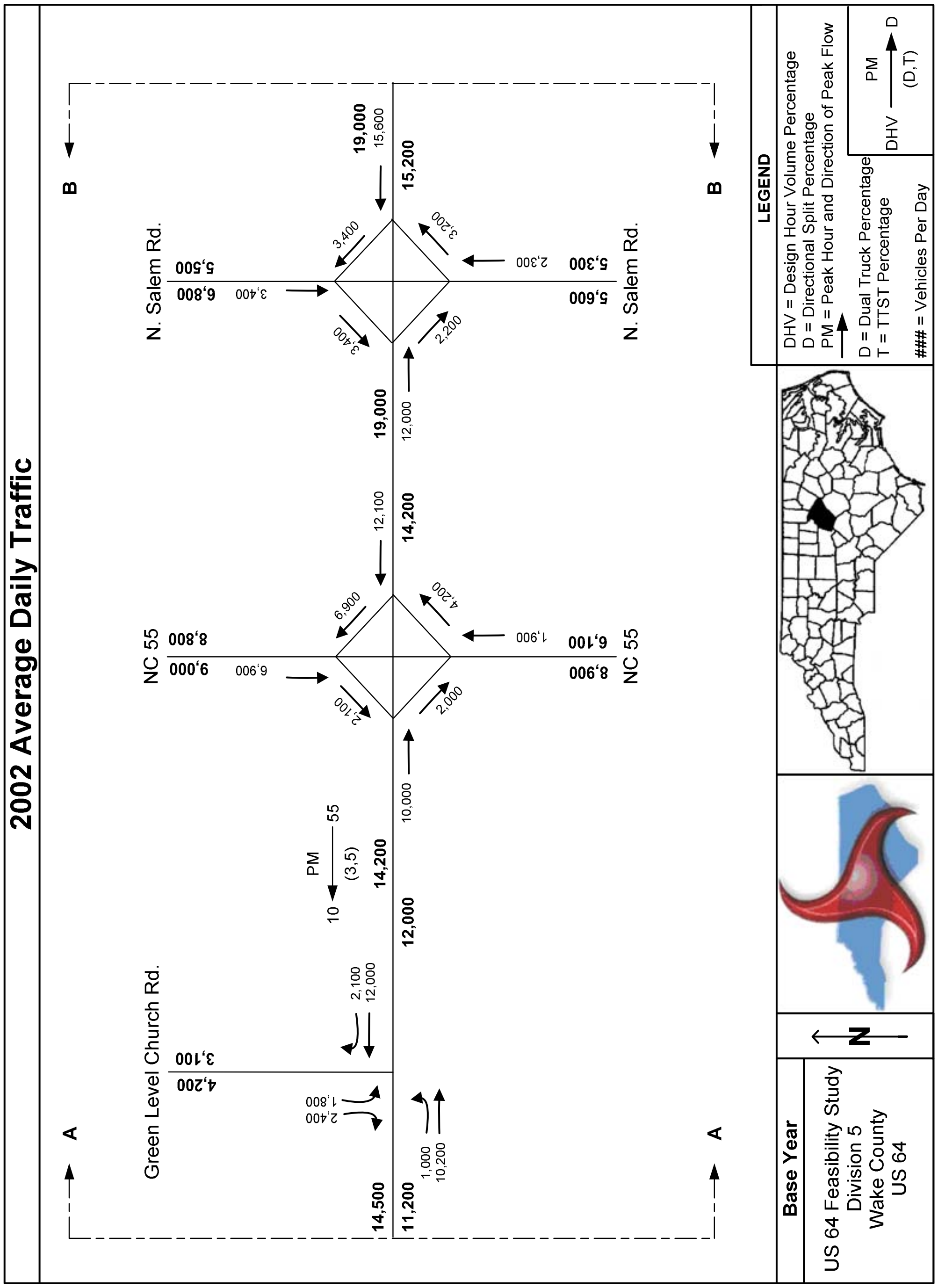


Figure 4b: Base Year Stick Diagram



Note: The NCDOT format of the quarter turning movements shown for the ramps obscure turning movements on the Y-line. The Y-line turning movements can only be determined from actual counts or from making assumptions.

Figure 4c: Base Year Stick Diagram

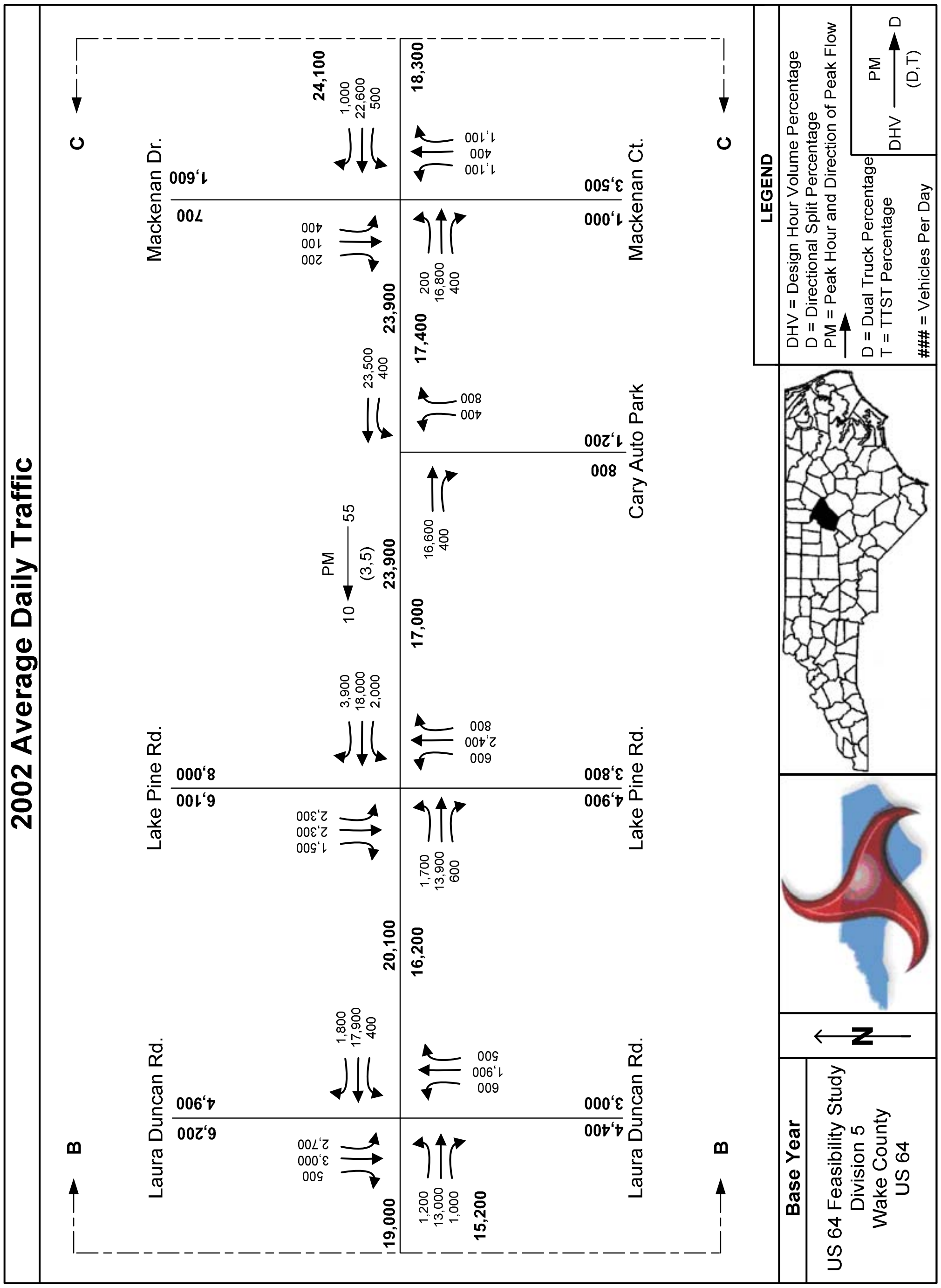
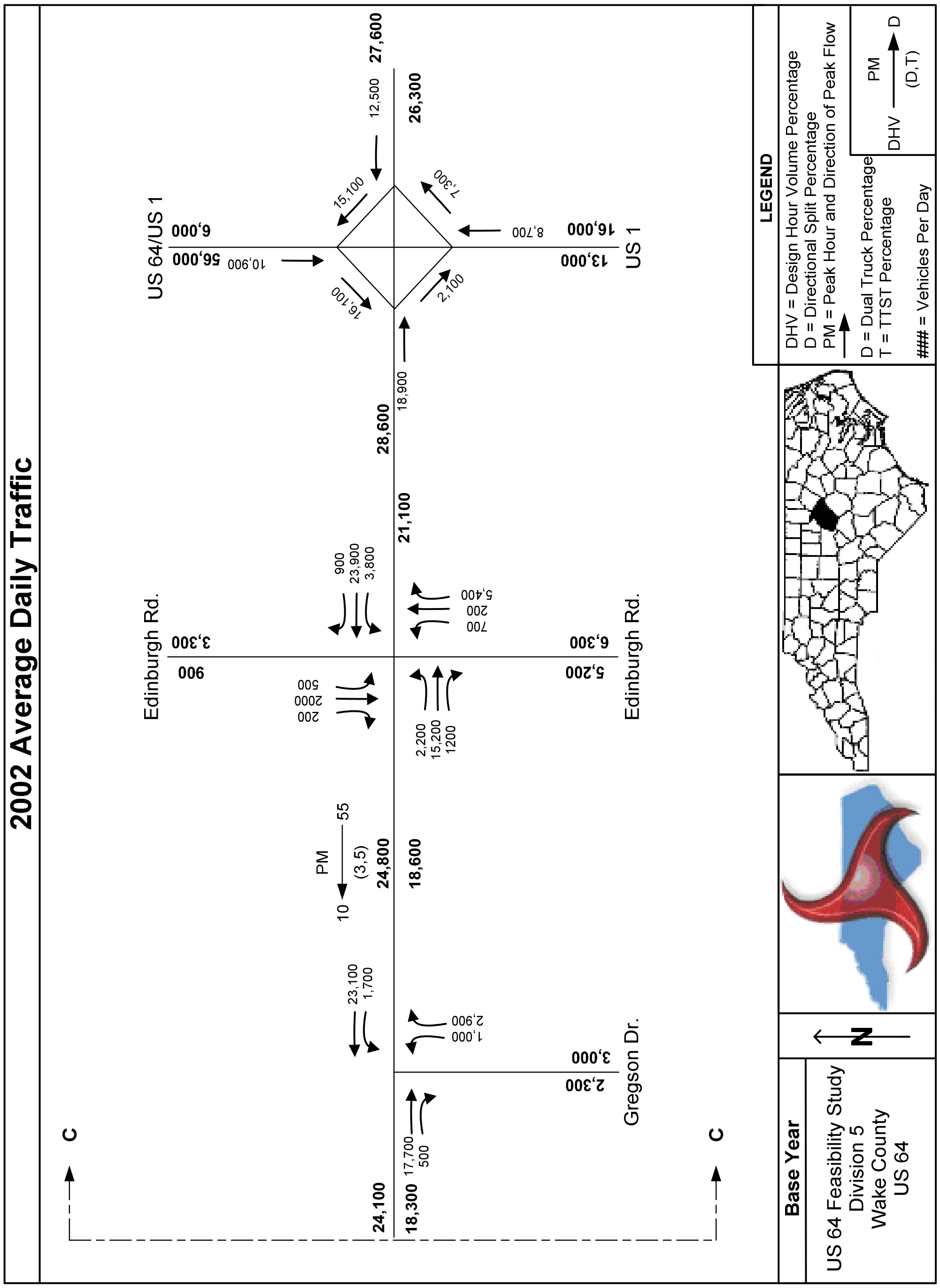


Figure 4d: Base Year Stick Diagram



Note: The NCDOT format of the quarter turning movements shown for the ramps obscure turning movements on the Y-line. The Y-line turning movements can only be determined from actual counts or from making assumptions.

3.0 FUTURE YEAR FORECAST

3.1 Analysis Selection

The future US-64 through the PSA is modeled in TranPlan as an expressway in the CAMPO Triangle Regional Model. Some intersections are at grade others are grade separated. This model contains accepted land use and roadway networks for the future year 2025. However, the Traffic Analysis Zones (TAZs) are very aggregate in this model, diminishing the accuracy of a forecast at the PSA level. A synthesis of both the Hand and TransCAD methods was therefore chosen to refine the 2025 ADTs and turning movements provided by the Triangle Regional Model. Such a forecast falls under the "Special" (S) category and will provide more detailed analysis of individual intersections within the PSA, due to the more detailed consideration of corridor development concepts as expressed by Apex and Cary planners. For truck traffic the growth factor method was chosen to grow truck traffic from the base year to 2025.

3.2 Expected Future Condition

Contact was made with the planning directors for the Towns of Cary and Apex to discuss future growth in the PSA. Future land use plans were obtained and the sections relevant to the PSA are shown in Appendix A. Growth around US-64 is expected to vary greatly, depending on location and available land. The sections of US-64 between the US-1, US-64 split and the Cary Auto Mall are expected to remain fairly stable. Only the addition of a few town home developments and perhaps a small hotel will be built because there is very little land in this section for further large scale development. However, along the US 64 corridor through Apex and beyond, there is a large amount of prime land available for commercial, industrial and residential development. For example, a large retail center, possibly the size of Cary's Crossroads mall, is planned for the south side of US-64 between NC 55 and I-540.

For this scenario, US-64 is modeled by NCDOT Statewide Planning as a six lane expressway section. This reflects NCDOT's goal of improving service on NCDOT by improving US-64 and limiting access. Furthermore, six lanes appear to be warranted to carry the traffic that is forecast. If the model showed that a six-lane freeway would not effectively carry the future traffic, a freeway design could be tested. The grade-separated, higher speed freeway option could potentially reduce congestion while attracting traffic from the I 85/I 40 corridor.

The network and the expected growth and future land use of the region are contained within the Triangle Regional Model. The Capital Area Metropolitan Planning Organization has approved all parameters of this model. For this reason, the 2025 forecast will begin with the Triangle Regional Model traffic estimates on US 64. Then the estimates based on aggregate TAZ land use information will be refined as discussed below.

3.3 Vehicle Forecasting Process

1. A growth factor (GF) was determined using the 2001 counts and the ADTs from the CAMPO TranPlan Triangle Regional Model. The function for determining this growth factor is:

   $ADT_{2025\ i} = ADT_{2001}\ (1 + GF_i)^n$ where i = section, n = number of years = (2025 – 2001)

   The ADT_{2001} was determined by summing the 15-minute counts provided by NCDOT, local consulting firms and the Towns of Cary and Apex.

   Growth factors were determined at several spots along the corridor using the above equation. The growth factor was higher in developing areas, such as around I-540, and lower in more developed areas, such as McGregor Downs. However, the growth factor obtained in each instance was close to the 3% growth anticipated by NCDOT for the region.

2. The future turning movements and ADTs were estimated by applying the growth factor for the section to the base year turning movements and ADTs.

3. Because the growth factors were different along the corridor, the future turning movements were not balanced. The turning movements were smoothed considering the detailed land use and growth predictions that were received in the meetings with the planning heads of Cary and Apex.

3.4 Truck Percentage Forecasting

The following truck forecasting method assumes that NCDOT truck counts are annualized to common Annual Average Daily Truck Traffic values. Actual data, however, is not, and the apparent change in truck traffic data may be due more to counts at different times of the year than to real growth. The method, however, is valid and demonstrates what can be done with good data.

There is only one data collection station in the case study US 64 corridor. During the five-year data collection period, there was lane-adding construction, which caused a negative growth rate. To obtain an unbiased growth factor for the subject link, the data of collection stations in adjacent counties were used. Data from eight stations provide an overall truck growth factor of 3.83% (Appendix A, Table 1). By class the growth factors were 4.22 % for Dual (FHWA class 4 to 7) and 3.72 % for TTST (FHWA class 8 to 13). The averaged 1996 base year truck volumes are 753 trucks/day and 1294 trucks/day for Dual and TTST respectively. It is interesting to note from Table 1 that truck traffic is not measured yearly and that truck traffic percentages are assumed constant at all but one station. Since truck traffic is the primary factor in pavement design and has significant impacts on highway capacity, the estimates should be realistic.

Based on the growth factor and base year truck volume, the future truck traffic for US 64 by type for the forecast year 2025 are:

$$Dual_{2025} = Dual_{1996}(1 + AGF)^{(2025-1996)} = 753(1 + 0.0422)^{29} = 2497 \text{ Dual/day}$$

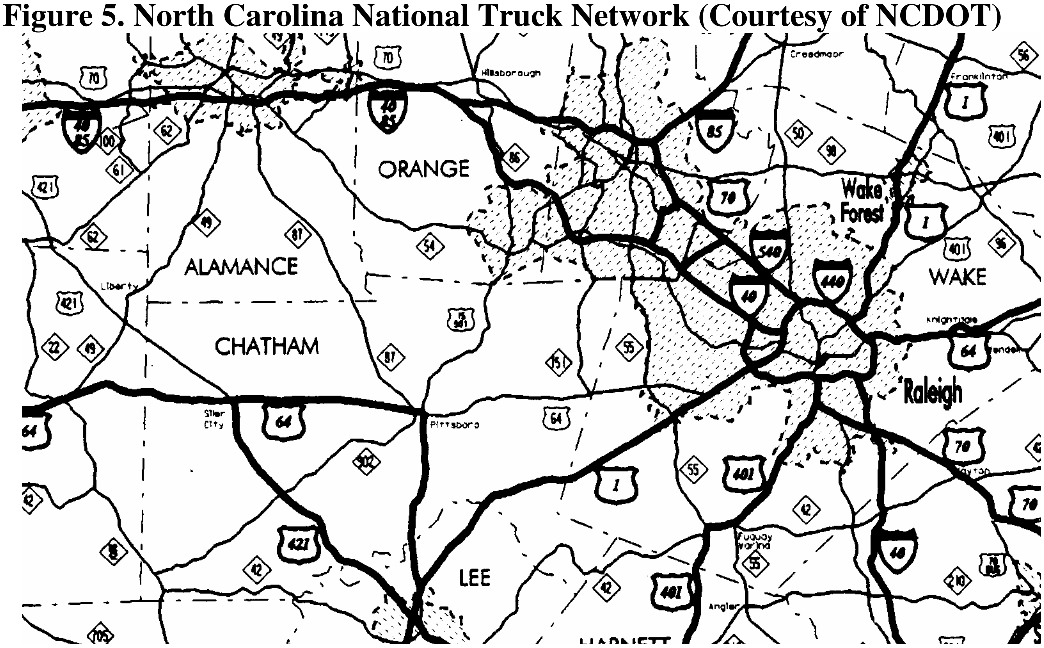
$$TTST_{2025} = TTST_{1996}(1 + AGF)^{(2025-1996)} = 1294(1 + 0.0372)^{29} = 3732 \text{ TTST/day}$$

Besides forecasting truck traffic growth, route diversion of trucks from slower more congested highways to improved routes should be considered by the forecaster. This may be done automatically with an urban regional model which contains major truck routes. But for rural projects outside regional models require special attention. Ideally an interregional model, at least for truck traffic could be built. Otherwise, simplified estimating procedures should be applied.

Route diversion analysis requires the identification of competing routes. Route selection involves many factors such as travel time, service frequency, reliability, safety and transport cost. At this point, information about these factors is limited. Therefore, truck volume to capacity ratio of each link is used as a simplified method for route diversion. Truck carriers particularly may have large fixed investments in certain routes; therefore, truck route diversion is not as likely to occur as automobiles. However, a new facility attracts truck carriers and shippers and enhances the possibility of truck traffic migration from competing routes if the travel time and other factors favor the new facility.

To estimate regional route diversion, interstate I-85/40 is selected as a competing link for US 64. Bold lines in Figure 5 show the North Carolina national truck network near US 64.

Figure 5. North Carolina National Truck Network (Courtesy of NCDOT)



The screenline spreadsheet method can be used to show truck diversion to the new route when there are three or more parallel routes. Here, I-85/40 is the only alternative route through the area. In lieu of the screenline procedure, a simplified approach will be used based on volume to capacity (v/c) ratios.

The main idea of the method is that some amount of truck volume moves from higher v/c ratio link to the link with lower v/c ratio. The following equation shows the main idea of the proposed method.

$$\frac{v_L + x}{c_L} = \frac{v_H - x}{c_H}$$

where, x = transferring truck volume from high v/c ratio link to low v/c ratio link
v_L = adjusted volume in lower v/c ratio link
v_H = adjusted volume in higher v/c ratio link
c_L = capacity of lower v/c ratio link
c_H = capacity of higher v/c ratio link

From the above equation:

$$x = \frac{v_H c_L - v_L c_H}{c_H + c_L}$$

This equation shows the diverted truck volume from higher v/c ratio link to lower v/c ratio link. The base year 1996 truck volumes of the competing route I-85/40 average 3600 dual truck/day and 6315 TTST/day and 0.9 % of growth factor was obtained (Appendix A, Table 2). With these values the target year 2025 forecast truck volumes are 4667 dual truck/day and 8188 TTST/day. By year 2025, US 64 may become a six-lane highway while I-85/40 is an eight-lane freeway. The capacity of each type of facility can be approximated using the NCDOT Facility Capacity table at LOS “D”. According to the table, the capacity of US 64 is approximately 75,700 veh/day and I-85/40 is approximately 108,000 veh/day. The simplified route diversion method can be applied to the data. The target year truck volumes are 6,229 and 12,855 trucks/day on US 64 and I-85/40, respectively. Based on the v/c ratio, 0.08 for US 64 and 0.12 for I-85/40, the diverted truck volume can be calculated as follows.

$$x = \frac{v_H c_L - v_L c_H}{c_H + c_L} = \frac{12855 \times 75700 - 6229 \times 108000}{108000 + 75700} = 1{,}635 \text{ trucks/day}$$

When 1,635 trucks are diverted from higher v/c ratio route (I-85/40) to lower v/c ratio route (US 64), the v/c ratios are equalized. The final assigned truck volumes are 7,894 trucks/day on US 64 and 11,220 trucks on I-85/40. Table 1 shows predicted target year truck volume, diverted truck volume and final assigned truck volumes on each route.

This simple example assumes the same average volumes throughout the Durham County I85/40 corridor and, likewise, in Wake County, rather that calculating segment volumes.

A complete analysis would consider more segments. Better yet, a regional truck model should be used.

Table 1. Forecasted truck volume in target year 2025.

Link	US 64	I-85/40
Estimated truck volume (trucks/day)	6229	12855
Estimated capacity (veh/day)	75700	108000
v/c ratio	0.08	0.12
Diverted truck volume	1635	
Final assigned truck volume (trucks/day)	7894	11220
v/c ratio after route diversion	0.10	0.10

3.5 Traffic Forecast for 2025

This example uses a regional model to provide a more detailed look at traffic along a corridor. It also considers land use on a finer level. As regional modelers begin to take advantage of parcel level data, this method will be needed less often. However, in the interim, this method helps evaluate an area that is too large for the hand method approach, but is too small to be adequately examined by an aggregate regional model.

The mainline volumes for US 64 provided by this approach are very similar to those output by the Triangle Regional Model (Figure 6). This reasonableness check should be performed whenever this method is used. By growing the existing turning movements using growth factors determined by the regional model, and smoothing the results considering future land use, the through volumes on major links should be very similar to those of the regional model, while turning movements, if provided by the regional model, may vary greatly. Using the regional model may increase the validity of the project-level traffic forecast by its evaluation of the traffic diversion and changes in land use on a regional scale. On the same note, the detailed data used in a project-level traffic forecast may enrich a forecast based solely on a regional model, by refining turning movements and considering local land use. However, any assumptions made in the development of the regional model may affect the project-level traffic forecast and should be considered by the forecaster when performing and documenting the forecast.

Figure 6a: Future Year Stick Diagram

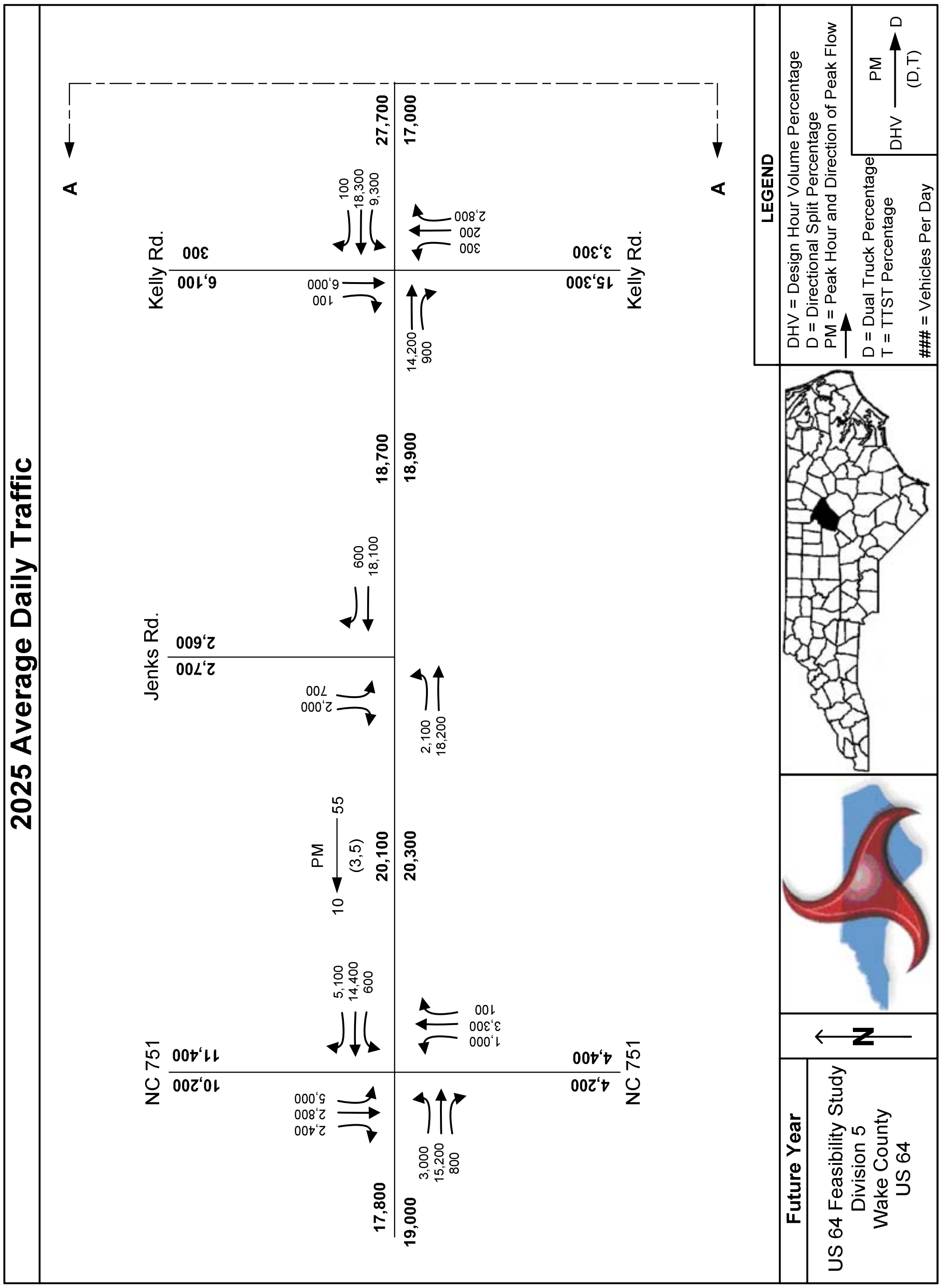
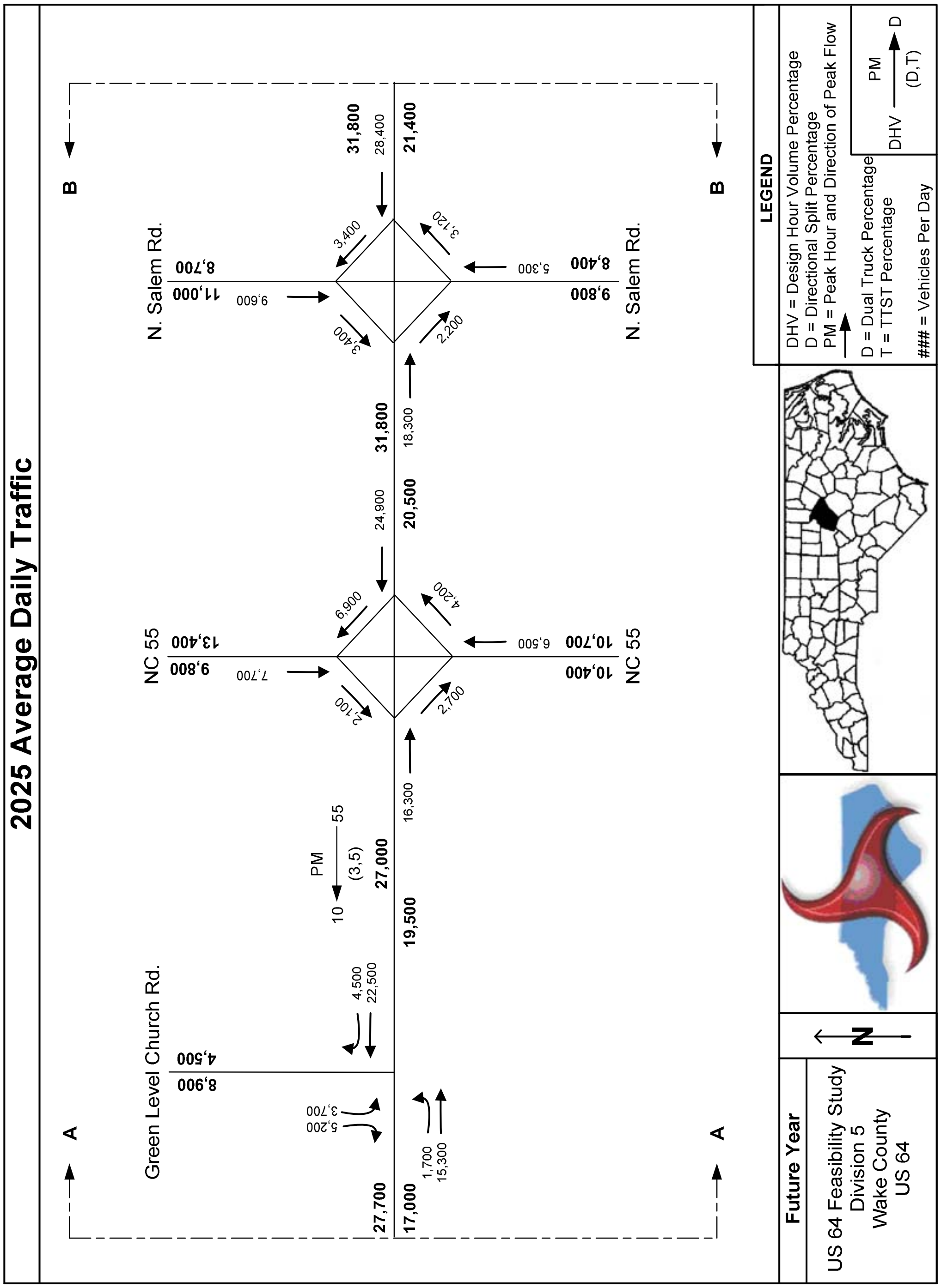


Figure 6b: Future Year Stick Diagram



Note: The NCDOT format of the quarter turning movements shown for the ramps obscure turning movements on the Y-line. The Y-line turning movements can only be determined from actual counts or from making assumptions.

Figure 6c: Future Year Stick Diagram

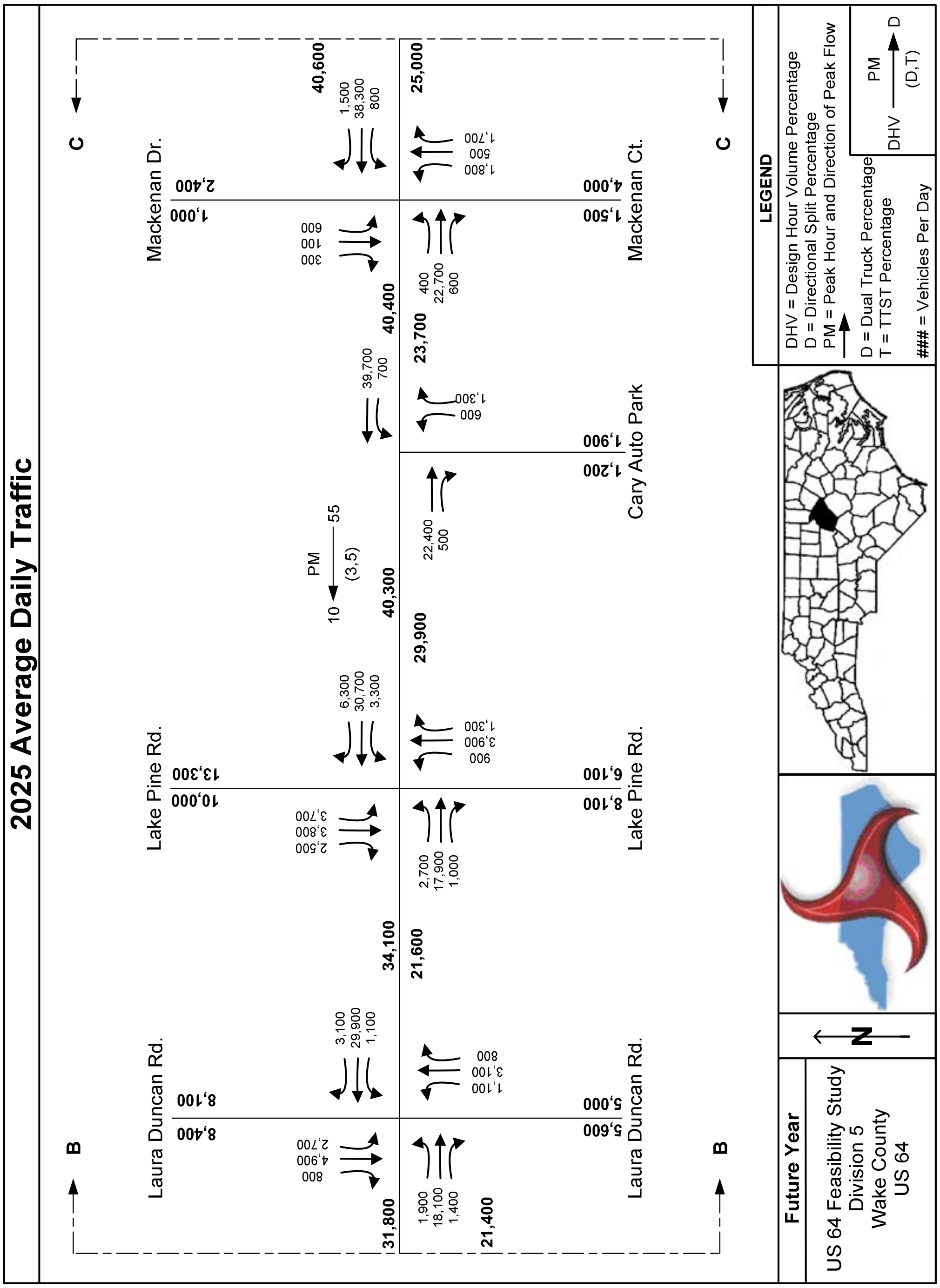
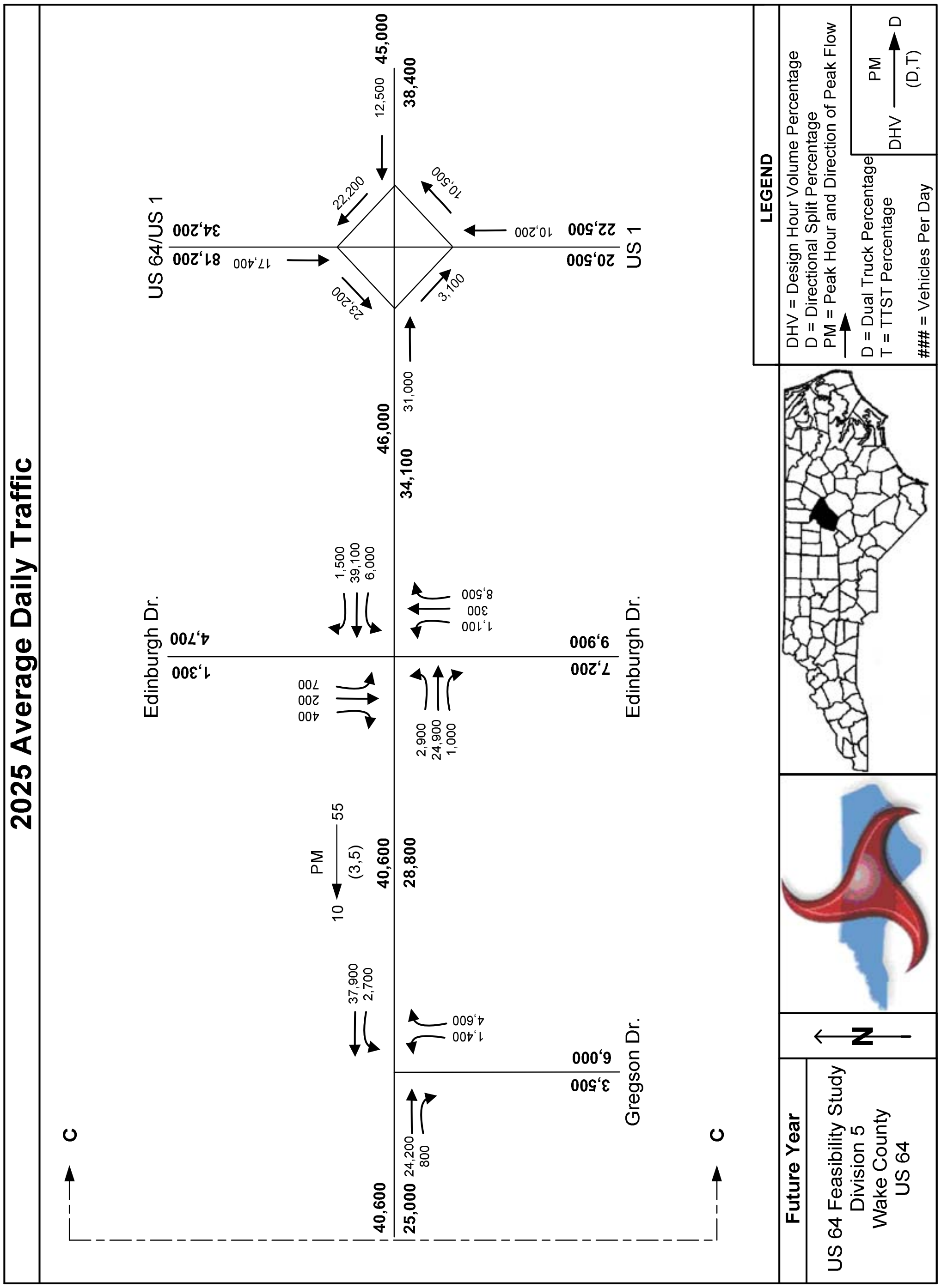


Figure 6d: Future Year Stick Diagram



Note: The NCDOT format of the quarter turning movements shown for the ramps obscure turning movements on the Y-line. The Y-line turning movements can only be determined from actual counts or from making assumptions.

Appendix A – Truck Volume Data and Growth Factor

Table 1. US 64 truck volume data and growth factor

County	Station Number	Year	Adt	Dual volume	TTST volume	Total Truck Volume	Yearly Growth Factor Dual	Yearly Growth Factor TTST	Yearly Growth Factor Truck Total	Station Avg. GF Truck	Station Avg. GF Dual	Station Avg. GF TTST	County Avg. GF Truck	County Avg. GF Dual	County Avg. GF TTST
		92	5800	321	681	1002									
		93	6300	349	740	1089	8.62%	8.62%	8.62%						
EDGECOMBE	310	94	6300	349	740	1089	0.00%	0.00%	0.00%	5.03%	5.03%	5.03%			
		95	7200	398	846	1244	14.29%	14.29%	14.29%						
		96	7000	387	822	1210	-2.78%	-2.78%	-2.78%				6.71%	6.71%	6.71%
		92	9900	252	595	847									
		93	10000	254	601	855	1.01%	1.01%	1.01%						
EDGECOMBE	311	94	10300	262	619	881	3.00%	3.00%	3.00%	8.38%	8.38%	8.38%			
		95	11000	280	661	941	6.80%	6.80%	6.80%						
		96	13500	343	812	1155	22.73%	22.73%	22.73%						
		92	13200	604	1741	2345									
		93	12700	582	1675	2257	-3.79%	-3.79%	-3.79%						
NASH	212	94	13900	636	1833	2470	9.45%	9.45%	9.45%	0.67%	0.67%	0.67%			
		95	14800	678	1952	2630	6.47%	6.47%	6.47%						
		96	13400	614	1767	2381	-9.46%	-9.46%	-9.46%						
		92	15600	528	1886	2414									
		93	13900	505	1461	1966	-4.40%	-22.55%	-18.58%				3.12%	4.31%	2.79%
NASH	316	94	14700	534	1545	2079	5.76%	5.76%	5.76%	2.00%	5.54%	1.01%			
		95	15700	570	1650	2220	6.80%	6.80%	6.80%						
		96	17900	650	1881	2531	14.01%	14.01%	14.01%						
		94	23200	819	1736	2555									
NASH	2077	95	26400	932	1976	2908	13.79%	13.79%	13.79%	6.71%	6.71%	6.71%			
		96	26300	929	1968	2897	-0.38%	-0.38%	-0.38%						
		92	8300	410	712	1122									
		93	8200	405	703	1109	-1.20%	-1.20%	-1.20%						
WAKE	25	94	8200	405	703	1109	0.00%	0.00%	0.00%	-1.54%	-1.54%	-1.54%			
		95	8000	395	686	1082	-2.44%	-2.44%	-2.44%						
		96	7800	385	669	1054	-2.50%	-2.50%	-2.50%						
		92	72000	1824	480	2303									
		93	70200	1778	468	2246	-2.50%	-2.50%	-2.50%						
WAKE	232	93	70200	1778	468	2246	0.00%	0.00%	0.00%	-2.88%	-2.88%	-2.88%	1.66%	1.66%	1.66%
		95	63100	1598	420	2019	-10.11%	-10.11%	-10.11%						
		96	63800	1616	425	2041	1.11%	1.11%	1.11%						
		92	35200	782	1428	2211									
		93	34700	771	1408	2179	-1.42%	-1.42%	-1.42%						
WAKE	340	94	42550	945	1727	2672	22.62%	22.62%	22.62%	9.38%	9.38%	9.38%			
		95	42000	933	1704	2638	-1.29%	-1.29%	-1.29%						
		96	49400	1098	2005	3102	17.62%	17.62%	17.62%						
US 64 Average Growth Factor													3.83%	4.22%	3.72%

Table 2. I – 85/40 truck volume data and growth factor

County	Station Number	Year	Adt	Dual volume	TTST volume	Total Truck Volume	Yearly Growth Factor			Station Avg. GF			County Avg. GF		
							Dual	TTST	Truck Total	Truck	Dual	TTST	Truck	Dual	TTST
		92	46000	2757	8443	11200									
		93	37300	2236	6846	9082	-18.91%	-18.91%	-18.91%						
DURHAM	235	94	37700	2260	6919	9179	1.07%	1.07%	1.07%	-7.47%	-7.47%	-7.47%			
		95	30700	1840	5635	7475	-18.57%	-18.57%	-18.57%						
		96	32700	1960	6002	7962	6.51%	6.51%	6.51%						
		90	53800	3229	4733	7961									
		90	56800	3409	4997	8405	5.58%	5.58%	5.58%						
DURHAM	238	94	66500	3991	5850	9841	17.08%	17.08%	17.08%	6.57%	6.57%	6.57%			
		95	66000	3961	5806	9767	-0.75%	-0.75%	-0.75%						
		96	68900	4135	6061	10196	4.39%	4.39%	4.39%						
		92	31500	2131	6139	8270									
		93	26300	1779	5126	6905	-16.51%	-16.51%	-16.51%						
DURHAM	239	94	28400	1921	5535	7456	7.98%	7.98%	7.98%	-1.07%	-1.07%	-1.07%			
		95	28200	1908	5496	7404	-0.70%	-0.70%	-0.70%						
		96	29600	2002	5769	7771	4.96%	4.96%	4.96%				0.90%	0.90%	0.90%
		92	73900	4771	9096	13867									
		93	69700	4500	8579	13079	-5.68%	-5.68%	-5.68%						
DURHAM	241	94	76400	4932	9404	14336	9.61%	9.61%	9.61%	1.99%	1.99%	1.99%			
		95	78200	5049	9626	14674	2.36%	2.36%	2.36%						
		96	79500	5133	9786	14918	1.66%	1.66%	1.66%						
		92	57100	3359	6478	9837									
		93	54500	3206	6183	9389	-4.55%	-4.55%	-4.55%						
DURHAM	242	94	59800	3518	6784	10302	9.72%	9.72%	9.72%	2.83%	2.83%	2.83%			
		95	60400	3553	6852	10406	1.00%	1.00%	1.00%						
		96	63500	3736	7204	10940	5.13%	5.13%	5.13%						
		92	57800	4249	2814	7064									
		93	53300	3919	2595	6514	-7.79%	-7.79%	-7.79%						
DURHAM	366	94	61800	4544	3009	7553	15.95%	15.95%	15.95%	2.55%	2.55%	2.55%			
		95	60400	4441	2941	7381	-2.27%	-2.27%	-2.27%						
		96	63000	4632	3067	7699	4.30%	4.30%	4.30%						
I - 85/40 AVERAGE GROWTH FACTOR													0.90%	0.90%	0.90%

APPENDIX E: US 15-501 CASE STUDY

–Example–
–For Illustrative Purposes Only–

Traffic Forecast For TIP Project R-2628:

A Proposed 15-501 Bypass Around Pittsboro, NC

Prepared For:

THE NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION
STATEWIDE PLANNING BRANCH

Prepared By:

North Carolina State University Department of Civil Engineering

June 2002

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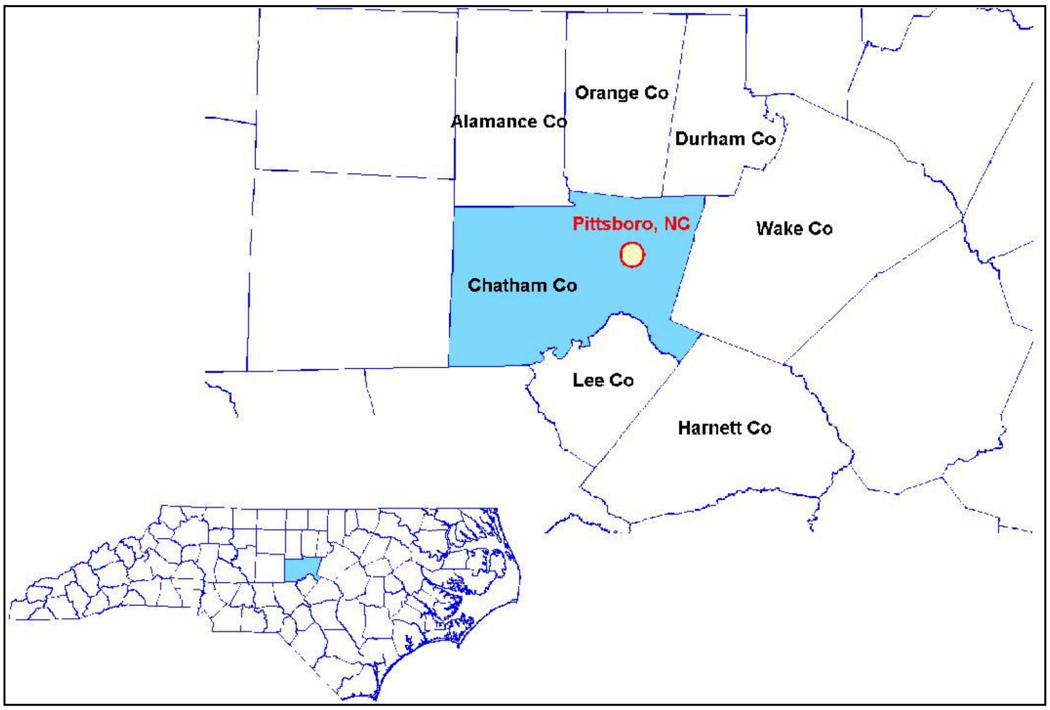
Appendices

1.0 INTRODUCTION

1.1 Project Description

Project R-2628 is a proposed bypass of US 15-501 around Pittsboro, NC in Chatham County (Figure 1). The proposed north-south US 15-501 facility would be a five-mile section of four-lane divided freeway from NC 87 to the US 64 bypass. Traffic projections were developed for three alternatives: a no-build scenario (Alternative A), a proposed alignment to the west of Pittsboro (Alternative B), and a proposed alignment to the east of Pittsboro (Alternative C). The base year of this forecast is 2000 and the future year projections are for 2025.

Figure 1 – Project Location

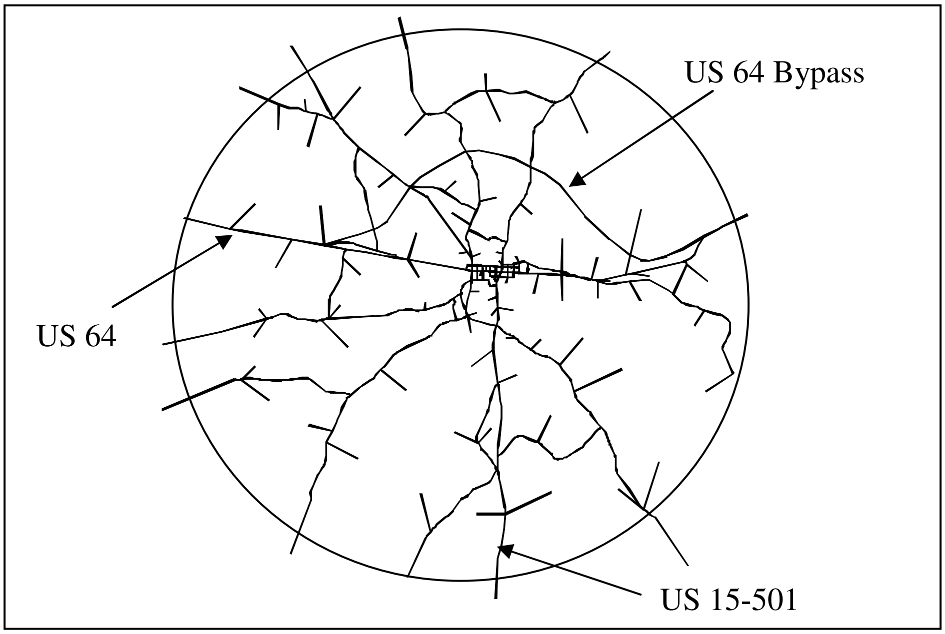


Source: NCDOT GIS Mapping Unit, 2002.

1.2 Project Study Area

Pittsboro (pop. 2,226), the county seat of Chatham County, is a small town located at the intersection of US 15-501 and US 64. In 2000 there were approximately 5,700 people within the Pittsboro planning area and 49,000 residents in Chatham County. The project study area is made up of 72 square miles surrounding Pittsboro (Figure 2). Pittsboro is considered a rural community. It is 20 miles from Chapel Hill and 35 miles from Raleigh. US 64 and US 15-501 are the major facilities that serve Pittsboro and are both classified as Rural Major Freeways. US 64 runs east-west and is a major facility that spans the entire state from the Outer Banks to the Tennessee border. US 15-501 runs north-south and is a major facility that runs from South Carolina to Virginia. In 2000 an east-west US 64 bypass was opened around Pittsboro to alleviate local congestion.

Figure 2 – Primary Study Area



Source: NCDOT GIS Mapping Unit, 2002.

2.0 EXISTING CONDITIONS

2.1 Population

Based on US Census Bureau population data gathered from the North Carolina State Demographics Data Center, the population of Pittsboro has increased at a pace of 3.73% per year from 1990 to 2000 (Table 1). Over the same time period, the population of Chatham County has increased 2.66% per year and the population of North Carolina has increased 2.14% per year. The North Carolina State Demographics Data Center has projected Pittsboro and Chatham County to increase population by 2.01% annually to 2020. At the same time, North Carolina's population is projected to increase by 1.76% annually to 2020. The construction of the US 64 and US 15-501 bypasses will make Pittsboro more convenient to Chapel Hill, Raleigh, and the Research Triangle Park. Consequently, developers are likely to build housing and commercial properties that will accelerate growth.

Table 1 – Pittsboro, Planning Area, Chatham County, and State Population

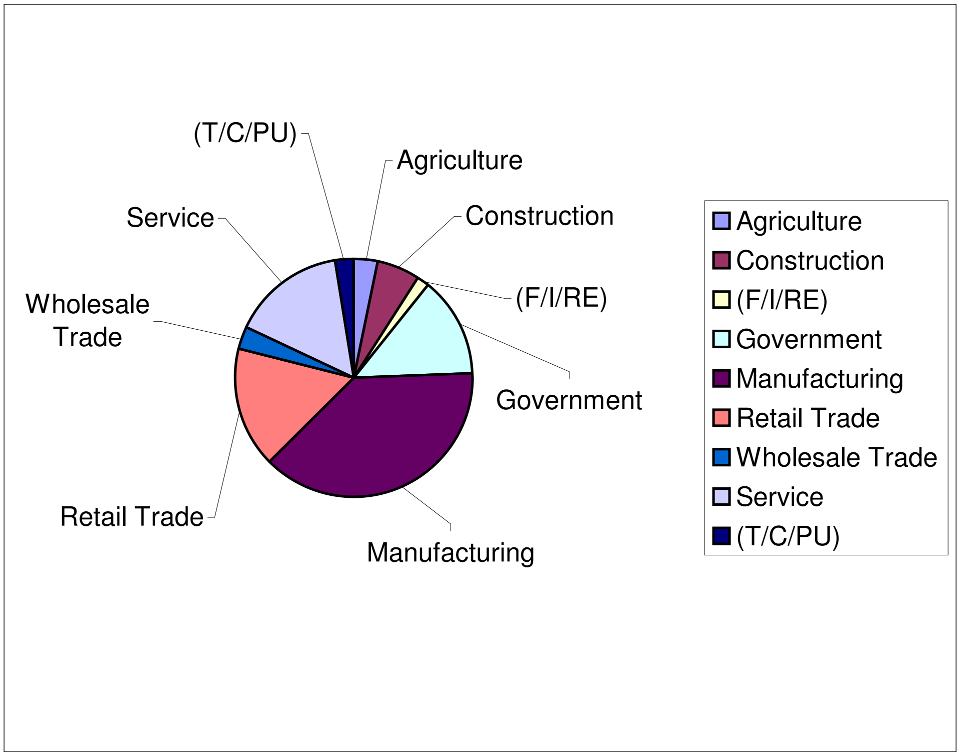
	1990	2000	2020	2025	1990-2000 annual % change	2000-2020 annual % change
Pittsboro	1,621	2,226	3,119	3,443	+ 3.73 %	+ 2.01 %
Planning Area	-	5,700	7,988	8,819	-	+ 2.01 %
Chatham County	38,979	49,329	69,137	-	+ 2.66 %	+ 2.01 %
North Carolina	6,632,448	8,049,313	10,895,220	-	+ 2.14 %	+ 1.76 %

Source: North Carolina State Demographics Data Center, 2002.

2.2 Employment

Close to 39% of the Chatham County labor force is employed in manufacturing (Figure 3). Retail and service make up 32% of the labor force. Even though agriculture only accounts for 3% of the workforce, farms take up large tracts of land in and around Pittsboro. Residents of Pittsboro also commute to work in Raleigh via US 64 and Chapel Hill by US 15-501.

Figure 3 – 2001 Chatham County Workforce



Source: North Carolina Department of Commerce, 2002.

As the population has increased in Chatham County, the number of employees has kept pace. From 1990 to 2001 Chatham County saw a 2.02% annual increase in number of employees (Table 2). The Chatham County unemployment rate in 2001 was 3.2%. The 2001 Chatham County employment to population (E/P) ratio is 0.32. The 2001 employment to population (E/P) ratio in the Pittsboro planning area is 0.467. The E/P ratio provides an indication of the level of economic activity and is needed to forecast future economic growth. The 2001 E/P ratio for North Carolina is 0.48.

Table 2 – Number of Employees in Chatham County

	1990	1995	2000	2001	Annual % Change
Chatham County	21,380	22,630	26,140	26,160	+ 2.02 %

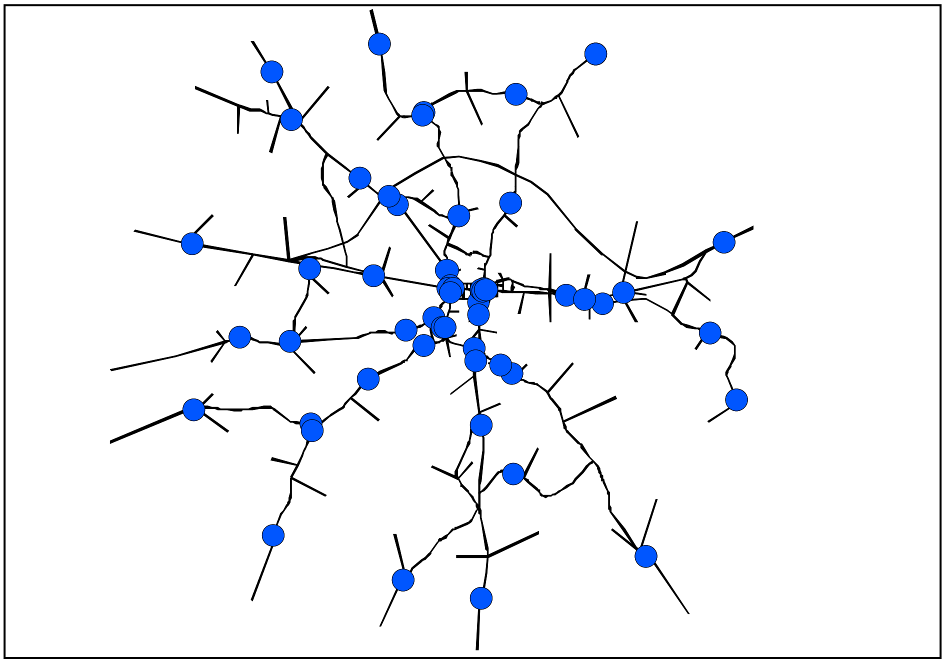
Source: North Carolina State Employment Securities Commission, 2002.

2.3 Base Year Model

The NCDOT Statewide Planning Unit created a base year TransCAD regional area model for the Pittsboro planning area by using several base year data sources (Appendix A – D):

- Chatham County Planning Department: Pittsboro TAZ GIS file
- NCDOT GIS Mapping Unit: Pittsboro streets GIS file
- NCDOT Statewide Planning Unit: Pittsboro windshield survey results
- NCDOT Statewide Planning Unit: Pittsboro employment survey results
- NCDOT Traffic Survey Unit: Pittsboro traffic counts for 2000 (Figure 4)

Figure 4 – Traffic Count Locations



Source: NCDOT Traffic Survey Unit, 2002.

Data from the windshield and employment surveys was assigned to the different Traffic Analysis Zones (TAZs) and formatted for input into the NCDOT Internal Data Summary (IDS) program (Table 3).

Table 3 – Pittsboro Base Year Data

	HH1	HH2	HH3	HH4	HH5	TOTAL
Households	206	1064	886	209	20	2385
%	8 %	40 %	33 %	8 %	1 %	100 %
	IND	RET	HWY	OFF	SER	TOTAL
Employees	666	226	191	383	1198	2664
%	25 %	8 %	7 %	14 %	45 %	100 %

Source: NCDOT Statewide Planning Unit, 2001.

The windshield surveyors visited and rated all households in the Pittsboro study area on a scale of 1 (poor) to 5 (excellent). Employment data was condensed into five types of employment: industrial (IND), retail (RET), highway retail (HWY), office (OFF), and service (SER). The IDS program was run with the correctly formatted data and the following Pittsboro specific trip generation rates (Equation 1 and 2).

Equation 1 – Pittsboro Production Equation

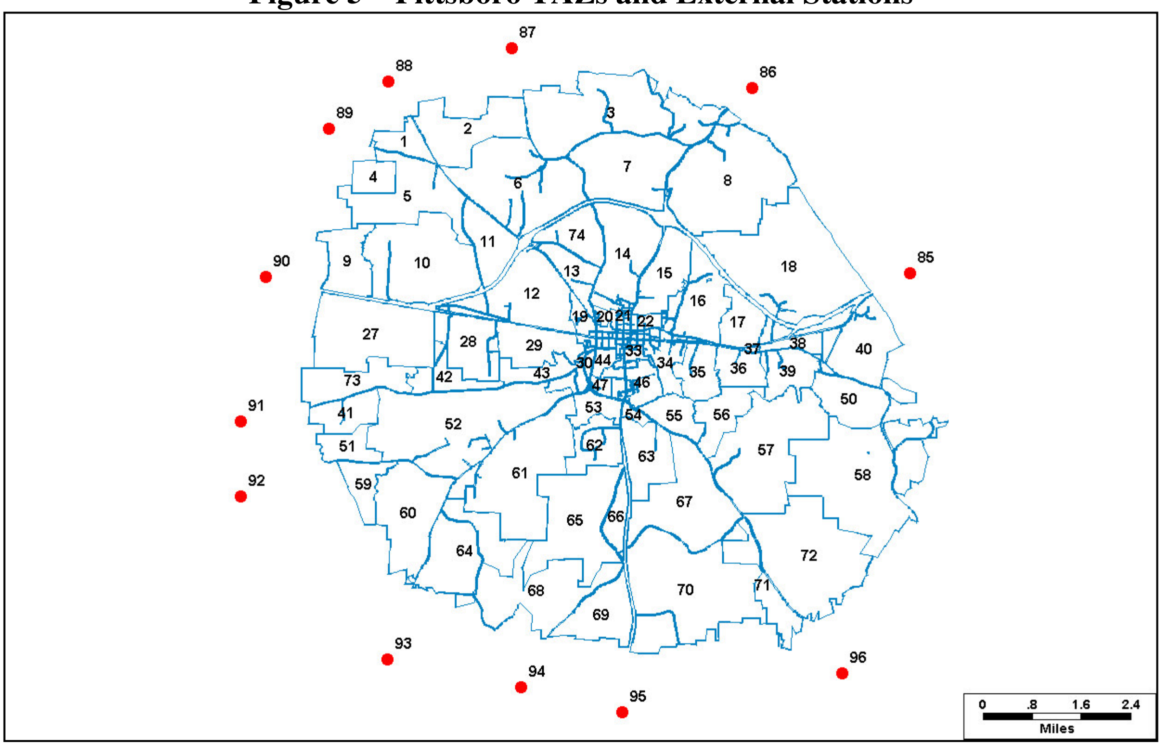
Total trips produced by TAZ = 5(HH1) + 7(HH2) + 8(HH3) + 10(HH4) + 12(HH5)

Equation 2 – Pittsboro Attraction Equation

Total trips attracted by TAZ = 0.1(IND) + 2(RET) + 8.4(HWY) + 2.6(OFF) + 2.5(SER)

A roadway network containing speed, capacity, and length as attributes was created to model all of the routes available to Pittsboro drivers. 74 TAZs, 12 external stations, and 10 dummy nodes formed the loading points for the network (Figure 5). Count station data was entered into the NCDOT SYNTH program to produce through trip ratios for the external stations.

Figure 5 – Pittsboro TAZs and External Stations



Source: NCDOT Statewide Planning Unit, 2002.

After the TransCAD regional land use and transportation model was completed and the IDS and SYNTH results were completed, the gravity model was run to distribute trips between the zones. TAZs with production and attraction rates and a roadway network TransCAD computed shortest paths between each TAZ and external station based on travel times. TransCAD also calculated friction factors between each TAZ and external stations with NCHRP 365 gamma function parameters. The traffic assignment method selected for the Pittsboro regional model was all-or-nothing.

The base year results of the Pittsboro regional model were compared against the 2000 count station data to confirm the validity of the predicted traffic flows. The predicted traffic flows described the ground counts accurately and the base year model was accepted for regional and project level traffic forecasting use.

3.0 FUTURE CONDITIONS

3.1 Future Year Model

NCDOT contacted the Chatham County Economic Development Commission, the Chatham County Manager, and the Pittsboro Town Planner. The NCDOT Statewide Planning Engineer assigned to Pittsboro obtained future growth scenarios, population and employment data, as well as local knowledge to guide the development of the future year model. The local officials were especially helpful in identifying growth areas of Pittsboro and commenting on the availability of residential land. TAZ characteristics were updated to reflect the future growth of Pittsboro after speaking to all interested parties (Table 5).

Table 4 – Pittsboro Future Year Data

	HH1	HH2	HH3	HH4	HH5	TOTAL
Future Year Addition	60	191	635	285	246	1417
Base Year	206	1064	886	209	20	2385
Total Households	**266**	**1255**	**1521**	**494**	**266**	**3802**
%	7	33	40	13	7	100
	INDEMP	RETEMP	HWYRET	OFFEMP	SERVEMP	TOTAL
Future Year Addition	436	127	118	234	830	1745
Base Year	666	226	191	383	1198	2664
Total Employees	**1102**	**353**	**309**	**617**	**2028**	**4409**
%	25	8	7	14	46	100

The 2025 Average Daily Traffic (ADT) was calculated for all external stations based on linear trend analysis of historical count data (Table 5). Different growth rates were applied to the different external stations based on functional class, growth potential, and conversations with local officials. These future TAZ and external trip estimates are the basis for the future year model (Appendix E – G).

Future year truck percentages were determined by engineering judgment considering the following information:

- US 64 Pittsboro Bypass traffic forecast (TIP # R-2219)
- Feasibility Study of Converting US 64 to an Expressway traffic forecast
- Conversations with the SWP Engineer in charge of the Pittsboro area

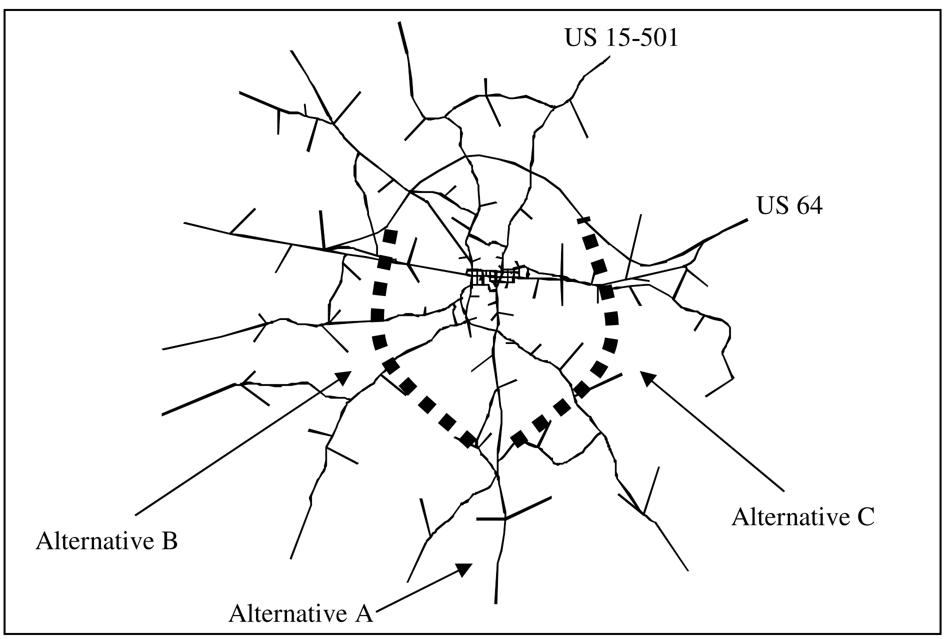
Table 5 – External Station ADTs

External Station	2000 ADT	2030 ADT	Annual % Change 2000-2030
US 64 E	10000	22400	4
US 15/501 N	11200	26100	4
SR1520	700	2300	8
NC 87 N	2900	6600	4
SR 1346	1050	2800	6
US 64 W	9250	20100	4
SR 2159	250	1000	10
NC 902	1500	3800	5
SR 1010	1700	4000	5
SR 1953	150	1000	19
US 15/501 S	6800	14500	4
SR 1012	2400	6000	5

3.2 The Future Year Alternatives

Alternative A, the no-build scenario, would keep US 15-501 a two-lane facility through town and calls for no other facility upgrades. Alternative B is the edition of a proposed US 15-501 bypass around the west side of Pittsboro (Figure 6). Alternative C is the edition of a proposed US 15-501 bypass around the east side of Pittsboro (Figure 6). Alternatives B and C for the US 15-501 bypass of Pittsboro would be 55 mph four- lane divided facilities with access limited to major interchanges with US 64 Business and US 64 Bypass. For alternatives B and C the current US 15-501 facility would remain a two-lane road for local use and be renamed US 15-501 Business.

Figure 6 – The Future Year Alternatives



Source: NCDOT Transportation Improvement Plan, 2002.

3.3 Project-Level Traffic Forecast

Using the regional NCDOT TransCAD model for Pittsboro, year 2025 project-level traffic forecasts were developed for the three US 15-501 alternatives. Since the regional model is the basis of the project-level traffic forecast, the 2025 model reflects the appropriate future traffic patterns in Pittsboro, as well as traffic for Alternatives A, B, and C. The results are shown in Figures 7 – 11.

3.4 Discussion of Results

Table 6 summarizes and compares significant features of the no-build Alternative A with the 15-501 Bypass Alternative B and C. By building a 15-501 Bypass on the east or west traffic on US 15-501 (Business) will be reduced by up to 50% on the section north and south of the traffic circle. Traffic circle traffic will reduce by up to 60% on some quadrants. US 64 Business traffic is most affected by the eastern bypass alignment (Alternative C).

Table 6 – Summary of Alternatives A, B, and C

	Alternatives				
Section	**A (No-Build)**	**B (West Bypass)**	**B (15-501 Bus)**	**C (East Bypass)**	**C (15-501 Bus)**
US 64 Business (E)	20,600 ADT	-	19,700 ADT	15,300 ADT	13,700 ADT
US 64 Business (W)	9,300 ADT	9,200 ADT	8,100 ADT	-	9,300 ADT
US 15-501 (N)	20,600 to 23,000 ADT	4,300 ADT	15,200 to 21,300 ADT	19,000 ADT	10,000 to 14,800 ADT
Traffic Circle	12,600 to 16,000 ADT	-	8,800 to 12,600 ADT	-	7,100 to 9,900 ADT
US 15-501 (S)	14,500 to 20,700 ADT	6,800 ADT	10,900 to 20,400 ADT	11,900 ADT	7,600 to 8,900 ADT

Before any alternative is judged advantageous other factors such as the environment, costs, property impacts, etc. must also be evaluated. Furthermore, while TransCAD accommodates future growth and develops turning movements at proposed intersections automatically, certain limitations of the Pittsboro TransCAD model must be realized. They include:

- Growth estimates occur at the TAZ level rather than the property level.
- All streets have an assumed capacity of 9000 ADT.
- All-or-nothing traffic assignment is used.
- Truck travel demand patterns are not modeled.

Appropriate adjustments should be made, if necessary, as the project design process progresses.

Figure 7 – Alternative A (No-Build): 15-501 Corridor Traffic Forecast

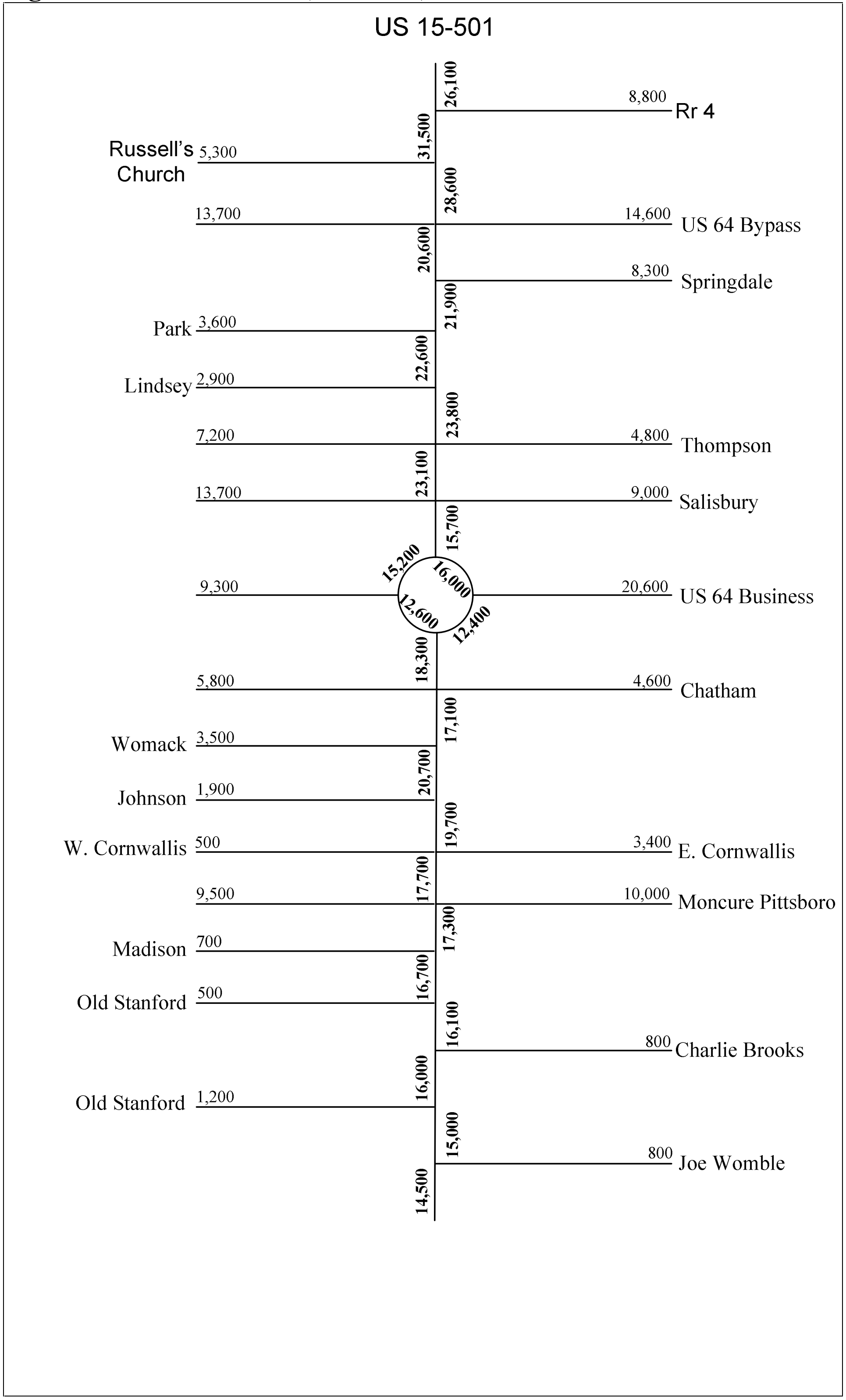


Figure 8 – Alternative B (West Bypass): Project-Level Traffic Forecast

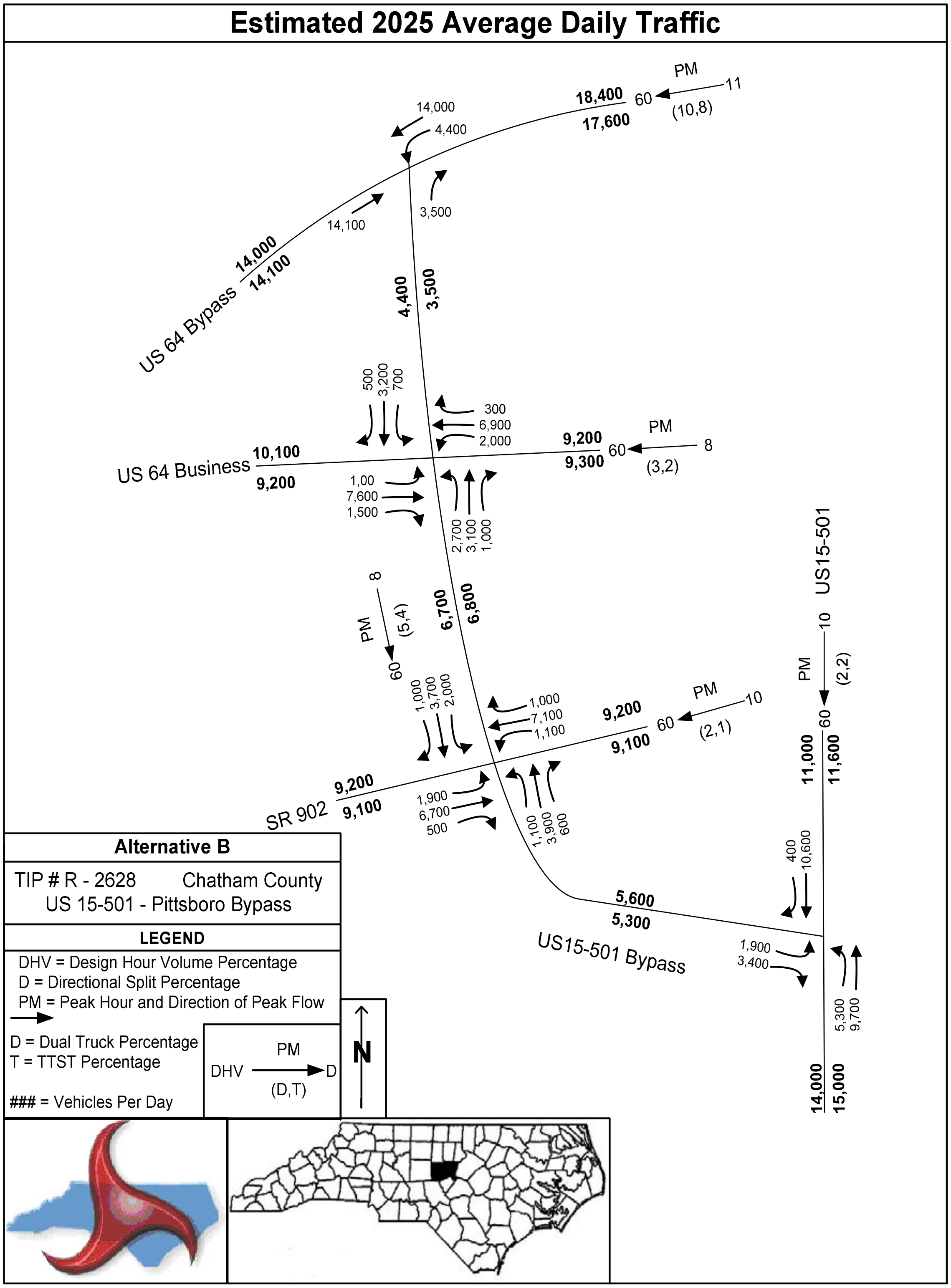


Figure 9 – Alternative B (West Bypass): 15-501 Corridor Traffic Forecast

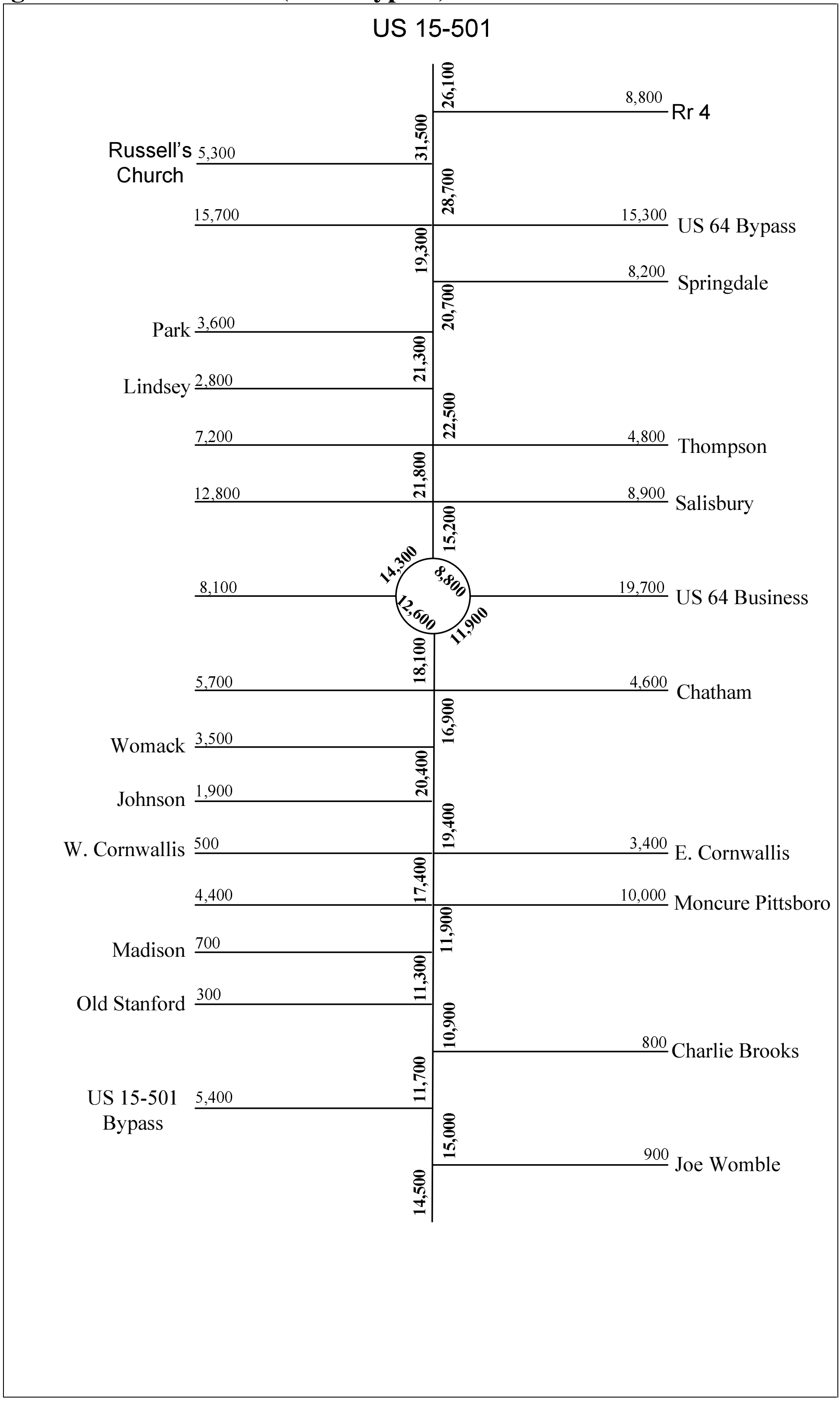


Figure 10 – Alternative C (East Bypass): Project-Level Traffic Forecast

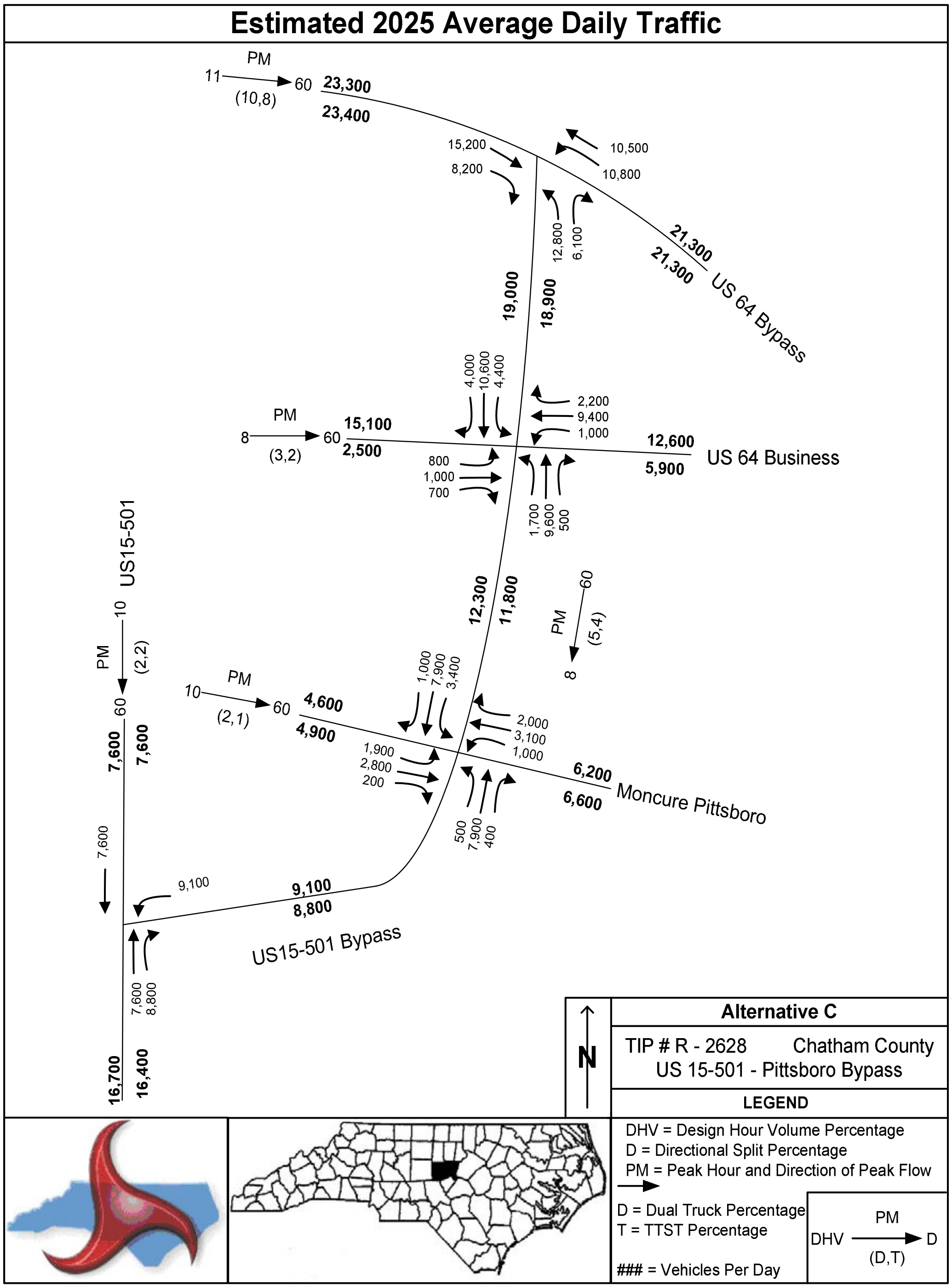
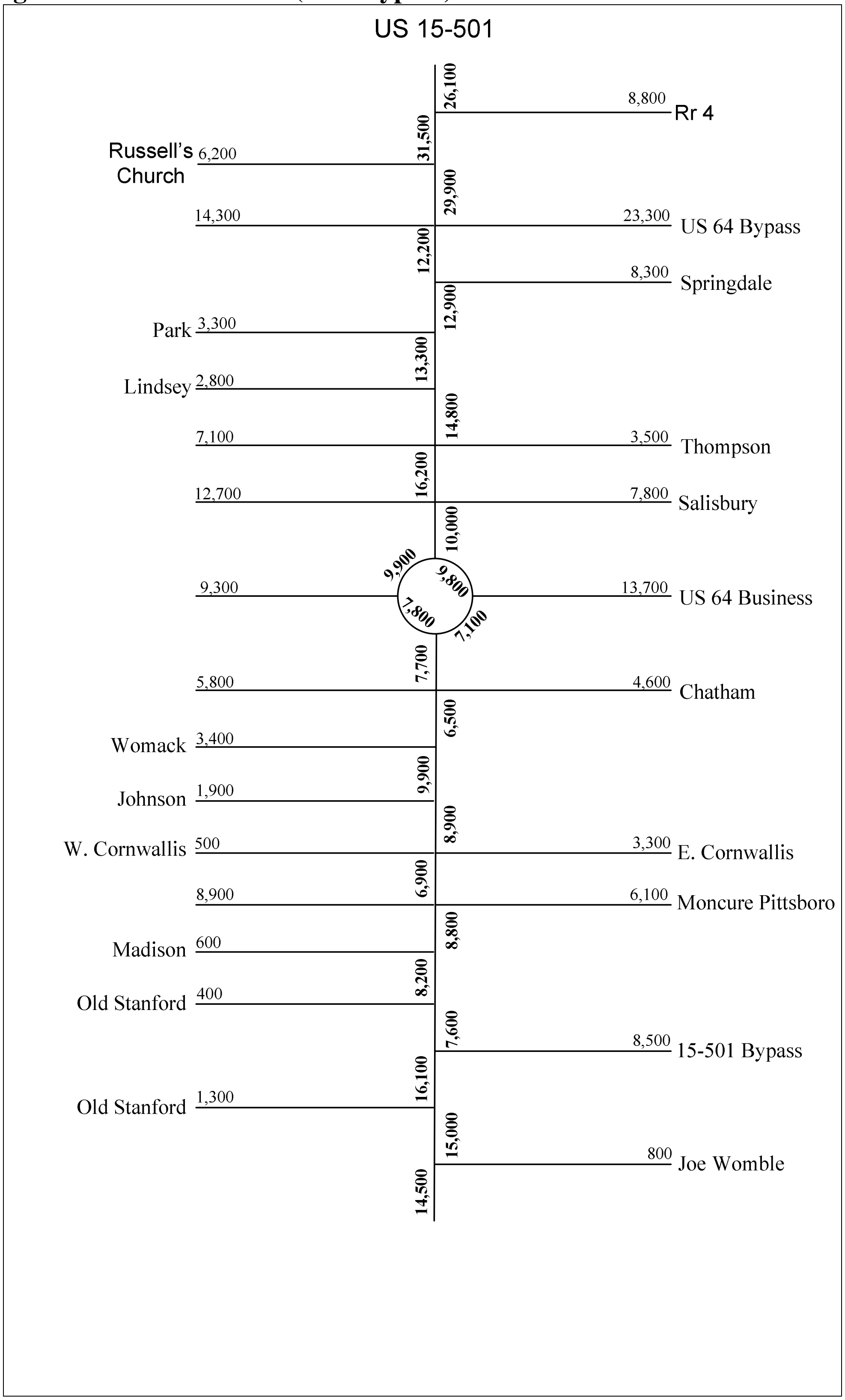


Figure 11 – Alternative C (East Bypass): 15-501 Corridor Traffic Forecast



Appendix A – Base Year TAZ Characteristics

This table is included for future replication and discussion. Normally this is included in a CD or data file as part of the documentation.

TAZ	IND	RET	HWY	OFF	SER	TOT	HH1	HH2	HH3	HH4	HH5	TOTHH
1	0	0	0	0	1	1	1	23	3	0	0	27
2	2	0	0	0	0	2	1	3	7	4	1	16
3	3	11	0	0	0	14	3	20	21	8	0	52
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	1	10	27	4	4	0	45
6	0	1	0	0	9	10	5	42	41	14	1	103
7	7	1	0	0	95	103	3	31	26	8	1	69
8	2	28	0	0	67	97	63	38	24	1	0	126
9	17	0	0	4	0	21	0	0	0	1	0	1
10	0	0	0	0	0	0	0	12	12	3	0	27
11	0	0	0	0	0	0	3	17	12	2	0	34
12	3	0	0	0	0	3	5	6	7	3	2	23
13	0	0	0	0	15	15	0	14	43	10	0	67
14	19	2	31	3	0	55	18	31	53	6	0	108
15	0	0	4	1	36	41	4	24	19	1	0	48
16	0	0	0	0	0	0	8	22	40	0	0	70
17	37	6	4	0	56	103	2	54	9	0	0	65
18	1	0	0	0	1	2	0	3	3	3	0	9
19	4	6	3	0	82	95	0	9	15	12	1	37
20	0	0	0	0	149	149	0	169	11	0	0	180
21	0	0	2	0	0	2	5	12	19	9	1	46
22	1	3	0	0	12	16	19	17	7	1	0	44
23	12	1	4	0	16	33	0	17	13	5	0	35
24	6	29	5	37	99	176	5	15	11	3	0	34
25	3	37	32	20	24	116	0	7	10	1	0	18
26	0	0	1	28	4	33	4	17	12	0	0	33
27	0	0	0	0	0	0	0	2	0	0	0	2
28	5	5	0	0	0	10	3	25	27	8	0	63
29	0	0	0	0	0	0	0	0	3	0	0	3
30	0	0	0	0	7	7	1	27	36	0	0	64
31	0	0	0	80	16	96	0	3	2	1	0	6
32	5	11	9	31	47	103	2	13	12	0	0	27
33	28	7	35	118	41	229	4	10	7	1	0	22
34	0	71	42	36	174	323	5	31	13	0	0	49
35	0	0	19	0	66	85	0	17	1	0	0	18
36	0	2	0	0	2	4	1	12	12	1	0	26
37	0	0	0	0	0	0	0	5	3	0	0	8
38	0	0	0	0	0	0	0	4	0	1	0	5
39	0	0	0	0	0	0	0	9	14	0	0	23
40	0	0	0	0	0	0	0	11	7	11	5	34
41	0	0	0	0	0	0	1	9	2	0	0	12
42	0	0	0	0	0	0	2	12	11	2	0	27

TAZ	IND	RET	HWY	OFF	SER	TOT	HH1	HH2	HH3	HH4	HH5	TOTHH
43	0	0	0	0	0	0	0	6	15	3	0	24
44	0	0	0	0	87	87	0	4	5	0	0	9
45	0	0	0	25	7	32	0	8	11	0	0	19
46	0	0	0	0	65	65	6	35	21	0	0	62
47	0	0	0	0	0	0	0	0	11	2	0	13
48	0	0	0	0	0	0	0	6	13	14	0	33
49	0	0	0	0	5	5	0	0	0	0	0	0
50	0	5	0	0	0	5	1	9	10	0	0	20
51	0	0	0	0	0	0	0	1	3	0	0	4
52	0	0	0	0	0	0	4	57	47	4	0	112
53	0	0	0	0	0	0	0	4	6	0	0	10
54	500	0	0	0	0	500	0	1	2	1	0	4
55	0	0	0	0	0	0	0	3	2	0	0	5
56	0	0	0	0	0	0	0	7	6	0	0	13
57	0	0	0	0	0	0	0	7	8	2	0	17
58	0	0	0	0	0	0	2	0	3	7	2	14
59	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	7	7	6	0	0	20
61	0	0	0	0	0	0	1	8	13	4	0	26
62	0	0	0	0	0	0	0	0	12	27	6	45
63	3	0	0	0	0	3	0	5	3	1	0	9
64	0	0	0	0	0	0	5	9	11	2	0	27
65	0	0	0	0	2	2	0	18	15	2	0	35
66	8	0	0	0	2	10	0	5	13	1	0	19
67	0	0	0	0	9	9	0	10	15	1	0	26
68	0	0	0	0	0	0	0	5	14	0	0	19
69	0	0	0	0	0	0	0	4	5	1	0	10
70	0	0	0	0	0	0	0	3	3	0	0	6
71	0	0	0	0	1	1	2	2	6	2	0	12
72	0	0	0	0	0	0	0	4	3	4	0	11
73	0	0	0	0	0	0	0	5	10	0	0	15
74	0	0	0	0	0	0	0	11	22	7	0	40

Appendix B – Base Year SYNTH Files

SYNTH Input File

Population of the planning area: 5700

STATION	ADT	TRUCK %	CLASS	PTTDES	ADT/CD
1. US 64 EAST	10000	14	P	54.24	0.20877
2. US 15/501 N	11200	5	P	44.04	0.23382
3. SR 1520	700	2	L	12.30	0.01461
4. NC 87 N	2900	16	M	38.74	0.06054
5. SR 1346	1050	2	L	13.21	0.02192
6. US 64 W	9250	14	P	52.29	0.19311
7. SR 2159	250	2	L	11.13	0.00522
8. NC 902	1500	7	J	21.78	0.03132
9. SR 1010	1700	3	L	16.38	0.03549
10. SR 1953	150	2	L	10.87	0.00313
11. US 15/501 S	6800	11	M	41.48	0.14196
12. SR 1012	2400	17	J	38.92	0.05010

ROUTE CONTINUITY

```
 1  to  6 : US 64 EAST to US 64 W
 2  to  11 : US 15/501 N to US 15/501 S
 4  to  11 : NC 87 N to US 15/501 S
 6  to  1 : US 64 W to US 64 EAST
 11  to  2 : US 15/501 S to US 15/501 N
 11  to  4 : US 15/501 S to NC 87 N
```

SYNTH Output Summary File

```
  UNBALANCED THROUGH TRIP END MATRIX:
  -----------------------------------
     0  1038    19   187    30  1837     6    68    62     3   385
206
  1012     0    21   210    34   892     7    59    69     4  1094
180
     1     1     0     7     2     1     0     3     3     0    14
9
   614   542     5     0     8   541     2    36    17     1   763
109
    32    28     2    14     0    28     1     5     6     0    28
14

 2019   980    17   172    28     0     6    64    57     3   355   195
     0     0     0     0     0     0     0     1     0     0     0
2
   221   195     3    22     4   195     1     0     8     0    46
45
   119   105     3    26     5   105     1     9     0     1    54
29
     0     0     0     0     0     0     0     0     0     0     0
1
   806  1513    13   446    20   710     4    47    42     2     0
144
   600   529     4    40     7   529     1    35    14     1    82
0

  DESIRED TOTALS:
  ---------------
  5424  4933    86  1124   139  4837    28   327   279    16  2821
934

  FOLDED TRIP END MATRIX:
  -----------------------
     0
  1025     0
    10    11     0
   400   376     6     0
    31    31     2    11     0
  1928   936     9   356    28     0
     3     3     0     1     0     3     0
   144   127     3    29     4   129     1     0
    90    87     3    22     5    81     1     9     0
     2     2     0     0     0     2     0     0     0     0
   595  1304    13   605    24   532     2    47    48     1     0
   403   355     7    75    11   362     2    40    21     1   113
0

  TOTALS FOR FOLDED TRIP END MATRIX:
  ----------------------------------
  4633  4258    64  1881   148  4367    16   534   367     9  3284
1388

  FRATAR FACTORS FOR THE MATRIX:
```

```
  ------------------------------
 1.171 1.159 1.348 0.597 0.939 1.108 1.753 0.612 0.758 1.877 0.859
0.673

  TRIP END MATRIX AFTER ITERATION # 9 :
  --------------------------------------
     0
  1582     0
    18    21     0
   247   243     4     0
    34    36     2     7     0
  2488  1270    14   251    28     0
     7     8     1     1     1     6     0
    94    87     2    10     2    70     0     0
    76    77     3    10     3    57     1     5     0

 4     5     0     1     0     3     0     1     0     0
   577  1328    15   320    18   430     2    32    35     1     0
   297   275     6    30     6   222     1    21    12     1    64
0

  FRATAR FACTORS:
  ---------------
 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000

  BALANCED THROUGH TRIP MATRIX:
  -----------------------------
     0   791     9   123    17  1244     4    47    38     2   288
148
   791     0    11   122    18   635     4    44    38     2   664
137
     9    11     0     2     1     7     0     1     1     0     7
3
   123   122     2     0     3   126     1     5     5     0   160
15
    17    18     1     3     0    14     0     1     2     0     9
3
  1244   635     7   126    14     0     3    35    28     2   215
111
     4     4     0     1     0     3     0     0     0     0     1
1
    47    44     1     5     1    35     0     0     3     0    16
11
    38    38     1     5     2    28     0     3     0     0    17
6
     2     2     0     0     0     2     0     0     0     0     1
0
   288   664     7   160     9   215     1    16    17     1     0
32
   148   137     3    15     3   111     1    11     6     0    32
0

  COLUMN TOTALS:
  --------------
  2711  2466    42   562    68  2420    14   163   138     7  1410
467
```

External-Internal Trip Calculations

Calculating External-Internal Trips from SYNTH Output			
Tot Ext Prod	Percent through	Through trips	Ext-Int trips
10000	0.5424	5424	4576
11200	0.4404	4932	6268
700	0.123	86	614
2900	0.3874	1123	1777
1050	0.1321	139	911
9250	0.5229	4837	4413
250	0.1113	27.825	222
1700	0.223	379	1321
1700	0.1638	278	1422
150	0.1087	16	134
6800	0.4148	2820	3979
2400	0.3892	93	1466
500	0.1178	59	441
48600		21057	27543

Appendix C – Base Year IDS Files

<u>IDS Input File</u>

```
  IDS PITTSBORO BASE YEAR DATA 2001
  96 ZONES (74 ZONES+22 STATIONS)
    96       48600        9900
          85    22    52    26
         250   250   250   250   250
        1200  1000   800   700   500                    670    67
670  670
   100   100   100   100   100
030
   010   200   840   260   250
010
   020   200   840   260   250
010



   050   200   840   260   250
010
     1     0     0     3    23     1                      0     0     0
     2     1     4     7     3     1                      0     0     0
     3     0     8    21    20     3                      0     0     0
     4     0     0     0     0     0                      0     0     0
     5     0     4     4    27    10                      0     0     0
     6     1    14    41    42     5                      0     0     0
     7     1     8    26    31     3                      0     0     0
     8     0     1    24    38    63                      0     0     0
     9     0     1     0     0     0                      0     8     0
    10     0     3    12    12     0                      0     0     0
    11     0     2    12    17     3                      0     0     0
    12     2     3     7     6     5                      0     4     0
    13     0    10    43    14     0                      0     0     0
    14     0     6    33    21    10                      0     0     0
    15     0     1    19    24     4                      0     0     0
    16     0     0    40    22     8                      0     0     0
    17     0     0     9    54     2                      0     1     0
    18     0     3     3     3     0                      0     0     0
    19     1    12    15     9     0                      0     1     0
    20     0     0    11    45     0                      0    10     0
    21     1     9    19    12     5                      0     0     0
    22     0     1     7    17    19                      0     6     0
    23     0     5    13    17     0                      0     3     0
    24     0     3    11    15     5                      0     8     0
    25     0     1    10     7     0                      0     8     0
    26     0     0    12    17     4                      0     5     0
    27     0     0     0     2     0                      0     0     0
    28     0     8    27    25     3                      0     1     0
    29     0     0     3     0     0                      0     0     0
    30     0     0    36    27     1                      0     2     0
    31     0     1     2     3     0                      0    13     0
    32     0     0    72    13     2                      0     4     0
    33     0     1     7    10     4                      0     8     0
    34     0     0    13   120     5                      0     6     0
    35     0     0    51    17     0                      0    10     0
```

36	0	1	12	12	1	0	0	0
37	0	0	3	5	0	0	0	0
38	0	1	0	4	0	0	0	0
39	0	0	14	9	0	0	0	0
40	5	11	7	11	0	0	0	0
41	0	0	2	9	1	0	0	0
42	0	2	11	12	2	0	0	0
43	0	3	15	6	0	0	0	0
44	0	0	5	4	0	0	6	0
45	0	0	11	8	0	0	0	0
46	0	0	21	35	6	0	8	0
47	0	2	11	0	0	0	0	0
48	0	14	13	6	0	0	0	0
49	0	0	0	0	0	0	2	0
50	0	0	10	9	1	0	0	0
51	0	0	3	1	0	0	0	0
52	0	4	47	57	4	0	0	0
53	0	0	6	4	0	0	30	0
54	0	1	2	1	0	0	0	0
55	0	0	2	3	0	0	0	0
56	0	0	6	7	0	0	0	0
57	0	2	8	7	0	0	0	0
58	2	7	3	0	2	0	0	0
59	0	0	0	0	0	0	0	0
60	0	0	6	7	7	0	0	0
61	0	4	13	8	1	0	0	0
62	6	27	12	0	0	0	0	0
63	0	1	3	5	1	0	0	0
64	0	2	11	9	5	0	0	0
65	0	2	15	18	0	0	0	0
66	0	1	13	5	0	0	1	0
67	0	1	15	10	0	0	0	0
68	0	0	14	5	0	0	0	0
69	0	1	5	4	0	0	0	0
70	0	0	3	3	0	0	0	0
71	0	2	6	2	2	0	0	0
72	0	4	3	4	0	0	0	0
73	0	0	10	5	0	0	0	0
74	0	7	22	11	0	0	0	0
75								
76								
77								
78								
79								
80								
81								
82								
83								
84								
85								
86								
87								
88								
89								
90								
91								
92								

93					
94					
95					
96					
1	0	0	0	0	1
2	2	0	0	0	0
3	3	11	0	0	0
4	0	0	0	0	0
5	0	0	0	0	1
6	0	1	0	0	9
7	7	1	0	0	95
8	2	28	0	0	67
9	17	0	0	4	0
10	0	0	0	0	0
11	0	0	0	0	0
12	3	0	0	0	0
13	0	0	0	2	15
14	10	2	21	3	0
15	0	0	4	1	36
16	0	0	0	0	0
17	37	6	4	0	56
18	1	0	0	0	1
19	4	6	3	0	50
20	0	0	0	0	60
21	0	0	2	0	0
22	1	3	0	0	12
23	12	1	4	0	16
24	6	15	5	20	25
25	3	15	13	10	13
26	0	0	1	28	4
27	0	0	0	0	0
28	5	5	0	0	0
29	0	0	0	0	0
30	0	0	0	0	7
31	0	0	0	35	16
32	5	8	9	15	15
33	10	7	15	30	20
34	0	20	18	15	55
35	0	0	10	0	36
36	0	2	0	0	2
37	0	0	0	0	0
38	0	0	0	0	0
39	0	0	0	0	0
40	0	0	0	0	0
41	0	0	0	0	0
42	0	0	0	0	0
43	0	0	0	0	0
44	0	0	0	0	67
45	0	0	0	25	7
46	0	0	0	0	55
47	0	0	0	0	0
48	0	0	0	0	0
49	0	0	0	0	5
50	0	0	0	0	0
51	0	0	0	0	0
52	0	0	0	0	0
53	0	0	0	0	0

54	500	0	0	0	0
55	0	0	0	0	0
56	0	0	0	0	0
57	0	0	0	0	0
58	0	0	0	0	0
59	0	0	0	0	0
60	0	0	0	0	0
61	0	0	0	0	0
62	0	0	0	0	0
63	3	0	0	0	0
64	0	0	0	0	0
65	0	0	0	0	2
66	8	0	0	0	2
67	0	0	0	0	9
68	0	0	0	0	0
69	0	0	0	0	0
70	0	0	0	0	0
71	0	0	0	0	1
72	0	0	0	0	0
73	0	0	0	0	0
74	0	0	0	0	0

75
76
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78
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80
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82
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84
85
4576
86
6268
87
614
88
1777
89
911
90
4413
91
222
92
1321
93
1422
94
134
95
3979
96
1466

IDS Output File

Zone	hbwp	hbwa	hbop	hboa	nhbp	nhba	extintp	extinta
1	33	10	76	9	19	18	0	33
2	22	7	50	2	7	7	0	13
3	68	34	155	46	99	100	0	186
4	0	0	0	0	0	0	0	0
5	53	16	121	12	26	26	0	47
6	135	47	308	58	126	125	0	226
7	90	143	206	421	911	911	0	1657
8	138	156	313	402	870	870	0	1577
9	1	24	3	20	48	48	0	120
10	36	9	82	3	7	7	0	13
11	43	12	99	5	12	11	0	20
12	29	10	67	3	7	7	0	20
13	92	43	209	83	181	181	0	326
14	90	65	204	334	726	726	0	1331
15	61	64	139	223	483	483	0	872
16	90	23	206	12	26	26	0	47
17	81	142	184	332	733	734	0	1397
18	12	5	28	5	12	11	0	20
19	51	86	116	283	611	612	0	1111
20	71	89	161	264	571	571	0	1031
21	60	17	137	36	78	77	0	140
22	49	34	111	68	147	147	0	266
23	46	50	105	136	298	299	0	565
24	43	94	97	323	704	704	0	1277
25	24	69	55	339	737	737	0	1337
26	41	49	94	160	347	347	0	625
27	2	0	6	0	0	0	0	0
28	83	33	188	27	62	63	0	120
29	4	0	10	0	0	0	0	0
30	85	30	193	39	86	85	0	153
31	8	61	18	223	483	483	0	872
32	35	70	79	291	630	630	0	1151
33	27	103	62	461	1003	1003	0	1829
34	47	139	108	632	1367	1368	0	2468
35	22	59	51	298	645	645	0	1164
36	34	13	77	19	40	41	0	73
37	10	2	24	0	0	0	0	0
38	6	1	15	0	0	0	0	0
39	31	7	70	3	7	7	0	13
40	48	12	109	5	12	11	0	20
41	15	3	34	2	4	4	0	7
42	35	9	79	3	7	7	0	13
43	33	8	75	3	7	7	0	13
44	12	80	27	286	619	619	0	1118

Zone	hbwp	hbwa	hbop	hboa	nhbp	nhba	extintp	extinta
45	25	43	58	143	310	310	0	559
46	78	85	177	243	527	527	0	951
47	18	3	42	2	4	4	0	7
48	45	10	103	5	12	11	0	20
49	0	6	0	20	44	44	0	80
50	26	6	59	3	7	7	0	13
51	6	1	13	0	0	0	0	0
52	146	38	331	19	40	41	0	73
53	13	2	31	2	4	4	0	7
54	6	584	13	85	369	369	0	1663
55	7	1	15	0	0	0	0	0
56	17	3	39	2	4	4	0	7
57	23	6	52	2	4	4	0	7
58	19	5	44	2	4	4	0	7
59	0	0	0	0	0	0	0	0
60	23	6	53	3	7	7	0	13
61	35	8	79	3	7	7	0	13
62	66	15	149	7	15	15	0	27
63	13	6	29	2	4	4	0	13
64	34	9	77	3	7	7	0	13
65	46	14	105	14	29	29	0	53
66	26	17	59	12	29	29	0	67
67	35	19	79	43	92	92	0	166
68	26	6	59	2	4	4	0	7
69	13	2	31	2	4	4	0	7
70	8	1	18	0	0	0	0	0
71	15	5	35	5	12	11	0	20
72	15	3	34	2	4	4	0	7
73	20	5	46	2	4	4	0	7
74	54	13	124	7	15	15	0	27
75	0	0	0	0	0	0	0	0
76	0	0	0	0	0	0	0	0
77	0	0	0	0	0	0	0	0
78	0	0	0	0	0	0	0	0
79	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0
81	0	0	0	0	0	0	0	0
82	0	0	0	0	0	0	0	0
83	0	0	0	0	0	0	0	0
84	0	0	0	0	0	0	0	0

Appendix D – Base Year Count Validation

Link	2001 Ground Count	Modeled Flow	% Difference	Acceptable % Difference
435	150	464	209	16
437	150	148	-1	16
311	250	412	65	16
313	350	612	75	40
406	350	1011	189	16
319	450	1095	143	16
392	500	93	-81	16
419	625	1292	107	16
269	700	350	-50	40
391	700	698	0	16
404	700	93	-87	16
291	925	1300	41	40
420	950	282	-70	40
48	1000	3090	209	16
242	1000	3541	254	40
58	1050	1499	43	16
37	1200	1570	31	16
405	1200	3992	233	16
443	1400	6168	341	16
350	1500	1669	11	16
413	1500	1647	10	16
372	1700	1698	0	16
354	1950	1950	0	16
439	2400	2400	0	16
330	2625	2649	1	16
446	2700	2649	-2	16
408	2900	2901	0	16
454	3287	11200	241	16
441	3500	3288	-6	16
416	3600	3757	4	16
90	3900	4112	5	16
322	4000	3757	-6	16
150	4300	6215	45	16
421	5300	4107	-23	16
428	5825	6384	10	16
201	6500	4051	-38	16
438	6800	6799	0	16
433	6900	7296	6	16
246	7400	4695	-37	16
442	7913	11200	42	16
432	8000	8135	2	16
231	8700	10308	18	16
272	9200	11331	23	16
410	9250	9322	1	16
287	9500	11331	19	16

Link	2001 Ground Count	Modeled Flow	% Difference	Acceptable % Difference
389	9700	10218	5	16
386	10000	9575	-4	16
393	10000	9998	0	16
409	10000	10949	9	16
397	10500	9177	-13	16
202	11200	11714	5	16
399	11200	6066	-46	16
205	12200	8084	-34	16
204	14000	6042	-57	16
396	14000	5422	-61	16
395	15400	12650	-18	16
total	273000	272459	0	
ground count/model ratio		1.00	average error	31 %

Appendix E – Future Year TAZ Characteristics

TAZ	IND	RET	HWY	OFF	SER	TOT	HH1	HH2	HH3	HH4	HH5	TOTHH
1	1	3	13	6	6	29	1	23	3	0	0	27
2	3	3	13	6	5	30	1	3	7	4	1	16
3	4	14	13	6	5	42	3	20	21	8	0	52
4	1	3	13	6	5	28	0	0	0	0	0	0
5	1	3	13	6	6	29	10	27	4	4	0	45
6	1	4	13	6	14	38	5	42	61	66	1	175
7	7	1	0	0	95	103	19	41	46	70	1	177
8	3	32	21	9	75	140	79	48	44	63	0	234
9	17	0	0	4	0	21	0	9	0	1	0	10
10	0	0	0	0	0	0	0	21	12	3	0	36
11	1	3	12	6	5	27	3	17	32	54	0	106
12	4	3	12	6	5	30	5	6	27	75	2	115
13	1	3	12	6	20	42	0	14	43	30	0	87
14	19	6	53	12	9	99	34	41	73	68	0	216
15	1	4	25	10	44	84	20	34	39	63	0	156
16	0	4	21	9	9	43	14	22	40	0	0	76
17	37	10	25	9	64	145	8	54	9	27	0	98
18	2	4	21	9	10	46	0	3	3	3	0	9
19	4	6	3	0	82	95	0	9	15	12	1	37
20	0	0	0	0	149	149	0	169	11	12	0	192
21	0	0	2	0	0	2	15	12	34	22	1	84
22	1	3	0	0	12	16	19	17	7	13	0	56
23	12	1	4	0	16	33	0	17	13	18	0	48
24	6	29	5	37	99	176	15	15	26	15	0	71
25	3	37	32	20	24	116	10	7	25	14	0	56
26	0	0	1	28	4	33	10	17	12	12	0	51
27	1	5	18	8	7	39	0	2	0	0	0	2
28	6	10	18	8	7	49	3	25	27	28	0	83
29	1	5	18	8	7	39	0	0	3	20	0	23
30	1	5	18	8	14	46	1	27	36	0	0	64
31	0	0	0	80	16	96	0	3	2	14	0	19
32	5	11	9	31	47	103	12	13	27	20	0	72
33	28	7	35	118	41	229	4	10	22	13	0	49
34	0	71	42	36	174	323	11	31	13	27	0	82
35	0	0	19	0	66	85	0	32	1	27	0	60
36	0	2	0	0	2	4	1	27	12	28	0	68
37	0	0	0	0	0	0	0	20	3	0	0	23
38	0	0	0	0	0	0	0	19	0	28	0	47
39	0	0	0	0	0	0	0	9	14	27	0	50
40	0	0	0	0	0	0	0	11	7	11	5	34
41	1	5	25	11	9	51	1	9	2	0	0	12
42	1	5	18	8	7	39	2	12	11	2	0	27

TAZ	IND	RET	HWY	OFF	SER	TOT	HH1	HH2	HH3	HH4	HH5	TOTHH
43	1	5	19	8	7	40	0	6	15	3	0	24
44	0	0	0	0	87	87	0	4	5	0	0	9
45	0	0	0	25	7	32	0	8	11	0	0	19
46	1	3	18	8	72	102	6	35	21	0	0	62
47	1	3	18	8	7	37	0	0	11	2	0	13
48	1	3	18	8	7	37	0	6	13	14	0	33
49	0	0	0	0	5	5	0	0	0	0	0	0
50	0	5	0	0	0	5	1	9	10	0	0	20
51	1	5	25	11	9	51	0	1	3	0	0	4
52	1	5	25	11	9	51	4	57	47	4	0	112
53	1	3	18	8	7	37	0	4	6	0	0	10
54	501	3	18	8	7	537	0	1	2	1	0	4
55	1	3	18	8	7	37	0	3	2	0	0	5
56	0	0	0	0	0	0	0	7	6	0	0	13
57	4	7	0	0	0	11	0	7	8	2	0	17
58	4	7	0	0	0	11	2	0	3	7	2	14
59	1	5	25	11	9	51	0	0	0	0	0	0
60	1	5	27	11	9	53	7	7	6	0	0	20
61	4	7	0	0	0	11	1	8	13	4	0	26
62	5	10	19	8	7	49	0	0	12	27	6	45
63	3	0	0	0	0	3	0	5	3	1	0	9
64	4	7	0	0	0	11	5	9	11	2	0	27
65	4	7	0	0	2	13	0	18	15	2	0	35
66	8	0	0	0	2	10	0	5	13	1	0	19
67	0	0	0	0	9	9	0	10	15	1	0	26
68	4	7	0	0	0	11	0	5	14	0	0	19
69	0	0	0	0	0	0	0	4	5	1	0	10
70	0	0	0	0	0	0	0	3	3	0	0	6
71	0	0	0	0	1	1	2	2	6	2	0	12
72	4	7	0	0	0	11	0	4	3	4	0	11
73	1	5	18	8	7	39	0	5	10	0	0	15
74	1	3	13	6	5	28	0	11	42	59	0	112

Appendix F – Future Year SYNTH Files

SYNTH Input File

Population of the planning area: 8819

STATION	ADT	TRUCK %	CLASS	PTTDES	ADT/CD
1. US 64 EAST	22400	14	P	54.00	0.20253
2. US 15/501 N	26100	5	P	44.00	0.23599
3. SR 1520	2300	2	L	12.00	0.02080
4. NC 87 N	6600	16	M	39.00	0.05967
5. SR 1346	2800	2	L	13.00	0.02532
6. US 64 W	20100	14	P	52.00	0.18174
7. SR 2159	1000	2	L	12.12	0.00904
8. NC 902	3800	7	J	22.00	0.03436
9. SR 1010	4000	3	L	16.00	0.03617
10. SR 1953	1000	2	L	12.00	0.00904
11. US 15/501 S	14500	11	M	42.00	0.13110
12. SR 1012	6000	17	J	39.00	0.05425

ROUTE CONTINUITY

```
 1  to  6 : US 64 EAST to US 64 W
 2  to  11 : US 15/501 N to US 15/501 S
 4  to  11 : NC 87 N to US 15/501 S
 6  to  1 : US 64 W to US 64 EAST
 11  to  2 : US 15/501 S to US 15/501 N
 11  to  4 : US 15/501 S to NC 87 N
```

SYNTH Output File

UNBALANCED THROUGH TRIP END MATRIX:

0	2398	58	416	77	3940	25	171	138	25	802	504
2267	0	68	488	90	1932	30	170	161	29	2364	500
12	11	0	29	7	10	2	14	12	2	56	40
1379	1275	16	0	22	1175	7	78	39	7	1639	231

```
    74    69     6    38     0    63     3    17    15     3    74
49
  4455  2242    52   372    69     0    23   157   123    22   717
462
     0     0     2     4     2     0     0     5     4     1     7
16
   515   476     9    58    12   439     4     0    21     4   111
107
   251   232    10    62    13   214     4    27     0     4   119
79
     0     0     2     4     2     0     1     5     4     0     7
16
  1783  3525    37  1003    50  1519    16   114    88    16     0
336
  1359  1256    15   100    20  1158     6    77    35     6   193
0

  DESIRED TOTALS:
  ---------------
 12096 11484   276  2574   364 10452   121   836   640   120  6090
2340

  FOLDED TRIP END MATRIX:
  -----------------------
     0
  2332     0
    35    40     0
   898   881    23     0
    76    80     7    30     0
  4198  2087    31   774    66     0
    13    15     2     5     2    11     0
   343   323    11    68    14   298     5     0
   194   196    11    50    14   169     4    24     0
    13    15     2     5     2    11     1     5     4     0
  1293  2944    47  1321    62  1118    12   113   104    12     0
   932   878    27   165    34   810    11    92    57    11   264
0

  TOTALS FOR FOLDED TRIP END MATRIX:
  ----------------------------------
 10326  9792   235  4222   388  9574    81  1297   827    80  7289
3283

  FRATAR FACTORS FOR THE MATRIX:
  ------------------------------
 1.171 1.173 1.173 0.610 0.938 1.092 1.499 0.645 0.774 1.495 0.836
0.713

  TRIP END MATRIX AFTER ITERATION # 16 :
  --------------------------------------
     0
  3725     0
    55    67     0
   570   602    15     0
    85    96     8    19     0
  5284  2830    41   546    66     0
    27    33     4     6     4    19     0
```

236	240	8	26	8	168	3	0				
167	182	9	24	9	119	3	15	0			
25	32	4	6	4	18	1	7	6	0		
1200	2944	44	687	45	848	11	75	72	10	0	
723	734	22	72	21	514	9	51	33	8	155	0

FRATAR FACTORS:

1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

BALANCED THROUGH TRIP MATRIX:

0	1862	27	285	43	2642	13	118	84	13	600	361
1862	0	33	301	48	1415	17	120	91	16	1472	367
27	33	0	7	4	20	2	4	5	2	22	11
285	301	7	0	9	273	3	13	12	3	344	36
43	48	4	9	0	33	2	4	5	2	23	10
2642	1415	20	273	33	0	10	84	59	9	424	257
13	17	2	3	2	10	0	2	2	1	5	4
118	120	4	13	4	84	2	0	7	3	37	26
84	91	5	12	5	59	2	7	0	3	36	16
13	16	2	3	2	9	1	3	3	0	5	4
600	1472	22	344	23	424	5	37	36	5	0	77
361	367	11	36	10	257	4	26	16	4	77	0

COLUMN TOTALS:

6048	5742	137	1286	183	5226	61	418	320	61	3045	1169

External-Internal Trip Calculations

Calculating External-Internal Trips from SYNTH Output			
Tot Ext Prod	Percent through	Through trips	Ext-Int trips
22400	0.5424	12150	10250
26100	0.4404	11494	14606
2300	0.123	283	2017
6600	0.39	2574	4026
2800	0.1321	370	2430
20100	0.5229	10510	9590
1000	0.1113	111	889
3800	0.223	847	2953
4000	0.1638	655	3345
1000	0.12	120	880
14500	0.42	6090	8410
6000	0.39	2340	3660
22400	0.5424	12150	10250
110600		47545	63055

Appendix G – Future Year IDS Files

<u>IDS Input File</u>

```
 IDS PITTSBORO FUTURE YEAR DATA 2025
  96 ZONES (74 ZONES+22 STATIONS)
    96       110600       28359
          80    22    50    28
         230   230   230   230   230
        1200  1000   800   700   500                        670    67
670  670
   100   100   100   100   100
030
   010   200   840   260   250
010
   020   200   840   260   250
010





   050   200   840   260   250
010
     1     5     6    16    26     2                          0    0    0
     2     5    10    20     6     2                          0    0    0
     3     5    14    34    23     4                          0    0    0
     4     5     6    13     3     1                          0    0    0
     5     5    10    17    30    11                          0    0    0
     6     6    20    54    45     6                          0    0    0
     7     1     8    26    31     3                          0    0    0
     8     8    10    45    42    64                          0    0    0
     9     0     1     0     0     0                          0    8    0
    10     0     3    12    12     0                          0    0    0
    11     5     8    24    20     4                          0    0    0
    12     7     9    19     9     6                          0    4    0
    13     5    16    55    17     1                          0    0    0
    14     9    15    55    25    10                          0    0    0
    15     8    10    40    28     5                          0    0    0
    16     9     9    61    26     8                          0    0    0
    17     8     9    30    58     2                          0    1    0
    18     9    12    24     7     1                          0    0    0
    19     1    12    15     9     0                          0    1    0
    20     0     0    11    45     0                          0   10    0
    21     1     9    19    12     5                          0    0    0
    22     0     1     7    17    19                          0    6    0
    23     0     5    13    17     0                          0    3    0
    24     0     3    11    15     5                          0    8    0
    25     0     1    10     7     0                          0    8    0
    26     0     0    12    17     4                          0    5    0
    27     7     8    18     7     1                          0    0    0
    28     7    16    45    30     4                          0    1    0
    29     7     8    21     5     1                          0    0    0
    30     7     8    54    32     2                          0    2    0
    31     0     1     2     3     0                          0   13    0
    32     0     0    72    13     2                          0    4    0
    33     0     1     7    10     4                          0    8    0
    34     0     0    13   120     5                          0    6    0
    35     0     0    51    17     0                          0   10    0
    36     0     1    12    12     1                          0    0    0
    37     0     0     3     5     0                          0    0    0
    38     0     1     0     4     0                          0    0    0
    39     0     0    14     9     0                          0    0    0
    40     5    11     7    11     0                          0    0    0
    41     9    11    27    14     2                          0    0    0
    42     7    10    29    17     3                          0    0    0
    43     7    11    34    11     1                          0    0    0
```

44	0	0	5	4	0	0	6	0
45	0	0	11	8	0	0	0	0
46	7	8	39	38	7	0	8	0
47	7	10	29	3	1	0	0	0
48	7	22	31	9	1	0	0	0
49	0	0	0	0	0	0	2	0
50	0	0	10	9	1	0	0	0
51	9	11	28	6	1	0	0	0
52	9	15	72	62	5	0	0	0
53	7	8	24	7	1	0	30	0
54	7	9	20	3	1	0	0	0
55	7	8	20	6	1	0	0	0
56	0	0	6	7	0	0	0	0
57	0	2	8	14	4	0	0	0
58	2	7	3	7	6	0	0	0
59	9	11	25	5	1	0	0	0
60	9	11	33	12	8	0	0	0
61	0	4	13	15	5	0	0	0
62	13	35	31	10	5	0	0	0
63	0	1	3	5	1	0	0	0
64	0	2	11	16	9	0	0	0
65	0	2	15	25	4	0	0	0
66	0	1	13	5	0	0	1	0
67	0	1	15	10	0	0	0	0
68	0	0	14	12	4	0	0	0
69	0	1	5	4	0	0	0	0
70	0	0	3	3	0	0	0	0
71	0	2	6	2	2	0	0	0
72	0	4	3	11	4	0	0	0
73	7	8	28	10	1	0	0	0
74	5	13	35	14	1	0	0	0
75								
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96								
1	0	0	0	0	1			
2	2	0	0	0	0			
3	3	11	0	0	0			
4	0	0	0	0	0			
5	0	0	0	0	1			
6	0	1	0	20	61			
7	7	17	10	20	157			
8	2	44	10	20	129			
9	103	0	9	4	0			
10	85	0	9	0	0			
11	0	0	0	20	52			

12	3	0	0	20	72
13	0	0	0	2	35
14	10	18	22	23	62
15	0	16	10	21	98
16	0	6	0	0	0
17	37	12	4	0	83
18	1	0	0	0	1
19	4	6	3	0	50
20	0	0	0	0	72
21	0	10	2	15	13
22	1	3	0	0	24
23	12	1	4	0	29
24	6	25	5	35	37
25	3	25	13	25	26
26	0	6	1	28	16
27	0	0	0	0	0
28	5	5	0	0	20
29	0	0	0	0	20
30	0	0	0	0	7
31	0	0	0	35	29
32	5	18	9	30	35
33	10	7	15	45	32
34	0	26	18	15	82
35	40	0	25	0	63
36	0	2	15	0	29
37	0	0	15	0	0
38	0	0	15	0	27
39	0	0	0	0	27
40	0	0	0	0	0
41	0	0	0	0	0
42	0	0	0	0	0
43	0	0	0	0	0
44	0	0	0	0	67
45	0	0	0	25	7
46	0	0	0	0	55
47	0	0	0	0	0
48	0	0	0	0	0
49	0	0	0	0	5
50	0	0	0	0	0
51	0	0	0	0	0
52	0	0	0	0	0
53	0	0	0	0	0
54	500	0	0	0	0
55	0	0	0	0	0
56	0	0	0	0	0
57	0	0	0	0	0
58	0	0	0	0	0
59	0	0	0	0	0
60	0	0	0	0	0
61	0	0	0	0	0
62	0	0	0	0	0
63	28	0	0	0	0
64	0	0	0	0	0
65	0	0	0	0	2
66	8	0	0	0	2
67	25	0	0	0	9
68	0	0	0	0	0
69	0	0	0	0	0
70	175	0	0	0	0
71	0	0	0	0	1
72	0	0	0	0	0
73	0	0	0	0	0
74	0	0	0	20	52
75					

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2953
     93
3345
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880
     95
8410
     96
3660
```

IDS Output File

Zone	hbwp	hbop	nhbp	extintp	hbwa	hboa	nhba	extinta
1	77	176	37	0	20	13	36	61
2	66	149	17	0	16	6	18	38
3	115	261	136	0	43	47	136	236
4	44	100	9	0	9	3	9	15
5	99	225	41	0	25	14	41	69
6	185	420	990	0	140	343	991	1668
7	94	213	2580	0	268	893	2580	4357
8	206	468	2548	0	295	882	2548	4296
9	2	4	480	0	134	150	480	1043
10	37	84	430	0	118	135	430	914
11	87	197	851	0	104	295	851	1432
12	74	168	1073	0	126	371	1073	1813
13	138	314	461	0	75	160	462	777
14	162	369	2032	0	196	702	2032	3443
15	130	295	1920	0	199	664	1919	3229
16	160	363	104	0	45	36	104	175

Zone	hbwp	hbop	nhbp	extintp	hbwa	hboa	nhba	extinta
17	148	337	1281	0	195	437	1281	2239
18	83	190	37	0	20	11	36	61
19	55	126	752	0	86	260	751	1272
20	71	161	837	0	102	290	837	1409
21	64	145	507	0	61	175	507	853
22	49	112	317	0	47	110	317	533
23	48	109	516	0	65	175	516	891
24	44	99	1267	0	137	437	1267	2140
25	24	56	1317	0	112	456	1317	2224
26	41	94	616	0	69	213	615	1036
27	64	145	17	0	14	6	18	30
28	147	334	321	0	69	110	321	548
29	66	149	244	0	37	85	244	411
30	146	332	122	0	43	42	122	206
31	8	19	742	0	75	257	742	1249
32	119	271	1294	0	142	448	1294	2194
33	28	63	1543	0	133	533	1543	2620
34	171	388	2082	0	211	721	2082	3504
35	93	211	1728	0	171	592	1729	3001
36	34	78	928	0	61	321	928	1561
37	10	24	570	0	20	197	570	960
38	7	15	878	0	50	304	878	1478
39	31	70	313	0	38	108	312	526
40	53	121	14	0	12	5	14	23
41	95	217	27	0	21	9	27	46
42	97	220	27	0	22	9	27	46
43	96	219	27	0	22	9	27	46
44	12	27	760	0	80	263	760	1280
45	25	58	380	0	43	132	380	640
46	137	311	665	0	97	230	665	1120
47	78	177	22	0	16	8	23	38
48	109	248	32	0	23	11	32	53
49	0	0	54	0	6	19	54	91
50	26	59	9	0	6	3	9	15
51	86	196	22	0	19	8	23	38
52	227	517	73	0	56	25	72	122
53	72	164	17	0	16	6	18	30
54	63	144	471	0	592	85	471	1935
55	65	149	17	0	14	6	18	30
56	17	39	5	0	3	2	5	8
57	36	81	9	0	9	3	9	15
58	35	79	9	0	8	3	9	15
59	81	183	22	0	17	8	23	38
60	107	243	32	0	24	11	32	53
61	48	110	14	0	13	5	14	23
62	149	340	41	0	32	14	41	69
63	13	30	27	0	35	5	27	114

Zone	hbwp	hbop	nhbp	extintp	hbwa	hboa	nhba	extinta
64	47	106	14	0	13	5	14	23
65	59	134	41	0	17	14	41	69
66	26	60	37	0	17	11	36	76
67	35	80	136	0	47	42	136	282
68	38	87	14	0	9	5	14	23
69	14	31	5	0	2	2	5	8
70	8	18	158	0	204	28	158	670
71	16	37	14	0	5	5	14	23
72	28	65	9	0	7	3	9	15
73	81	185	22	0	19	8	23	38
74	101	229	851	0	107	295	851	1432
75	0	0	0	0	0	0	0	0
76	0	0	0	0	0	0	0	0
77	0	0	0	0	0	0	0	0
78	0	0	0	0	0	0	0	0
79	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0
81	0	0	0	0	0	0	0	0
82	0	0	0	0	0	0	0	0
83	0	0	0	0	0	0	0	0
84	0	0	0	0	0	0	0	0
85	0	0	0	10250	0	0	0	0
86	0	0	0	14606	0	0	0	0
87	0	0	0	2017	0	0	0	0
88	0	0	0	4026	0	0	0	0
89	0	0	0	2430	0	0	0	0
90	0	0	0	9590	0	0	0	0
91	0	0	0	889	0	0	0	0
92	0	0	0	2953	0	0	0	0
93	0	0	0	3345	0	0	0	0
94	0	0	0	880	0	0	0	0
95	0	0	0	8410	0	0	0	0
96	0	0	0	3660	0	0	0	0