Traffic Forecasting Guidelines

August 2012

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Acknowledgments

These Traffic Forecasting Guidelines (Guidelines), document the Nevada Department of Transportation's (NDOT) techniques and accepted procedures for forecasting travel demand on NDOT maintained roadways within the State of Nevada (State). These Guidelines are a continuation of NDOT's efforts to develop and publish an improved and consistent traffic forecasting procedure.

These Guidelines have been developed using the Florida Department of Transportation (FDOT) *Project Traffic Forecasting Handbook* as a model. However, procedures, examples, and information specific to the State are included herein. These Guidelines outline the traffic forecasting process, which has been part of the State's forecasting procedures for several years, into one document.

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Chapter 1
Introduction and Overview

This chapter provides a general introduction and overview of the Traffic Forecasting Guidelines (Guidelines). This chapter discusses:

- The purpose and objectives of these Guidelines;
- A general overview of the nine chapters included in these Guidelines;
- The authority, references, definitions, and acronyms that are used throughout these Guidelines;
- The guiding principles that are relevant in creating and preparing traffic forecasts; and
- The deliverables necessary to complete the traffic forecasting process.

In addition, the Guidelines note useful references throughout to assist the analyst with the traffic forecasting process.

1.1. Purpose and Objective of the Traffic Forecasting Guidelines

The purpose of these Guidelines is to document the Nevada Department of Transportation's (NDOT) techniques and accepted procedures for forecasting travel demand on NDOT maintained roadways within the State of Nevada (State). Traffic forecasts are ultimately used to determine the number of lanes a corridor or project may require. The objective of the Guidelines is to facilitate the creation and evaluation of traffic forecasts that are reproducible and defendable, resulting in consistent and sound forecasts and analyses on all applicable transportation projects. The intended audience for these Guidelines are practitioners who develop traffic forecasts for state highways in Nevada. These Guidelines are written to eliminate conflicts and provide consistency in accepting and approving technical methodologies for traffic forecasts, which in turn lead to time and cost savings for applicants, consultants, travel demand model users, and NDOT.

In all, the Guidelines identify the traffic parameters necessary for accurate traffic forecasting across various types of transportation projects. The Guidelines also offer direction for producing traffic forecasts for planning projects, environmental analyses/studies, design projects, and operational studies/projects. Also presented is the method on how to use the outputs from travel demand models to produce traffic forecasts and how to implement historical trend projection analysis techniques for producing traffic forecasts when a travel demand model is not available for the project location.

1.2. Chapter Overview

These Guidelines consist of nine chapters, and a brief overview of each chapter is provided below.

Chapter One: Introduction and Overview

In part, this chapter describes an overall purpose and objective of these Guidelines, all current and applicable references, and the definitions used in the traffic forecasting process. The truth-in-data principle (requirements for reporting sources and uncertainties in forecast) and the rounding convention (American Association of State Highway and Transportation Officials [AASHTO] rounding convention to reflect uncertainty of estimates and forecasts) are both explained in this chapter.

Chapter Two: Traffic Forecasting for Different Types of Projects

This chapter refers the analyst to appropriate sections within the Guidelines that relate to specific project requirements. The chapter also addresses traffic forecasting requirements for planning projects, environmental analysis projects, design projects, and operational analysis projects, all the while directing the analyst to the appropriate Guidelines chapter for methodology descriptions.

Chapter Three: Traffic Data Sources and Factors

This chapter describes the traffic data sources and factors used in forecasting traffic, which are Seasonal Factors, Axle Factors, Annual Average Daily Traffic (AADT) volumes, the Design Hour Factor (K_{30}), the Directional Distribution Factor (D_{30}), and Truck Percent (T%). The chapter also speaks to the connection between these traffic factors and NDOT's sources for these factors. The relationship among Average Daily Traffic (ADT), the various traffic factors and AADT, and the procedure to estimate AADT volumes from ADT volumes is also explained with appropriate examples.

Chapter Four: Traffic Forecasting Parameters, K_{30} & D_{30}

This chapter describes the process of estimating K_{30} and D_{30} for future years. The chapter also discusses the acceptable value ranges of K_{30} and D_{30} by roadway functional classification. An example of estimating K_{30} and D_{30} for future years is provided alongside NDOT's policy for establishing forecast years and guidance on the time periods and years for which forecasts are to be developed.

Chapter Five: Traffic Forecasting with Travel Demand Models

This chapter presents a description of the appropriate methods and procedures for forecasting future corridor or project traffic in areas that have a travel demand model. The chapter explains the use of travel demand model outputs for traffic forecasting. Methods for using travel demand model outputs, analysis of travel demand model results, refinements to base year travel demand models, comparison of travel demand model performance, and reasonableness checks for future years in the traffic forecasting process are discussed therein. The chapter also provides acceptable accuracy levels for corridor and project specific use.

Chapter Six: Traffic Forecasting without a Travel Demand Model

This chapter describes the appropriate methods of performing historical trend projection analysis. Relevance of growth rates from historical traffic counts as well as examination of local land use plans, population forecasts, and other indicators of future growth in the traffic forecasting process are also included in the chapter.

Chapter Seven: Directional Design Hourly Volume Estimates

This chapter defines the appropriate method for the calculation of Directional Design Hourly Volumes (DDHV) from AADT volumes. DDHV is the basic traffic projection to be used in State roadway projects that require traffic forecasts.

Chapter Eight: Estimating Intersection Turning Movements

This chapter explains the popular methods and tools available for balancing and estimating turning movement volumes at intersections. Many of these tools use the techniques outlined in National Cooperative Highway Research Program (NCHRP) Report 255 and other iterative methods. The chapter includes a thorough overview of the preferred tool (TurnsW32) for use when estimating turning movements as well as the other techniques and tools that are acceptable for use in the State.

Chapter Nine: Truck Traffic Estimation

This chapter describes the guidelines and techniques for forecasting truck volumes.

Appendices

Appendix A offers guidance for identifying Automatic Traffic Recorders (ATRs) at locations with characteristics similar to that of the project location. Appendix B offers a simple calculation technique for obtaining balanced turning movement volumes from approach volumes at three-legged and four-legged intersections.

1.3. Authority

The following policies and statutes establish the authority upon which these Guidelines are structured.

- *Process for Requesting, Developing and Approving Traffic Data Used on NDOT Projects*, NDOT Policy # 03-03
- NDOT's Transportation Policy (TP)
- Nevada Revised Statutes (NRS) 277, 277A, 278, 278A, 408, 410, 481A, and 540A

1.4. References

The following references provide insight to assist the analyst with the traffic forecasting process.

AASHTO. 2011. *A Policy on Geometric Design of Highways and Streets*. 6th Edition.

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1.5. Definitions

The following are the definitions of terms used throughout these Guidelines. Many of these terms are referenced from the Highway Capacity Manual (HCM 2010), A Policy on Geometric Design of Highways and Streets (AASHTO), and the Process for Requesting, Developing, and Approving Traffic Data Used on NDOT Projects (NDOT Policy # 03-03).

Annual Average Daily Traffic (AADT): The total volume of traffic on a roadway segment for one year, divided by the number of days in the year. This volume is usually estimated by adjusting a short-term traffic count with seasonal factors.

Annual Average Day of Week (AADW): The estimate of traffic volume for each day of the week, over the period of one year. It is calculated from ATR data as the sum of all traffic for each day of the week during a year, divided by the occurrences of that day during the year.

Annual Average Weekday Traffic (AAWDT): The estimate of typical traffic during a weekday (usually defined as Monday through Friday) calculated from data measured at ATRs. If AAWDT was not estimated based on traffic during the weekdays defined above, the weekdays that were the basis for the AAWDT estimate are to be specified. (e.g., Monday through Thursday).

Adjusted Count: An estimate of a traffic statistic calculated from a base traffic count that has been adjusted by application of axle, seasonal, or other defined factors (AASHTO).

Average Daily Traffic (ADT): The total traffic volume during a given time period (more than a day and less than a year), divided by the number of days in that time period. The

days that were the basis for the ADT measurement are to be specified. (e.g., Tuesday, Wednesday).

Average Weekday Traffic (AWDT): The total volume of traffic on a roadway segment during the weekdays (Monday through Thursday) and during a given time period (less than a year), divided by the number of weekdays in that period. If AWDT was not estimated based on traffic during the weekdays defined above, the weekdays that were the basis for the AWDT estimate are to be specified. (e.g., Monday through Thursday).

Axle Factor: The factor developed to adjust vehicle axle sensor base data for the incidence of vehicles with more than two axles. Axle Factor is the estimate of total axles based on automatic vehicle classification data, divided by the total number of vehicles counted.

Base Count: A traffic count that has not been adjusted with Axle Factors (effects of trucks) or for seasonal (day of the week/month of the year) effects (AASHTO).

Base Data: The unedited and unadjusted measurements of traffic volume, vehicle classification, and vehicle or axle weight (AASHTO).

Base Year: The initial year of the forecast period; base year is the year from which projections are made. The base year could be the same as or different from the model calibration year. For example, the model calibration year could be 2008, the year from which planning variables data are input for calibration. However, the base year for forecasts could be 2011, the year for which the model traffic volumes were validated. Typically, the base year is as close as possible to the existing year.

Calibration (Model): An extensive analysis of a travel demand model based on census, survey, traffic count, and other information.

Capacity: The maximum sustainable hourly flow rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of a lane or roadway during a given time period under prevailing roadway, environmental, traffic, and control conditions (HCM 2010).

Count: The data collected as a result of measuring and recording traffic characteristics, such as vehicle volume, classification, speed, weight, or a combination of these characteristics (AASHTO).

Counter: Any person or device that collects traffic characteristics data.

Current Traffic Data: Traffic data as it is estimated to exist today (NDOT Policy # 03-03).

Cutline: Similar to a screenline; however, a cutline is shorter and crosses corridors rather than regional flows. Cutlines should be established to intercept travel along only one axis.

Daily Truck Volume: The total volume of trucks on a roadway segment in a day.

Demand Volume: The traffic volume expected to desire service past a point or segment of a roadway at some future time, or the traffic currently arriving or desiring service past such a point, usually expressed as vehicles per hour (vph).

Design Hour: An hour with a traffic volume that represents a reasonable value for designing the geometric and control elements of a roadway. Design hour is usually the 30^{th} highest hour of the design year.

Design Hour Volume (DHV): The traffic volume expected to use a roadway segment during the 30^{th} highest hour of the design year. The DHV is related to AADT by the K-factor.

Design Period: The number of years from the initial application of traffic until the first planned major resurfacing or overlay (AASHTO).

Design Year: The year for which the roadway is designed. This is usually 20 years from the opening year but may be any time within a range of years from the present (for restoration type projects) to 20 or more years in the future (for new construction type projects).

Directional Design Hour Volume (DDHV): The traffic volume expected to use a roadway segment during the 30^{th} highest hour of the design year in the peak direction.

D-Factor: The percentage of total, two-way peak hour traffic that occurs in the peak direction. D-factor is also known as Directional Distribution.

D_{30}: The proportion of traffic in the 30^{th} highest hour of the design year traveling in the peak direction.

Existing Year: The latest year for which field traffic data is available.

Factor: A number that represents a ratio of one number to another number. The factors used in these Guidelines are K-factor, D-factor, Peak Hour Factor (PHF), Seasonal Factor, and Axle Factor.

Forecast Period: The total length of time covered by the traffic forecast. It is equal to the period from the base year to the design year. For existing roads, the forecast period will extend from the year in which the forecast is made and, therefore, must include the period prior to the project being completed as well as the life of the project improvement.

Future Traffic Data: Traffic data that must be forecasted (NDOT Policy # 03-03).

Future Year: Any year that is later than the base year.

Historical Traffic Data: Traffic data from a time period before today (NDOT Policy # 03-03).

Horizon Years: Horizon years of the Regional Transportation Plan (RTP) are the years identified as those used for air quality modeling and project funding. Horizon years include the final year of the RTP and interim years. The interim years must begin "no more than 10 years from the base year used to validate the transportation demand planning model," be no more than 10 years apart, and end no later than the plan.

Interim Year: Interim year can be any year between the opening year and the design year of a project. It is usually 10 years into the future from the opening year of a project and 10 years prior to the design year of the project.

K-Factor: The ratio of the traffic volume in the study hour to the AADT.

K_{30}: The proportion of AADT occurring during the 30^{th} highest hour of the design year. K_{30} is also commonly known as the Design Hour Factor.

Level of Service (LOS): A quantitative stratification of a performance measure or measures that represent quality of service. LOS is measured on an A to F scale, with LOS A representing the best operating conditions from the traveler's perspective and LOS F the worst (HCM 2010).

Long Range Plan: A document with a 20-year planning horizon required of each MPO that forms the basis for an annual transportation improvement program (TIP). A long range plan is developed pursuant to Title 23 United States Code 134 and Title 23 Code of Federal Regulations Part 450 Subpart C. The long range plan is also known as the RTP.

Model Calibration Year: The year the travel demand model was calibrated for, and the year the planning variables (land use, population, etc.) were based upon.

Model Output Conversion Factor (MOCF): The MOCF is used to convert the traffic volumes (if other than AADT) generated by a travel demand model to AADT.

Monthly Average Daily Traffic (MADT): The estimate of mean traffic volume for a month, calculated by the sum of Monthly Average Days of the Week (MADWs) divided by seven; or in the absence of a MADW for each day of the week, divided by the number of available MADWs during the month (AASHTO).

Monthly Average Days of the Week (MADW): The estimate of traffic volume for each day of the week over the period of one month. MADW is calculated from ATR data as the sum of all traffic for each day of the week during a month, divided by the occurrences of that day during the month.

Monthly Average Weekday Traffic (MAWDT): The estimate of traffic volume for weekdays (defined as Monday through Thursday in the State) over the period of a given month. It is calculated from ATR data as the sum of all traffic for weekdays (Monday through Thursday in the State) of the month, divided by the number of occurrences of weekdays during the same month.

Monthly Average Weekend Traffic (MAWET): The estimate of traffic volume for the weekends (Saturday and Sunday) over the period of a given month. It is calculated from ATR data as the sum of all traffic for the weekends (Saturday and Sunday) during a month, divided by the number of occurrences of weekend days during the same month.

Monthly Seasonal Factor: A seasonal adjustment factor derived by dividing the AADT by the MADT.

Opening Year: The year in which a given roadway will be opened/available for use by the public.

Peak Hour Factor (PHF): The hourly volume during the analysis hour divided by the peak 15-minute flow rate within the analysis hour. The PHF is also considered a measure of traffic demand fluctuation within the analysis hour (HCM 2010).

Peak Hour-Peak Direction: The direction of travel (during the 60-minute peak hour) that contains the highest percentage of travel.

Peak-to-Daily Ratio: The highest hourly volume of a day divided by the daily volume.

Permanent Count: A traffic count continuously recorded at an ATR.

Regional Transportation Plan (RTP): An RTP is an urbanized region's long-term plan for its transportation system. An RTP serves as a region's master plan for guiding future transportation investments and often has a time horizon of 20 to 30 years into the future. An RTP may also be referred to as a region's long range transportation plan, and it is prepared and adopted by a region's MPO (see long range plan). An RTP is based on projections of growth and economic activity and the resulting need for improvements to transportation infrastructure. An RTP is required by State and federal law for MPOs designated in urbanized areas with a population greater than 50,000.

Screenline: An imaginary line that intercepts major traffic flows through a region. A screenline is usually along a physical barrier, such as a river or railroad tracks, and splits

a study area into parts. Traffic counts and possibly interviews are conducted along this line as a means to compare simulated travel demand model results to field results as part of the calibration/validation of a travel demand model.

Seasonal Factor: Parameters used to adjust base counts that consider travel behavior fluctuations by day of the week and month of the year.

Service Flow Rate: The maximum directional rate of flow that can be sustained in a given segment under prevailing roadway, traffic, and control conditions without violating the criteria for a given LOS standard (HCM 2010).

Standard Deviation: A measure of the dispersion of a set of data from its mean.

T_{P-D}: The proportion of daily truck traffic occurring in the peak hour of truck traffic. T_{P-D} is the ratio of peak hour truck volume to the daily truck volume.

Traffic Analysis Zone (TAZ): The basic unit of analysis representing the spatial aggregation of people within an urbanized area. A TAZ may have a series of zonal characteristics associated with it that are used to explain travel flows among zones. Typical characteristics include the number of households and the number of people that work and/or live in a particular area.

Traffic Data: Any measure of movement by persons or vehicles (NDOT Policy # 03-03).

Truck Percent (T%): The proportion of the number of trucks on a roadway to the total number of vehicles on the roadway, expressed as a percentage.

Validation: An analysis of a travel demand model based on traffic count and other information. A validation is usually less extensive than a calibration.

Vehicle Hours of Travel (VHT): A statistic describing the amount of vehicular travel time in a given area. It is calculated by multiplying the total number of vehicles with the total number of hours that vehicles travel. The VHT is most commonly used to compare alternative transportation systems in a planning context. In general, if alternative “A” reflects a VHT of 150,000 and alternative “B” reflects a VHT of 200,000, it can be concluded that alternative “A” is better in that drivers are getting to their destinations quicker.

Vehicle Miles of Travel (VMT): A statistic describing the amount of vehicular travel in a given area. It is calculated by multiplying the total number of vehicles with the total number of miles that are traversed by those vehicles.

Volume to Capacity Ratio (v/c): Either the ratio of demand volume to capacity or the ratio of service flow volume to capacity, depending on the particular situation.

1.6. Acronyms

The following is a list of the acronyms that are used throughout these Guidelines.

ADT	Average Daily Traffic
AADT	Annual Average Daily Traffic
AADW	Annual Average Day of Week
AASHTO	American Association of State Highway and Transportation Officials
AAWDT	Annual Average Weekday Traffic
ADT	Average Daily Traffic
ATR	Automatic Traffic Recorder
AWDT	Average Weekday Traffic
D-Factor	Proportion of traffic in the peak direction
D_{30}	Proportion of traffic in the peak direction for the 30th highest hour
DAF	Day Factor
DHV	Design Hour Volume
DDHV	Directional Design Hour Volume
FHWA	Federal Highway Administration
FTP	File Transfer Protocol
HCM	Highway Capacity Manual
K-Factor	Ratio of DHV to AADT
K_{30}	Ratio of DHV to AADT for the 30th highest hour
LGCP	Local Government Comprehensive Plan
LOS	Level of Service
MADT	Monthly Average Daily Traffic
MADW	Monthly Average Day of Week
MAWDT	Monthly Average Weekday Traffic (Weekdays considered: Monday to Thursday)
MAWET	Monthly Average Weekend Traffic
MOCF	Model Output Conversion Factor
MPO	Metropolitan Planning Organization
NCHRP	National Cooperative Highway Research Program
NDOT	Nevada Department of Transportation
NEPA	National Environmental Policy Act
PHF	Peak Hour Factor
RTP	Regional Transportation Plan
TAZ	Traffic Analysis Zone
TMS	Traffic Monitoring System
TRINA	Traffic Records Information Access
v/c	Volume to Capacity Ratio
VHT	Vehicle Hours of Travel

VMT	Vehicle Miles of Travel
vph	Vehicles Per Hour

1.7. Guiding Principles and Standards when Preparing and Documenting Traffic Forecasts

The truth-in-data principle and the rounding convention are both to be applied when preparing and documenting traffic forecasts.

1.7.1. Truth-in-data Principle

The controlling truth-in-data principle for creating traffic forecasts is to express the sources and uncertainties of the forecast. The goal of the principle is to provide the person reviewing the forecast with the information needed to make appropriate choices regarding the applicability of the forecast for particular purposes. For the analyst (the developer of the traffic forecast), it means clearly stating the input assumptions and their sources, defining known uncertainties, and providing the forecast in a form that a reviewer can understand and use.

1.7.2. Rounding Convention

To reflect the uncertainty of estimates and forecasts, volumes are to be reported according to the following rounding convention. Table 1-1 specifies the rounding convention relevant to the calculation of AADT; this rounding convention was adapted from AASHTO standards.

Table 1-1 Rounding Convention - Calculation of AADT

Forecast Volume	Round to Nearest
<100	10
100 to 999	50
1,000 to 9,999	100
10,000 to 99,999	500
>99,999	1,000

In the case of the calculation of DDHV, greater precision is usually required, and therefore, the estimates are to be rounded to the nearest 10. The analyst is to use five as the minimum value for a projected turning movement volume.

These recommendations apply only to reported values. The unrounded values are to be retained for the calculations and analysis; rounded values are not to be used in subsequent calculations.

1.8. Traffic Forecasting Documentation and Deliverables

Documenting all data sources, proposed methodology, assumptions, and deviations from the standard process are critical to successfully developing and presenting traffic forecast data and results. The following two required deliverables are designed to document the steps taken and results of the traffic forecasting process.

1.8.1. Methodology Memorandum

The analyst is to submit a traffic forecasting methodology memorandum to NDOT before beginning the process of traffic forecasting. The proposed traffic forecasting methodology may be submitted to NDOT as a part of an overall traffic analysis methodology memorandum, in this case the traffic forecasting methodology would be a sub-section of the traffic analysis methodology memorandum. The objective of the methodology memorandum is to document all the data sources, proposed methodology, and the assumptions involved in the traffic forecasting process along with securing NDOT's approval before beginning the process. It is recommended that the analyst document the following information when preparing the methodology memorandum.

- All data sources must be described. These sources may include:
  - The ATRs or NDOT short-term count stations from which the traffic parameters will be obtained.
  - Truck data from NDOT or other sources that will be used in the forecast.
  - Other relevant data (such as population, gas sales records, and economic activity) that will be used in the forecast, including all respective sources.
- Methodology must be clearly defined. Methodology may entail:
  - Description of the project location and the geographic limits.
  - Proposed base year, opening year, adopted RTP horizon year, and design year (as relevant to the project).
  - Forecast scenarios.
  - The duration, location, and the process of conducting the count if short-term counts are proposed to be conducted.
  - The use of a travel demand model versus historical data to obtain future year AADT.
    - If a travel demand model is chosen for traffic forecasting, information must be included about the travel demand model chosen for use.
    - If a travel demand model is unavailable or not chosen, information must be included about the data (traffic, gas sales, population) used in the historical trend analysis.
  - Truck traffic data and the forecasting methodology to be used.
- All assumptions must be documented, which could involve future land-use and network assumptions and various other assumptions (as applicable).

If the project is unique and NDOT's guidance is needed, the analyst may request a methodology meeting to discuss and build consensus regarding the methodology to be used in the traffic forecasting process.

1.8.2. Traffic Forecast Memorandum

A traffic forecast memorandum is to be developed and submitted to NDOT at the conclusion of the traffic forecasting process. This memorandum is to document every procedural step that was applied when developing the traffic forecast. The memorandum and related forecast are to adhere to the methodology memorandum that was approved by NDOT, including data sources, methodology, and assumptions that were used in the traffic forecasting process. The memorandum should also list all relevant references used in preparation of the forecasts. A checklist is provided as Table 1-2; this checklist is to be completed and attached with the traffic forecast memorandum. Only the specific guidelines that were followed in developing the traffic forecast and the traffic forecast memorandum should be checked in the checklist.

The following chapters provide guidelines for each step of the traffic forecasting process; specific information and details that are required for inclusion in the traffic forecast memorandum are also listed.

Table 1-2 Traffic Forecasting Guidelines Checklist

Instructions: Please check-off the specific guidance from the Traffic Forecasting Guidelines that were followed in the preparation of your traffic forecast			
No.	**Item**	**Description**	**Check**
1	Definitions	Terms used in your traffic forecast are in accordance with the definitions provided in the Traffic Forecasting Guidelines.	
2	Truth in Data Principle	The traffic forecast satisfies the requirements of the Truth in Data principle.	
3	Rounding Convention	The traffic forecast was developed adhering to the rounding convention.	
4	Methodology Memorandum	A methodology memorandum document was prepared and submitted to NDOT as per guidance offered in the Traffic Forecasting Guidelines. Any changes from the accepted methodology memorandum are documented clearly in the traffic forecasting report.	
5	Traffic Factors (Seasonal Factors, Axle Factors, AADT, K_{30}, D_{30}, T%, etc.)	The traffic factors were obtained according to the guidance offered in the Traffic Forecasting Guidelines.	
6	Data Sources	The data sources were chosen according to the guidance offered in the Traffic Forecasting Guidelines.	
7	Adjusting K_{30} and D_{30}	K_{30} and D_{30} values were adjusted according to the guidance offered in the Traffic Forecasting Guidelines.	
Items 8 through 10 are relevant only if a travel demand model was used for traffic forecasting.			
8	Accuracy Levels	The accuracy levels listed in the Traffic Forecasting Guidelines were met or the necessary NCHRP Report 255 adjustments were performed.	
9	Model Output Conversion Factor (MOCF) (if needed)	An MOCF was estimated to obtain AADT from model outputs.	
10	Reasonableness Check with Historical Trend Projection	Historical trend projection was carried out to evaluate the reasonableness of the model projected volumes.	
11	Historical Trend Projection	A historical trend projection analysis was carried out according to the guidance in the Traffic Forecasting Guidelines.	
12	Constrained Facilities (if needed)	Guidance offered in the Traffic Forecasting Guidelines pertaining to constrained facilities was adopted.	
13	Peak Hour Volumes from DDHV	Peak hours of traffic were identified and the peak hour volumes were obtained from DDHV as per guidance offered in the Traffic Forecasting Guidelines.	
14	Estimation of Intersection Turning Movements	Intersection turning movements were estimated following recommended methodologies.	
15	Truck Traffic Forecasting	Truck traffic was forecast according to the guidance offered in the Traffic Forecasting Guidelines.	
Comments			

Chapter 2
Traffic Forecasting for Different Types of Projects

This chapter provides a very brief overview of the information relevant to traffic forecasting on four specific types of projects. The chapter details general traffic parameters related to each type of project and offers chapter references within these Guidelines where additional discussions specific for each project type is further detailed.

2.1. Common Types of Projects

Traffic forecasting is often done for four different types of projects:

- Planning projects (e.g., corridor studies, sub-area plans, long range transportation plans, regional plans),
- Environmental analysis projects (e.g., projects that seek NEPA clearance, such as environmental assessments, environmental impact studies, and request for change of access to access controlled roadways),
- Design projects (e.g., final design of new [or physical improvements to] any State roadway), and
- Operational analysis projects (e.g., operational analysis of any State roadway or interstate, action plans, traffic impact studies [build-out horizon of five years or less]).

Any project that is completed or embarked on prior to pursuing NEPA clearance may be considered a planning project, although it must be noted that planning projects may require a greater level of detail to make it compatible with Planning and Environmental Linkage studies. Planning projects usually require the development of travel projections, which are used to make decisions that have important capacity and capital investment implications. Traffic forecasting for planning projects determines the required number of lanes to meet the future anticipated traffic demands. Traffic forecasting is required before establishing a new alignment and for expansion of existing roadways.

Traffic forecasting for other projects (i.e., environmental analysis projects, design projects, and operational analysis projects) require higher accuracy compared to planning projects. Of these projects, the degree of detail needed in traffic forecasting is the highest for operational analysis projects. However, the geographical extent and scope of the traffic forecasting process is largest for environmental analysis projects, smaller for design projects, and comparatively the smallest for operational analysis projects. Traffic forecasts are commonly used to develop lane requirements, determine intersection designs, and evaluate the operational efficiency of proposed improvements.

Figure 2-1 illustrates the varying scope and required accuracy levels for these four different types of projects.

Figure 2-1 Contrasting Characteristics of the Different Types of Projects

2.2. Traffic Parameters and Chapter References by Project Type

Not all traffic parameters are uniformly required for developing traffic forecasts for different types of projects. Table 2-1 lists some of the typical traffic parameters that are required; however, other parameters may also be needed for the completion of these projects. The estimation of these typical parameters is explained in the subsequent chapters, and the following lists the specific chapters of this Guidelines to refer to when developing the traffic forecast depending on the type of the project and the specific project requirements.

2.2.1. Traffic Forecasting for Planning Projects

To forecast traffic for planning projects, refer to the following chapters.

- Chapter 3: Traffic Data Sources and Factors
- Chapter 4: Traffic Forecasting Parameters, K_{30} & D_{30}
- Chapter 5: Traffic Forecasting with a Travel Demand Model
- Chapter 6: Traffic Forecasting without a Travel Demand Model
- Chapter 7: Directional Design Hourly Volume Estimates
- Chapter 9: Truck Traffic Forecasting

Table 2-1 Traffic Parameters for the Different Types of Projects[1]

Planning Projects	Environmental Analysis Projects	Design Projects	Operational Analysis Projects
The following parameters are needed for the base year or existing year, opening year, and design year of the project: • AADT, • K-factor, • D-factor, • Peak hour volumes, • PHF, and • Daily and peak hour truck volumes or T%.	**Analysis of Noise Impacts** The following parameters are needed for the base year or existing year, opening year, and the design year for the No-Action alternative and Build alternatives of the project: • AADT, • Peak hour volumes and resulting LOS, • LOS C, or representative LOS C hourly volumes by direction if the roadway(s) operate at LOS D or worse, and • Vehicle mix volumes or percentages. **Analysis of Air Quality Impacts** The following parameters are needed for the base year or existing year, opening year, adopted RTP horizon years, and the design year for the No-Action Alternative and Build alternatives of the project: • AADT, • Peak hour volumes and resulting LOS,	The following parameters are needed for the design year of the project: • AADT, • K_{30}, • D_{30}, • Peak hour volumes, • Peak hour intersection turning movement volumes, • PHF, and • Peak hour truck volumes by class. Additionally, AADT projections are to be prepared for the opening year and the interim year of a project per NDOT's Road Design Guide.	The following parameters are needed for the analysis years/scenarios of the project: • Peak hour volumes in 15 minute increments, • Peak hour intersection turning movement volumes in 15 minute increments, • PHF, • Peak hour truck volumes by class, and • Seasonal Factor

Planning Projects	Environmental Analysis Projects	Design Projects	Operational Analysis Projects
	• Peak hour intersection turning movement volumes, and • Vehicle mix volumes or percentages.		

[1] This table is not intended to be a comprehensive listing of all the parameters needed for the completion of the different types of projects. Rather, the table lists only the parameters that are related to the traffic forecasting process explained in these Guidelines.

2.2.2. Traffic Forecasting for Environmental Analysis Projects

To forecast traffic for environmental analysis projects, refer to the following chapters.

- Chapter 3: Traffic Data Sources and Factors
- Chapter 4: Traffic Forecasting Parameters, K_{30} & D_{30}
- Chapter 5: Traffic Forecasting with a Travel Demand Model
- Chapter 6: Traffic Forecasting without a Travel Demand Model
- Chapter 7: Directional Design Hourly Volume Estimates
- Chapter 8: Estimating Intersection Turning Movements
- Chapter 9: Truck Traffic Forecasting

2.2.3. Traffic Forecasting for Design Projects

To forecast traffic for design projects, refer to the following chapters.

- Chapter 3: Traffic Data Sources and Factors
- Chapter 4: Traffic Forecasting Parameters, K_{30} & D_{30}
- Chapter 5: Traffic Forecasting with a Travel Demand Model
- Chapter 6: Traffic Forecasting without a Travel Demand Model
- Chapter 7: Directional Design Hourly Volume Estimates
- Chapter 8: Estimating Intersection Turning Movements
- Chapter 9: Truck Traffic Forecasting

2.2.4. Traffic Forecasting for Operational Analysis Projects

To forecast traffic for operational analysis projects, refer to the following chapters.

- Chapter 3: Traffic Data Sources and Factors
- Chapter 4: Traffic Forecasting Parameters, K_{30} & D_{30}
- Chapter 6: Traffic Forecasting without a Travel Demand Model
- Chapter 7: Directional Design Hourly Volume Estimates
- Chapter 8: Estimating Intersection Turning Movements
- Chapter 9: Truck Traffic Forecasting

Note that traffic operational improvements such as improving shoulders or turn lanes, or restriping roads for operational improvements, are not covered in these Guidelines.

Chapter 3
Traffic Data Sources and Factors

Traffic data is the foundation of roadway transportation planning and is used in making numerous traffic operations and design decisions. Since accurate traffic data is a critical element in the transportation planning process, understanding and implementing the traffic forecasting process accurately can lead to better design decisions. This chapter provides an overview of the traffic data sources and factors outlined in these Guidelines. Because DDHV is usually the desired output from the traffic forecasting process and is essential when analyzing the different types of transportation projects, this chapter also explains the relationship between DDHV and AADT.

Beyond this, the chapter describes:

- How traffic data is collected and maintained;
- Definitions of permanent counts, classification counts, and short-term traffic counts;
- How to apply traffic adjustment factors;
- Definitions and calculation of AADT, K_{30}, D_{30}, T% and PHF; and,
- How to locate and determine data sources.

The chapter also presents a sample case of how to estimate AADT based on real world examples and calculations.

3.1. Traffic Data Collection Procedure

NDOT collects and stores a broad range of traffic data to assist transportation engineers in designing, maintaining, and operating safe, state-of-the-art, and cost-effective roadways. Current data on motor vehicle trends is often used to help design new construction that will serve the volume and type of traffic a roadway will carry or select new routes that serve the greatest area and maximum number of motorists while maintaining cost efficiency. NDOT Traffic Information Division is responsible for the collection, tabulation, and analysis of the trends related to type and volume of traffic on the State's roadway system.

Actual AADT, K_{30}, and D_{30} data are collected from ATRs. AADT is estimated for all other locations by applying adjustment factors (Seasonal Factors and Axle Factors [if needed]) to the traffic data from short-term count stations.

3.2. Permanent Counts and Classification Counts

The various traffic parameters, including actual AADT, K_{30}, D_{30}, T%, Seasonal Factors, and Axle Factors, are measured from the field using permanent count stations (ATRs) and classification count stations. These sources provide the base traffic data and the traffic adjustment factors for select locations throughout the State. This information is used, in conjunction with short-term traffic counts, to obtain AADT and other traffic forecast parameters. Short-term traffic counts are comparatively easier and less expensive to conduct because these counts do not involve

monitoring traffic throughout the year. NDOT's use of ATRs and classification count stations is explained below.

3.2.1. Automatic Traffic Recorders (ATRs)

NDOT staff collects data through permanently installed traffic counters located throughout the State. During 2010, hourly traffic volumes were monitored continuously at 94 locations Statewide at sites commonly referred to as ATRs. ATRs continuously record the distribution and variation of traffic flow by hours of the day, days of the week, and months of the year from year to year. The traffic information collected is used to produce the AADT, K-factor, and D-factor data for each permanent counter location. The information is also used to estimate seasonal factors, K_{30}, and D_{30}.

3.2.2. Automatic Vehicle Classification

NDOT collects vehicle classification distributions based on the number of vehicle axles as defined by FHWA. Figure 3-1 illustrates the FHWA Classification Scheme "F." These classification counts are used to calculate T% and Axle Factors. The automatic vehicle classification conducted by NDOT may either be permanent or short-term. The Permanent Continuous Vehicle Classification method is designed to collect vehicular and classification traffic counts 24 hours a day throughout the year. Whereas, the Short Term Vehicle Classification method is designed to collect vehicular and classification traffic counts for up to seven continuous days, 24 hours per day.

3.3. Short-Term Traffic Counts

As noted previously, it is often financially infeasible to operate permanent counters throughout the State. For this reason, short-term traffic counts are conducted at many locations. The count data from these short-term counters are used to calculate AADT. Short-term counts are carried out at approximately 3,600 locations Statewide. Traffic count locations are placed with emphasis on providing representative data for each segment of a roadway with unique traffic characteristics. NDOT roughly defines a segment of roadway as having unique traffic characteristics when that segment exhibits a 10 percent or greater difference in annual traffic volume compared to adjacent segments for the same roadway.

The volume data from the short-term count locations are taken and factored for seasonality and day of week using factors derived from permanent count locations. Traffic recorders are temporarily placed at specific locations throughout the State to record the distribution and variation of traffic flow.

FHWA CLASSIFICATION SCHEME "F"

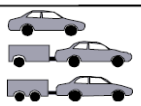
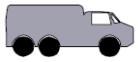
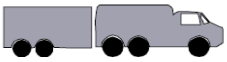
CLASS GROUP		DESCRIPTION	NO. OF AXLES
1		MOTORCYCLES	2
2		ALL CARS CARS W/ 1-AXLE TRAILER CARS W/ 2-AXLE TRAILER	2 3 4
3		PICK-UPS & VANS 1 & 2 AXLE TRAILERS	2, 3, & 4
4		BUSES	2 & 3
5		2-AXLE, SINGLE UNIT	2
6		3-AXLE, SINGLE UNIT	3
7		4-AXLE, SINGLE UNIT	4
8	  	2-AXLE, TRACTOR, 1-AXLE TRAILER (2S1) 2-AXLE, TRACTOR, 2-AXLE TRAILER (2S2) 3-AXLE, TRACTOR, 1-AXLE TRAILER (3S1)	3 4 4
9	 	3-AXLE, TRACTOR, 2-AXLE TRAILER (3S2) 3-AXLE, TRUCK, W/ 2-AXLE TRAILER	5 5
10		TRACTOR W/ SINGLE TRAILER	6 & 7
11		5-AXLE MULTI-TRAILER	5
12		6-AXLE MULTI-TRAILER	6
13	ANY 7 OR MORE AXLE		7 or more
14	NOT USED		
15	UNKNOWN VEHICLE TYPE		

Figure 3-1 FHWA Classification Scheme "F"

Source: FDOT, Project Traffic Forecasting Handbook 2012

3.4. Applying Traffic Adjustment Factors

The summary statistics from the ATRs and from the vehicle classification locations are used to obtain traffic adjustment factors (Seasonal Factors and Axle Factors). These traffic adjustment factors are applied to short-term traffic count locations to convert the traffic counts to AADT. Note that the AADT shown in NDOT hourly traffic reports (see Figure 3-3) are final adjusted AADT estimates, the adjustment factors should not be applied to this AADT value.

3.4.1. Seasonal Factor

AADT and MADT for each ATR are calculated from the data recorded by the ATRs. To calculate MADT, the data for each day of the week from the ATRs is averaged for the month. Following this, the seven average days (Sunday through Saturday) are averaged, which provides the MADT. The twelve MADTs (January through December) are then averaged, which yields the AADT. The Monthly Seasonal Factor for a particular month at a particular location is derived from the AADT for that location divided by the MADT for that month at that count site. Monthly Seasonal Factor is expressed as follows.

$$\text{Monthly Seasonal Factor} = \frac{\text{AADT}}{\text{MADT}}$$

3.4.2. Axle Factor

If axle counters are used to conduct a short-term traffic count, an Axle Factor would be needed in addition to the Seasonal Factor to calculate AADT from the traffic counts. However, most traffic counts use vehicle counters (rather than axle counters), and, therefore, the use of Axle Factors is often unneeded. NDOT may be contacted if Axle Factors are required due to the use of axle counters for a short-term count. In general, NDOT recommends that vehicle counters rather than axle counters be used for short-term counts.

3.5. AADT, K_{30}, D_{30}, T% and PHF

For traffic forecasting purposes, the data measured in the field is used to identify AADT, K-factor, D-factor, and T%. AADT is the best measure of the total use of a roadway and for use in traffic forecasts because it includes all traffic for an entire year. K_{30}, D_{30}, and T% are related to AADT. ATRs collect data 365 days a year, and at these ATR locations, actual AADT, K_{30}, D_{30}, and T% are measured. This information provides a statistical basis for estimating AADT, K_{30}, D_{30}, and T% for all other locations where short-term traffic counts were obtained. The following explain AADT, K_{30}, D_{30}, and T% factors in addition to the steps required to calculate each factor.

3.5.1. Annual Average Daily Traffic (AADT)

AADT is the estimate of typical daily traffic on a roadway segment for all seven days of the week over the period of one year. Conceptually, AADT is determined by dividing the total volume of

traffic on a roadway segment for one year by the number of days in the year. In order to calculate AADT from ATR data, the data for each day of the week is averaged for the month. Following this and as noted in part above, the seven average days (Sunday through Saturday) are averaged, which provides MADT. The 12 MADTs (January through December) are then averaged, which yields the AADT.

ADT is the average number of vehicles (two-way) passing a specific point in a 24-hour period. ADT is obtained by short-term traffic counts. ADT is typically a seven day, 24 hours per day, traffic count divided by seven. For traffic forecasts, the Seasonal Factor and Axle Factor (if needed) should be used to convert ADT to AADT.

$$\text{AADT} = \text{ADT} \times \text{Seasonal Factor} \times \text{Axle Factor}^*$$

*An Axle Factor is needed only if an axle counter is used for conducting the short-term counts.

3.5.2. K-Factor and K_{30}

K-factor is the proportion of AADT occurring in an hour. The K-factor is critical in traffic forecasts because it defines the peak hours of roadway use, which is typically traffic going to and from work. It is appropriate to design the system to handle this level of congestion because this is the system's period of maximum usage.

It is not financially feasible, however, to build for the peak hour of the year, so the 30th highest hour of the year is chosen as the design hour. K_{30} is the proportion of AADT occurring during the 30th highest hour of the design year. AADT and DHV are related to each other by the ratio commonly known as K_{30} and is expressed as follows.

$$\text{DHV} = \text{AADT} \times K_{30}$$

K_{30} is measured and not artificially computed using a mathematical equation. However, it is not possible to measure K_{30} at every count site because that would require traffic data collection over the entire year. For this reason, the information gathered by the ATRs is used to estimate K_{30} when short-term traffic counts are used. The basic assumption is that K_{30} is based on roadway type and land use characteristics and is relatively similar as long as the roadway type and land use characteristics stay constant.

The analyst must be aware that the Peak-to-Daily ratio is distinct from the K-factor. The Peak-to-Daily ratio is the proportion of the highest hourly volume in a day to the total daily volume; whereas, the K-factor is the proportion of traffic volume during any given hour to the AADT.

3.5.3. D-Factor and D_{30}

D-factor is the proportion of total, two-way peak hour traffic that occurs in the peak direction. In addition to the K-factor, the D-factor of traffic is also an important factor in traffic forecasting. D_{30} is the proportion of traffic in the 30th highest hour of the design year traveling in the peak

direction. Generally, the DDHV for the design year is the basis of the geometric design. The DDHV is the product derived by multiplying the DHV and D_{30} and is expressed as follows.

$$DDHV = DHV \times D_{30}$$

Figure 3-2 illustrates the various traffic factors and their application when calculating DDHV.

3.5.4. Truck Percent (T%)

NDOT's vehicle classification program consists of a mix of permanent/continuous counter vehicle classification devices and short-term vehicle classification devices. Short Term Traffic Monitoring/Vehicle Classification sample data are collected throughout the year at predetermined locations on a three year data collection cycle. The vehicle classification data provide the composition of traffic by vehicle types, and these classification counts are used to calculate the T%. NDOT has previously published the typical T% for each functional class of roadway in the State within their Annual Traffic Reports. In the future, NDOT plans to report truck AADT for State roadways. T% may be calculated for a specific roadway segment by dividing the truck AADT (if available) by the total AADT for that roadway segment. Truck AADT may be obtained from NDOT's Annual Vehicle Classification Report, and the total AADT may be obtained from NDOT's short-term count stations or ATRs. T% is expressed as follows.

$$T\% = \frac{\text{Truck AADT}}{\text{Total AADT}}$$

The analyst is recommended to consult NDOT regarding the availability of hourly truck volumes.

3.5.5. Peak Hour Factor (PHF)

PHF is the hourly volume during the analysis hour divided by the peak 15-minute flow rate within the analysis hour. PHF is a measure of the traffic demand fluctuation within the analysis hour and is expressed as follows.

$$PHF = \frac{\text{Hourly Volume}}{\text{Peak Flow Rate (within the hour)}}$$

For a detailed explanation of the PHF refer to the most current HCM.

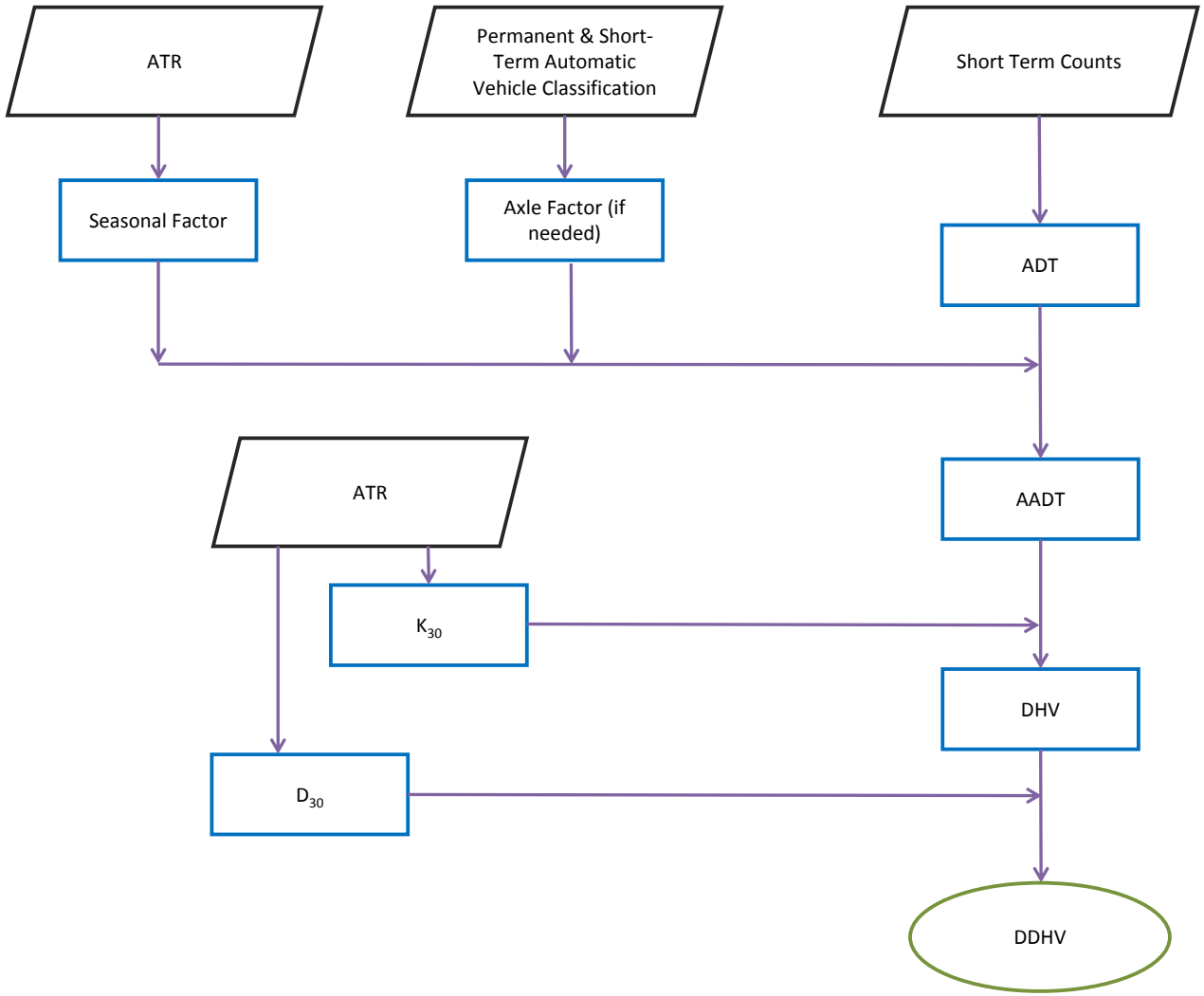


Figure 3-2 Traffic Factors

3.6. Locating and Using Data Sources

This section lists the NDOT traffic data sources (e.g., online resources and annual reports maintained and published by NDOT) that provide the different traffic factors discussed previously in this chapter. The section also directs the analyst on how to choose the most appropriate data source and how to identify a similar ATR if one is not located in or around the project location.

3.6.1. NDOT's Online Resources – TRINA and FTP Site

NDOT hosts traffic data online, which is accessible through either NDOT's TRINA Web site or through NDOT's FTP site (see Section 1.4 of these Guidelines for URL and website information). TRINA is a web-based GIS enabled application that provides maps and reports of traffic count and classification data. Single or multiple traffic count stations can be selected either through a map interface or through a database query. In addition, thematic maps can be generated; data and reports can be viewed related to specific traffic count locations. In addition to TRINA, for the State's approximately 3,600 short-term count stations, the hourly traffic data from the seven days of count at each of these locations are available at the NDOT's FTP site. Figure 3-3 shows a sample hourly traffic report from the short-term count station #030268, which is located along Las Vegas Boulevard in the City of Las Vegas. AADT estimates are also available from the short-term count stations' hourly traffic report, and it should be noted that the AADT estimates presented have been obtained after the application of necessary adjustment factors. Therefore, the AADT estimates obtained from these reports are not to be adjusted further.

The ATR data available at the FTP site includes the summary statistics available from the Annual Traffic Reports. A summary of the hourly variation of traffic over the days of a week and the monthly variation of traffic for each ATR location are also provided.

3.6.2. Annual Traffic Reports

In addition to the traffic data made available online, Annual Traffic Reports are compiled and published by NDOT and are available on NDOT's Web site (see Section 1.4 of these Guidelines for URL and website information). The Annual Traffic Reports contain a summary of the statistical information for each of the ATRs in operation within the State. This includes the historical trends in the variation of AADT over the years as well as the monthly variation of traffic. The K_{30} and D_{30} for the ATRs are provided in the Annual Traffic Reports. The Annual Traffic Reports also contain individual sections for each county of the State. The short-term count locations in each county are summarized, and the historical AADT from each of these locations is also provided.

Nevada Department of Transportation

Daily Volume from 05/09/2011 through 05/16/2011

Site Names: 030268, , , SR-604 (Las Vegas Bl)
County: Clark
Funct. Class: Urban Minor Arterial
Location: .1 mi S of SR-593 (Tropicana Av)

Seasonal Factor Type: 31
Daily Factor Type: 31
Axle Factor Type:
Growth Factor Type: 08

	Sun 05/08/2011			Mon 05/09/2011			Tue 05/10/2011			Wed 05/11/2011			Thu 05/12/2011			Fri 05/13/2011			Sat 05/14/2011		
	ROAD	S	N	ROAD	S	N	ROAD	S	N	ROAD	S	N	ROAD	S	N	ROAD	S	N	ROAD	S	N
00:00							1,600	701	899	1,576	792	784	1,821	941	880	1,963	1,070	893	2,598	1,404	1,194
01:00							986	424	562	999	527	472	1,262	656	606	1,325	677	648	2,007	1,044	963
02:00							766	367	399	757	373	384	951	463	488	1,121	572	549	1,586	846	740
03:00							734	381	353	697	409	288	847	432	415	935	489	446	1,426	719	707
04:00							711	453	258	728	427	301	745	435	310	893	530	363	1,196	647	549
05:00							814	482	332	778	476	302	857	524	333	954	575	379	1,017	593	424
06:00							1,208	693	515	1,175	670	505	1,202	694	508	1,274	734	540	1,041	583	458
07:00				1,876	1,004	872	2,009	1,083	926	2,035	1,082	953	1,902	998	904	2,024	1,118	906	1,449	786	663
08:00				2,186	1,069	1,117	2,249	1,083	1,166	2,361	1,179	1,182	2,287	1,125	1,162	2,246	1,011	1,235	1,689	793	896
09:00				2,197	1,063	1,134	2,456	1,276	1,180	2,405	1,222	1,183	2,400	1,191	1,209	2,421	1,109	1,312	2,146	1,044	1,102
10:00				2,546	1,262	1,284	2,580	1,353	1,227	2,650	1,381	1,269	2,707	1,362	1,345	2,694	1,319	1,375	2,638	1,254	1,384
11:00				3,053	1,484	1,569	2,924	1,451	1,473	2,861	1,425	1,436	2,979	1,530	1,449	3,097	1,539	1,558	3,260	1,529	1,731
12:00				2,941	1,393	1,548	2,835	1,352	1,483	2,809	1,347	1,462	2,899	1,390	1,509	3,039	1,450	1,589	3,566	1,594	1,972
13:00				3,151	1,452	1,699	2,934	1,354	1,580	2,904	1,356	1,548	3,099	1,442	1,657	3,353	1,569	1,784	1,898	933	965
14:00				3,115	1,429	1,686	2,988	1,414	1,574	2,796	1,263	1,533	3,193	1,468	1,725	3,373	1,520	1,853	5	4	1
15:00				3,190	1,451	1,739	2,974	1,378	1,596	3,074	1,397	1,677	3,328	1,472	1,856	3,493	1,519	1,974	2,816	1,244	1,572
16:00				3,306	1,494	1,812	3,172	1,379	1,793	3,204	1,504	1,700	3,307	1,522	1,785	3,805	1,650	2,155	3,554	1,670	1,884
17:00				3,386	1,455	1,931	3,194	1,499	1,695	3,381	1,676	1,705	3,370	1,669	1,701	3,704	1,640	2,064	3,643	1,744	1,899
18:00				3,056	1,341	1,715	2,865	1,332	1,533	3,070	1,471	1,599	3,065	1,449	1,616	3,245	1,492	1,753	3,485	1,571	1,914
19:00				2,443	1,085	1,358	2,428	1,109	1,319	2,600	1,183	1,417	2,671	1,235	1,436	3,056	1,393	1,663	3,246	1,551	1,695
20:00				2,271	1,026	1,245	2,475	1,152	1,323	2,531	1,083	1,448	2,667	1,158	1,509	3,033	1,351	1,682	2,941	1,326	1,615
21:00				2,138	965	1,173	2,377	1,058	1,319	2,515	1,118	1,397	2,593	1,183	1,410	2,829	1,317	1,512	3,345	1,544	1,801
22:00				2,227	1,084	1,143	2,255	1,130	1,125	2,506	1,300	1,206	2,518	1,204	1,314	2,653	1,213	1,440	3,234	1,556	1,678
23:00				1,869	965	904	2,033	1,028	1,005	2,248	1,192	1,056	2,219	1,182	1,037	2,779	1,341	1,438	3,102	1,647	1,455
Volume				44,951	21,022	23,929	51,567	24,932	26,635	52,660	25,853	26,807	54,889	26,725	28,164	59,309	28,198	31,111	56,888	27,626	29,262
AM Peak Vol							2,924	1,451	1,473	2,861	1,425	1,436	2,979	1,530	1,449	3,097	1,539	1,558	3,260	1,529	1,731
AM Peak Fct							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
AM Peak Hr							11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00
PM Peak Vol				3,386	1,494	1,931	3,194	1,499	1,793	3,381	1,676	1,705	3,370	1,669	1,856	3,805	1,650	2,155	3,643	1,744	1,972
PM Peak Fct				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PM Peak Hr				17:00	16:00	17:00	17:00	17:00	16:00	17:00	17:00	17:00	17:00	17:00	15:00	16:00	16:00	16:00	17:00	17:00	12:00
Seasonal Fct				1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Daily Fct				1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Axle Fct				0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
Pulse Fct				2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000

Created 06/01/2011 11:12:05AM **ROAD AADT 55,701** **S AADT 27,146** **N AADT 28,556** DV03: Page 1 of 2

Figure 3-3 Example Hourly Traffic Report from Short-Term Count Station #030268

Source: NDOT, Hourly Traffic Report

Nevada Department of Transportation

Daily Volume from 05/09/2011 through 05/16/2011

Site Names: 030268, , , SR-604 (Las Vegas Bl)
County: Clark
Funct. Class: Urban Minor Arterial
Location: .1 mi S of SR-593 (Tropicana Av)

Seasonal Factor Type: 31
Daily Factor Type: 31
Axle Factor Type:
Growth Factor Type: 08

	Sun 05/15/2011			Mon 05/16/2011			Tue 05/17/2011			Wed 05/18/2011			Thu 05/19/2011			Fri 05/20/2011			Sat 05/21/2011		
	ROAD	S	N	ROAD	S	N	ROAD	S	N	ROAD	S	N	ROAD	S	N	ROAD	S	N	ROAD	S	N
00:00	2,809	1,504	1,305	1,920	994	926															
01:00	2,726	1,532	1,194	1,137	585	552															
02:00	2,037	1,057	980	922	493	429															
03:00	1,726	895	831	823	479	344															
04:00	1,529	819	710	878	541	337															
05:00	1,156	612	544	958	621	337															
06:00	1,222	654	568	1,337	828	509															
07:00	1,447	807	640																		
08:00	1,694	838	856																		
09:00	2,119	1,061	1,058																		
10:00	2,958	1,441	1,517																		
11:00	3,431	1,660	1,771																		
12:00	3,604	1,783	1,821																		
13:00	3,481	1,725	1,756																		
14:00	3,405	1,717	1,688																		
15:00	3,653	1,844	1,809																		
16:00	3,309	1,608	1,701																		
17:00	3,342	1,603	1,739																		
18:00	2,923	1,361	1,562																		
19:00	2,934	1,445	1,489																		
20:00	2,784	1,329	1,455																		
21:00	2,589	1,355	1,234																		
22:00	2,457	1,211	1,246																		
23:00	2,335	1,262	1,073																		
Volume	61,670	31,123	30,547	7,975	4,541	3,434															
AM Peak Vol	3,431	1,660	1,771																		
AM Peak Fct	1.00	1.00	1.00																		
AM Peak Hr	11:00	11:00	11:00																		
PM Peak Vol	3,653	1,844	1,821																		
PM Peak Fct	1.00	1.00	1.00																		
PM Peak Hr	15:00	15:00	12:00																		
Seasonal Fct	1.000	1.000	1.000	1.000	1.000	1.000															
Daily Fct	1.000	1.000	1.000	1.000	1.000	1.000															
Axle Fct	0.500	0.500	0.500	0.500	0.500	0.500															
Pulse Fct	2.000	2.000	2.000	2.000	2.000	2.000															

Created 06/01/2011 11:12:05AM ROAD AADT 55,701 S AADT 27,146 N AADT 28,556 DV03: Page 2 of 2

Figure 3-3 Example Hourly Traffic Report from Short-Term Count Station #030268

Source: NDOT, Hourly Traffic Report

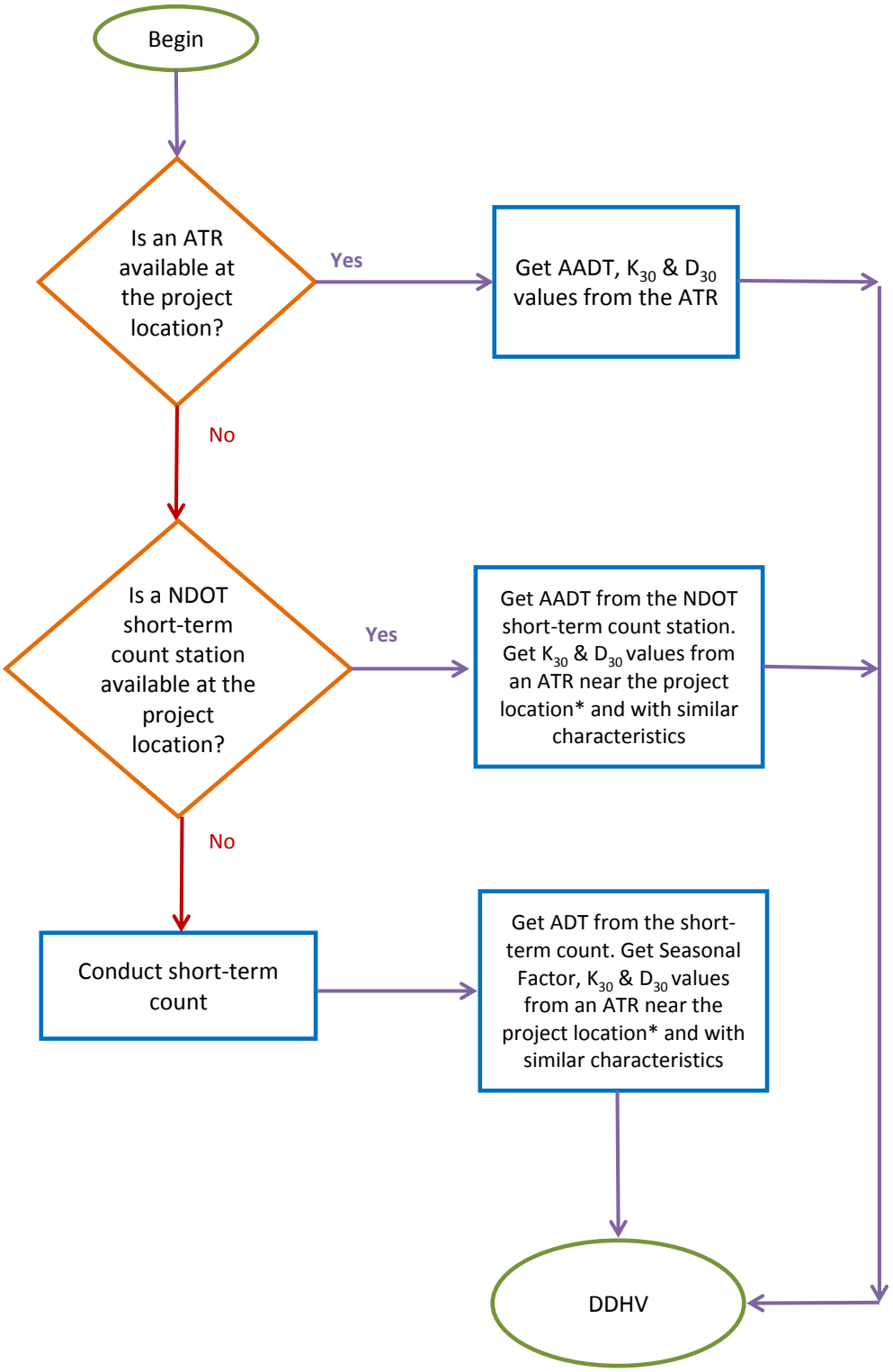
3.6.3. Choosing a Data Source

The ATRs monitor and collect traffic data throughout the year and provide a true representation of the traffic in that region. However, because it is infeasible to monitor traffic throughout the year at all locations in the State, short-term counts are carried out at many locations. These short-term counts provide statistically accurate traffic characteristics for a region based on adjustment data from the ATRs.

When performing a traffic forecast and in choosing a traffic count, the following guidance is to be considered.

- Identify the availability of an ATR at the project location. If a suitable ATR is available, obtain AADT, K_{30}, and D_{30} values for that ATR from TRINA, NDOT's FTP site or from NDOT's Annual Traffic Report.
- If an ATR is not available at the project location, identify the availability of a short-term count station at the project location.
    - If a suitable short-term count station is available, obtain AADT from the short-term count station and obtain K_{30} and D_{30} values from an ATR near the project location and with similar traffic characteristics to that of the project location. If an ATR near the project location has traffic characteristics that are dissimilar to that of the project location, then K_{30} and D_{30} is to be obtained from another ATR that has similar traffic characteristics.
    - Similar to the above, the AADT, K_{30}, and D_{30} values can be obtained from TRINA, NDOT's FTP site or from NDOT's Annual Traffic Report.
- If a suitable short-term count station is unavailable, conduct a short-term count. (NDOT's recommendations and requirements for conducting a short-term count can be obtained from NDOT's TMS document.)
    - Use the ADT from the short-term count and estimate AADT by using seasonal factors and Axle Factors (if needed). Seasonal Factors can be obtained from either an ATR or from an NDOT short-term count location (if the NDOT short-term count was conducted in the same month as that of this short-term count) near the project location and with similar traffic characteristics to that of the project location.
    - Obtain K_{30} and D_{30} values from an ATR near the project location and with similar traffic characteristics as that of the project location.
    - Similar to the above, K_{30} and D_{30} for an ATR can be obtained from TRINA, NDOT's FTP site or from NDOT's Annual Traffic Report.

Figure 3-4 illustrates the step-by-step process for choosing the most suitable data source to obtain the relevant traffic factors.



* It is possible to have adjacent count stations that are dissimilar in their traffic characteristics. In such cases, the "similarity in characteristics" are to be given precedence.

Figure 3-4 Obtaining Base Year Traffic Parameters from Relevant Data Sources

3.6.4. Identifying an ATR at a Location Similar to the Project Location

If an ATR is unavailable at the project location, the analyst is to identify an ATR near the project location or at a location with characteristics similar to that of the project location in order to determine the required Seasonal Factors, K_{30}, and D_{30}. If an ATR is not available near the project location, then an ATR with similar characteristics is to be identified.

To identify an ATR with similar characteristics, the analyst would initially attempt to determine the characteristics of the project location. Appendix A offers guidance for classifying a project location. Once the project location's characteristics have been identified, the analyst next attempts to determine suitable and similar ATRs by examining the characteristics of the ATRs. NDOT's TRINA database and Annual Traffic Reports are useful resources in this process.

If a suitable ATR cannot be identified, the analyst is to contact NDOT Traffic Information Division for guidance in choosing the most applicable ATR.

3.7. Estimating AADT: Sample Case

The following is an example estimate of AADT from a short-term traffic count. This short-term count was conducted over 48 hours instead of the generally recommended seven days. (Note that this 48-hour count still meets the NDOT prescribed minimum requirements for a short-term count explained in NDOT's TMS document.) In this case, in addition to the Monthly Seasonal Factor, the day of the week factor had to be applied to the short-term count data as well.

Location: Pyramid Way (SR-445) northbound between Sunset Springs Lane and Calle De La Plata
City: Sparks
Count Start Date: 11/07/2007

ATR 0312270 was available along the same project corridor as that of the count location and was chosen to obtain the traffic adjustment factors. To match the short-term count, the ATR summary statistics were obtained from NDOT's 2007 Annual Traffic Report.

Figure 3-5 shows the summary statistics specific to ATR 0312270; Figure 3-5 also illustrates the typical information that is available for NDOT ATRs. This information has been used in this example calculation. The day of the week factors from NDOT ATR 0312270, SR-445 (Pyramid Way) 0.6 miles north of Calle De La Plata Drive were obtained.

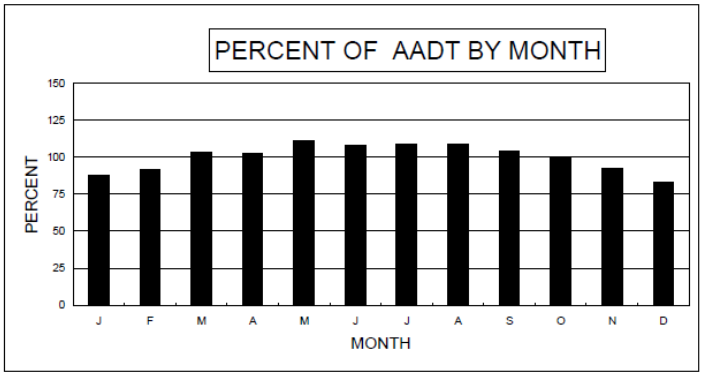
Factor for Wednesday = 100/99.6 = 1.004

Factor for Thursday = 100/99.6 = 1.004.

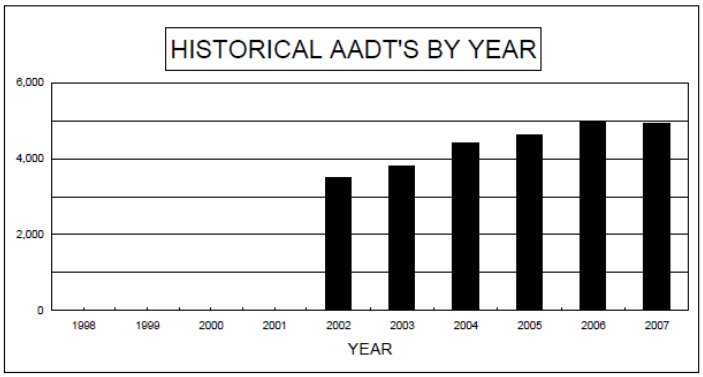
ATR 0312270

SR-445 (PYRAMID HWY.) 0.6 MI. N. OF CALLE DE LA PLATA DR

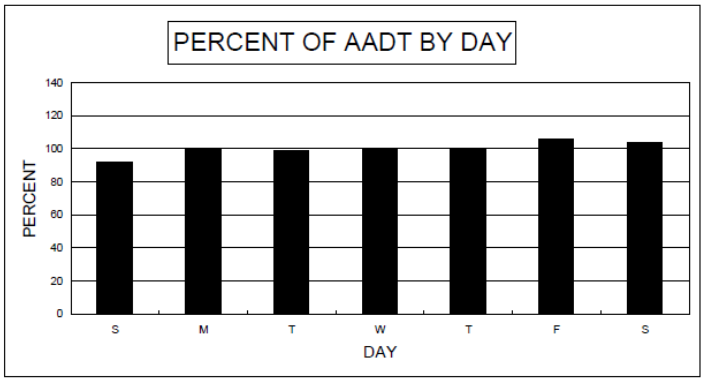
MONTHLY PERCENT		
MONTH	MADT	% OF AADT
JANUARY	4,325	87.8%
FEBRUARY	4,505	91.5%
MARCH	5,078	103.1%
APRIL	5,030	102.1%
MAY	5,475	111.2%
JUNE	5,334	108.3%
JULY	5,355	108.7%
AUGUST	5,352	108.7%
SEPTEMBER	5,118	103.9%
OCTOBER	4,879	99.1%
NOVEMBER	4,537	92.1%
DECEMBER	4,107	83.4%



HISTORICAL RECORD		
YEAR	AADT	% OF PREVIOUS YEAR
2007	4,925	98.5%
2006	5,000	108.0%
2005	4,631	104.8%
2004	4,419	116.4%
2003	3,795	108.3%
2002	3,505	
2001		
2000		
1999		
1998		



DAY OF WEEK		
DAY	ADT	% OF AADT
SUN	4,539	92.2%
MON	4,917	99.8%
TUE	4,872	98.9%
WED	4,907	99.6%
THU	4,907	99.6%
FRI	5,229	106.2%
SAT	5,100	103.6%
AVG WEEKDAY	4,901	99.5%
AVG WEEKEND	4,820	97.9%



PERCENT DESIGN HOUR VOLUME (DHV) IS OF ANNUAL AVERAGE	10.1%
PERCENT HIGH DIRECTION IS OF DHV	62.7%

Figure 3-5 Example ATR Summary Statistics

Source: NDOT, ATR Summary Statistics

Table 3-1 Application of Daily Factors to Raw Counts

Hour	Raw Count		Factored		
	Wednesday	Thursday	Wednesday	Thursday	Average
0:00 – 1:00	32	47	32	47	40
1:00 – 2:00	20	26	20	26	23
2:00 – 3:00	41	28	41	28	35
3:00 – 4:00	24	38	24	38	31
4:00 – 5:00	105	92	105	92	99
5:00 – 6:00	332	306	333	307	320
6:00 – 7:00	850	775	853	778	816
7:00 – 8:00	965	1,048	969	1,052	1,011
8:00 – 9:00	869	966	872	970	921
9:00 – 10:00	748	672	751	675	713
10:00 – 11:00	606	736	608	739	674
11:00 – 12:00	704	706	707	709	708
12:00 – 13:00	753	658	756	661	708
13:00 – 14:00	755	644	758	647	702
14:00 – 15:00	774	841	777	844	811
15:00 – 16:00	943	943	947	947	947
16:00 – 17:00	969	917	973	921	947
17:00 – 18:00	911	950	915	954	934
18:00 – 19:00	705	670	708	673	690
19:00 – 20:00	391	382	393	384	388
20:00 – 21:00	342	289	343	290	317
21:00 – 22:00	242	240	243	241	242
22:00 – 23:00	154	153	155	154	154
23:00 – 0:00	53	79	53	79	66
				Total	**12,296**

Table 3-1 was obtained by applying the daily seasonal factors (day of the week factors) to the raw counts to calculate the factored counts. These factored counts in turn have to be adjusted with the Monthly Seasonal Factor for November. The Monthly Seasonal Factor for November equals 100/92.1 or 1.0858. The "total" from Table 3-1 is the MADT for November, and the AADT was estimated by multiplying the Monthly Seasonal Factor with MADT.

AADT equals 12,296 multiplied by 1.0858, or 13,351.

AADT equals 13,500 (after rounding).

As listed in Figure 3-5, the K_{30} and D_{30} values can also be obtained from the ATR summary statistics. For ATR 0312270, K_{30} equals 10.1 percent, and D_{30} equals 62.7 percent.

Chapter 4
Traffic Forecasting Parameters, K_{30} & D_{30}

Traffic parameters (K_{30} and D_{30}) are required to convert AADT into DDHV. While the previous chapter introduced the concepts of K_{30} and D_{30}, this chapter provides detailed explanation and guidelines for estimation of K_{30} and D_{30} for the future years of a project. In addition, this chapter includes:

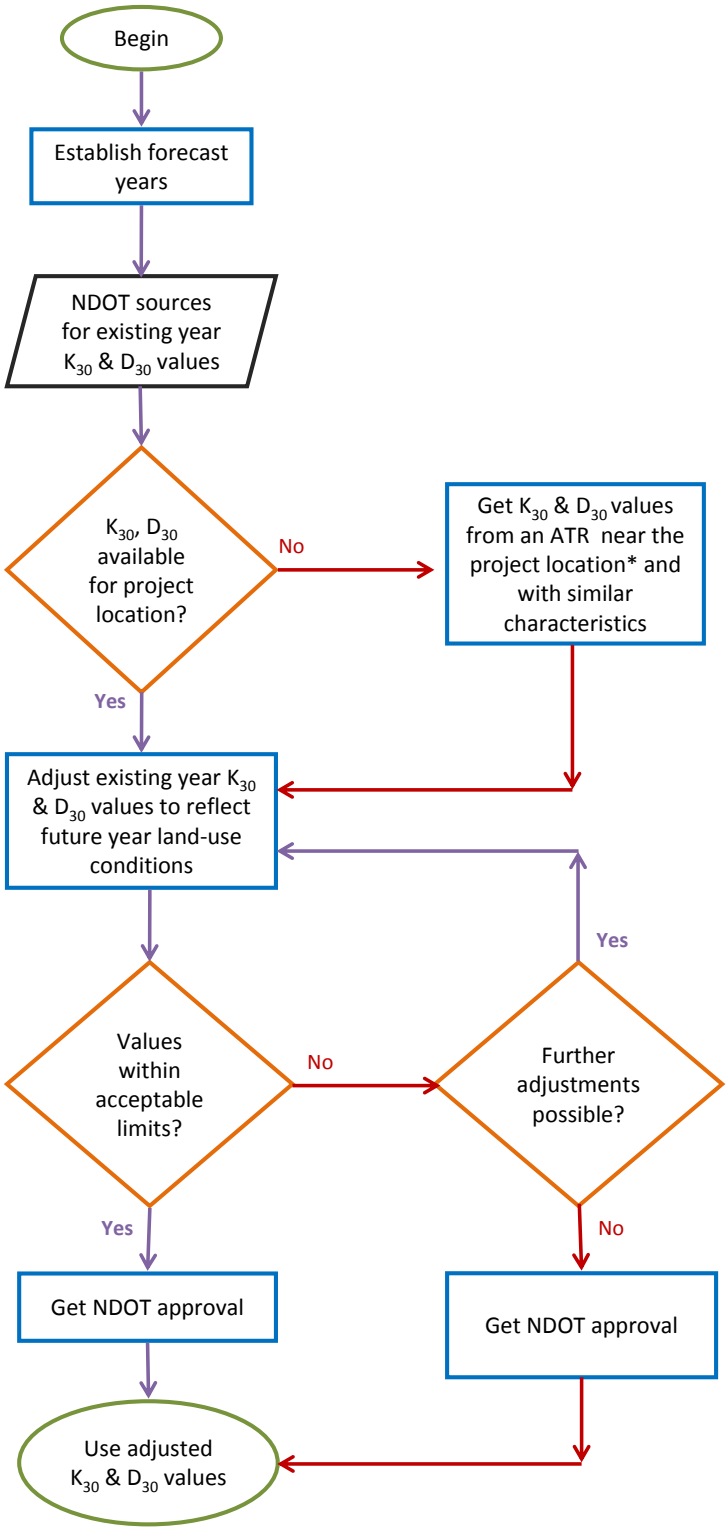
- The definitions of K_{30} and D_{30};
- An overview of and application for K_{30} and D_{30};
- A definition of demand volume;
- The process and methodology by which to establish forecast years;
- The approach by which to determine and adjust K_{30} and D_{30} values by roadway type, and
- The information needed for the traffic forecast memorandum.

4.1. Definitions of K_{30} and D_{30}

As noted, the K-factor is the ratio of the hourly, two-way traffic to the two-way AADT. K_{30} is the relationship between the 30th highest hour volume and the AADT for the design year, and it is the factor used to determine DHV. FHWA requires that the K_{30} be used for all traffic projections related to design projects. It is important to know that the K-factor is descriptive (i.e., it represents the ratio of two numbers). Existing K_{30} is not to be artificially computed by using a mathematical equation.

The D-factor is the percentage of the total two-way, peak hour traffic traveling in the peak direction. D_{30} is the proportion of traffic in the 30th highest hour of the design year traveling in the peak direction. The D-factor is an essential parameter used to determine the DDHV, which is the basis of geometric design.

Figure 4-1 illustrates the process of estimating the traffic forecasting parameters, K_{30} & D_{30}, for future years, and a detailed explanation of this process is provided in the subsequent sections.



* It is possible to have adjacent count stations that are dissimilar in their traffic characteristics. In such cases, the "similarity in characteristics" are to be given precedence.

Figure 4-1 Estimating the Future Year Traffic Forecasting Parameters

4.2. Overview and Application of K_{30}

Capacity analysis focuses on the traffic monitored at an intersection or along a roadway during a particular peak hour. The peak hour most frequently used to design roadways and intersections is the 30th highest hour occurring during the design year. The amount of traffic occurring during this hour is called the DHV. DHV is derived by multiplying the AADT by the estimated K_{30} (for the design year) based on data collected at traffic monitoring site surveys. This calculation is expressed as follows.

$$\mathrm{DHV} = \mathrm{AADT} \times \mathrm{K}_{30}$$

The K-factors represent typical conditions found around the State for relatively free-flow conditions and are considered to represent typical traffic demand on similar roadways. The magnitude of the K-factor is directly related to the variability of traffic over time. Rural and recreational travel routes, which are subject to occasional extreme traffic volumes, generally exhibit the highest K-factors. The millions of tourists traveling on interstate highways during a holiday are typical examples of the effect of recreational travel periods. Urban highways, with their repeating pattern of home-to-work trips, generally show less variability and, thus, have lower K-factors.

The 2010 HCM notes that the K-factor, in general, has the following characteristics.

- The K-factor decreases as the AADT on a roadway increases.
- The K-factor decreases as development density increases.
- The highest K-factors occur on recreational roadways, followed by rural, suburban, and urban roadways in descending order.

Figure 4-2 illustrates the relation between the highest hourly volumes and AADT on arterials taken from an analysis of traffic count data covering a wide range of volumes and geographic conditions. The curves on Figure 4-2 had been prepared by arranging all of the hourly volumes of one year, expressed as a percentage of AADT, in a descending order of magnitude. The curves represent the following roadways: rural, suburban, urban, and the average for all locations studied. The curves also represent a roadway with average fluctuation in traffic flow.

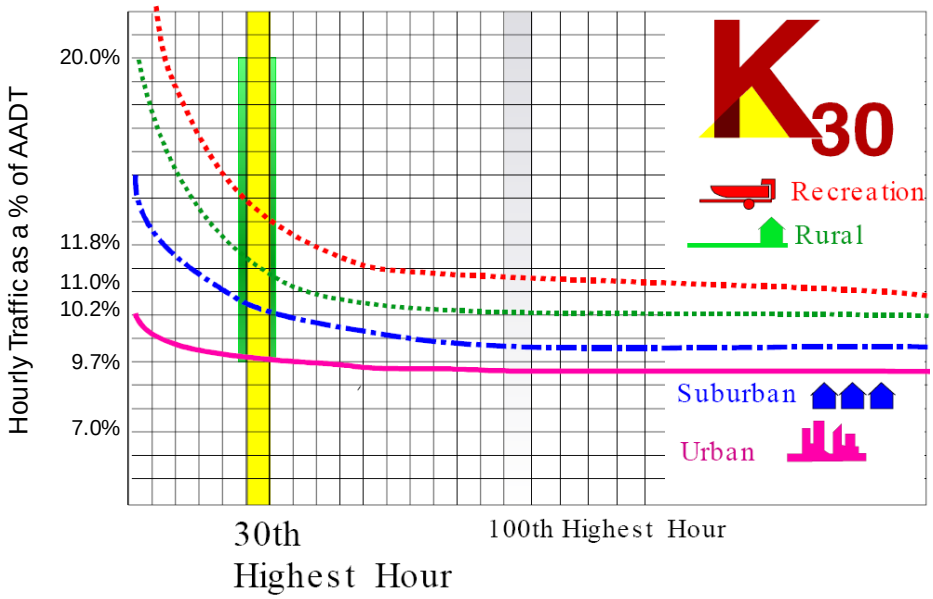


Figure 4-2 Relation between Peak-Hour and AADT Volume

Source: FDOT, Project Traffic Forecasting Handbook 2002

Analysis of these curves concludes that the hourly traffic used in design should be the 30th highest hourly volume of the year, abbreviated as 30 HV. The reasonableness of 30 HV as a design control is indicated by the change that results from choosing a somewhat higher or lower volume. The curves in Figure 4-2 steepen quickly to the left of the 30th highest hour, indicating much higher volumes for only a few hours. The curves flatten to the right, indicating many hours in which the volume approaches 30 HV. The decision to use 30 HV is also based on the economics of roadway construction. The State has adopted AASHTO guidelines, so that the roadway will experience a limited number of hours of congestion per year. The excessive expense of building a roadway to handle the first highest hour of the year is typically prohibitive.

K_{30} values can be obtained from the ATR summary statistics, which are available from NDOT's Annual Traffic Reports or NDOT's online resources (see Chapter 1 and Chapter 3 of these Guidelines for website information and more detailed discussion on obtaining traffic data).

4.3. Overview and Application of D_{30}

A roadway with a high percentage of traffic in one direction during the peak hours may require more lanes than a roadway having the same AADT but with a lower percentage. This percentage of traffic in one direction is referred to as the D-factor. During any particular hour, traffic volume may be greater in one direction than the other. An urban route, serving strong directional demands into a city during the morning (AM) commute and out of the city during the

evening (PM) commute, may display as much as a 2 to 1 imbalance in directional flows. Figure 4-3 illustrates this imbalance in the directional distribution.

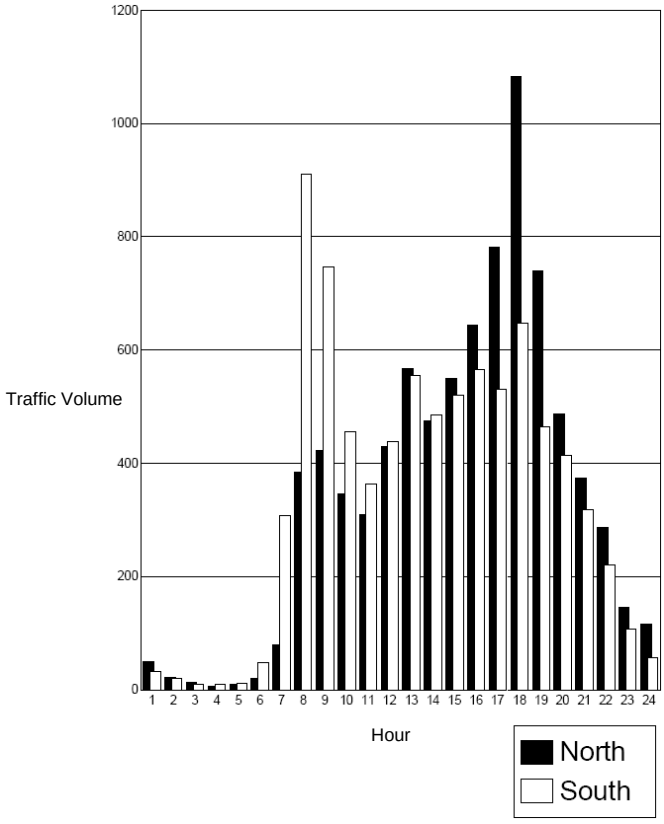


Figure 4-3 Traffic Volume Directional Distribution

Source: FDOT, Project Traffic Forecasting Handbook 2002

D-factor is an important parameter in roadway capacity analysis. This is particularly true for two-lane rural highways. Capacity and LOS vary substantially based on the D-factor because of the interactive nature of directional flows on such roadways. Queuing, slowness of traffic, land use impacts, and capacity are some of the considerations that affect the D-factor.

Urban radial routes have been observed to have up to two-thirds of their peak hour traffic in a single direction. Unfortunately, this peak occurs in one direction during the AM and in the other in the PM. Thus, both directions of the roadway must be adequate for the peak directional flow.

The D-factor is an essential traffic parameter used to determine DDHV for the design year and is to be the basis of the geometric design. The DDHV is the product obtained by multiplying the DHV and D_{30}, which is expressed as follows.

$$\mathrm{DDHV} = \mathrm{DHV} \times \mathrm{D}_{30}$$

D_{30} values can be obtained from the ATR summary statistics, which are available from NDOT's Annual Traffic Reports or NDOT's online resources (see Chapter 1 and Chapter 3 of these Guidelines for website information and more detailed discussion on obtaining traffic data).

4.4. Defining Demand Volume

The term demand volume means the traffic volume expected to desire service past a point or a segment of the roadway system at some future time. Demand volume could also be defined as the traffic currently arriving or desiring service past such a point, and demand volume is usually expressed in vph. When demand exceeds capacity, the PHF will approach 1.0 because of delayed traffic. If this situation of delayed traffic occurs, the observed condition is considered to be a constrained condition.

True demand cannot be directly measured on congested roads, and traffic surveys cannot be used to measure traffic demand during peak traffic hours. Under this situation, demand D_{30} is estimated based on the traffic data for unconstrained sites with similar roadway and geographic characteristics. The term "demand traffic" is used to distinguish the resulting DHV projections from those that may be constrained by capacity limitations.

To avoid assessing the future required number of lanes under constrained conditions, Table 4-1 lists the limits that may be placed on future PHF when conducting future analysis.

Table 4-1 Suggested Peak Hour factors for Future Years Analysis

Condition	Suggested PHF for Design and Horizon Years
Rural	Use Existing or 0.90
Suburban	Use Existing or 0.90
Urban: Unconstrained	Use Existing or 0.92
Urban: Constrained	Use Existing but not to exceed 0.95

4.5. Establishing Forecast Years

The guidelines provided in Table 4-2 assist the analyst in developing opening and design year traffic forecasts. The base year is the initial year of the forecast period. The plan horizon year is the year that corresponds with the planning horizon of the long range plan. The opening year is the first year in which the roadway will be open to traffic. The base year of a new roadway may be different than the opening year, if necessary. The model calibration year will usually be different from the opening year of the project.

Likewise, the design year is the year for which the roadway is designed, and the forecast year of the travel demand model may be different than the design year of the project. Standard

procedures, such as interpolation and extrapolation, are to be employed to ensure that traffic assignments are adjusted appropriately for both the opening and design year of the project.

For example, if a new roadway is expected to open in 2014; the travel demand model is validated to produce 2010 traffic volumes; and the Regional Transportation Plan corresponds to year 2035, then the base year would be 2010; the opening year would be 2014; and the design year would be 2034. The 2035 forecasts would have to be adjusted by one year to reach the design year.

As per NDOT's Road Design Guide, AADT projections are to be prepared for the opening year, the interim year and the design year of a project.

Table 4-2 Establishing Forecast Years

Project Type	Traffic Projection Period	Opening Year	Interim Year	Design Year
Planning project	20+ years	Planning projects generally require long range goals to be established over a 20 to 25 year period, and forecasts are for that planning horizon year		
Environmental analysis project	20+ years	First year of construction in adopted work program plus one year	Usually 10 years into the future from the opening year of a project and 10 years prior to the design year of the project	Opening year plus 20 years
Design project	20+ years	First year of construction in adopted work program plus one year	Usually 10 years into the future from the opening year of a project and 10 years prior to the design year of the project	Opening year plus 20 years
Operational analysis project	Typically current or maximum of five years	Existing year	Up to five years	

4.6. Determining Future Year K_{30} Values

For roadway improvement design, the variation in hourly traffic volumes is to be measured, and the proportion of AADT during the 30th highest hour determined. Where such measurement cannot be made and only the AADT is known, the analyst is to use the 30th-hour percentage factors (K_{30} and D_{30}) for similar highways in the same location operated under similar conditions. The K_{30} value obtained from the ATR may need adjustments to reflect the future year conditions of the project location. This adjustment may be needed regardless of whether the K_{30} is obtained from an ATR in the project location or the K_{30} is obtained from an ATR that is available at a location similar to the project location; the need for adjustment depends on the expected future year conditions.

4.6.1. Adjusting K_{30} values

The initial K_{30} may not accurately reflect the future year traffic characteristics of the project location, some compensating adjustment may be necessary. A higher K_{30} on rural routes may be expected as a result of tourist or recreational trips in the traffic flow during the design hour. An additional site-specific adjustment may be required to reflect the nature of the roadway in local traffic patterns (i.e., whether the roadway serves cross-town, radial, circumferential, or trip terminal traffic). The decision process for applying this adjustment will also lead to an estimate of when the DHV will occur, an important aspect when considering the timing of multiple peak traffic patterns. Table 4-3 lists the recommended K_{30} values by the type of roadway, to be used for traffic forecasting; these values are to be considered during the adjustment process.

The following are some examples of how the K_{30} adjustment process works.

- Interstate 80 between Utah and Elko may have a downward adjustment from an average K_{30} value because this section of Interstate freeway has less than average tourist travel.
- Portions of rural Interstate 15 may exhibit higher than average K_{30} values, and traffic forecasting estimates for these segments will need to reflect K_{30} values toward the upper part of the observed range.
- Urban interstate freeways show little variance and would receive no adjustments.
- The Urban Arterial group shows little variance, and any adjustments to the average K_{30} value for these routes would reflect trip continuation from a connecting rural route.
- Local access roads have a high traffic volume variance associated with the pattern of land use activities. An office park has high inbound traffic in the AM, mixed inbound/outbound traffic at lunch time, and high outbound traffic in the PM. A residential subdivision will have high outbound traffic in the AM and high inbound traffic in the PM. Multi-family housing developments often show peak volumes later

in the evening, around 7 PM to 8 PM. K_{30} values for such roadways may have to be adjusted higher to reflect these local conditions.

A K_{30} value that is too high may result in over-design for the design year, but continuing traffic growth in most instances will soon use the "excess" capacity. A K_{30} value that is too low will lead to early congestion and the need for additional capacity, a situation that is far more costly in the long run. Thus, a K_{30} value that is too low will generally produce higher life-cycle costs because of the reduced functional life of the project improvements. The use of a system-level demand K_{30} value, adjusted slightly for local conditions, will reduce the chance of underestimating the K_{30} value.

When policy or funding limits the capacity that can be provided, the analyst needs to know the actual traffic demand so that the design can best accommodate the expected congestion. In the case of a freeway capacity project, one possible technique to reduce the effect of anticipated congestion would be to design longer and/or wider ramps for queue storage to prevent queues extending back into mainline lanes. If the design hour volume were deliberately held low, the designer would not be aware of the congestion problem and could not prevent its dangerous effects.

4.6.2. Acceptable K_{30} Values

The K_{30} and related DHV are influenced by the timing of trips during the day. K_{30} will be lower on roadways that serve many trip purposes distributed during the day. Roads that serve few purposes will normally exhibit high hourly variance. Table 4-3 shows the recommended range of K_{30} values, by the type of roadway, to be used for traffic forecasting.

The values in Table 4-3 are taken from NDOT's ATRs for the years 2006 through 2010 and represent the ratio of the 30^{th} highest volume hour to the AADT. If the adjusted K_{30} for a specific project is outside the range prescribed in Table 4-3, then the justification for the unusual number must be included in the traffic forecast memorandum. In general, K_{30} values can range from a maximum value of 0.20 to a minimum value of 0.07. The 15^{th} percentile and 85^{th} percentile of K_{30} values are useful because these values often represent the practical minimum and maximum values in most cases. Note that the K_{30} values shown in NDOT's summary statistics are represented as a percentage.

If the chosen K_{30} values are acceptable, the analyst can develop future DDHV. However, if the K_{30} is not within the acceptable range of values, the analyst should modify K_{30} within the ranges shown in Table 4-3. Justification for all decisions relating to the K_{30} must be documented, especially as each relates to high or low values.

Table 4-3 Recommended K_{30} values for Traffic Forecasting

Roadway Type	Minimum K_{30}	15th Percentile of all K_{30}	Median K_{30}	Average K_{30}	85th Percentile of all K_{30}	Maximum K_{30}	Standard Deviation of K_{30}
Rural Major Collector	0.091	0.098	0.115	0.133	0.155	0.429	0.056
Rural Minor Arterial	0.097	0.102	0.116	0.122	0.142	0.198	0.021
Rural Minor Collector	0.100	0.102	0.103	0.103	0.104	0.104	0.001
Rural Principal Arterial: Interstate	0.088	0.095	0.103	0.104	0.109	0.132	0.009
Rural Principal Arterial: Other	0.093	0.103	0.122	0.124	0.143	0.262	0.024
Urban Collector	0.098	0.099	0.107	0.106	0.113	0.116	0.006
Urban Minor Arterial	0.092	0.097	0.107	0.106	0.111	0.133	0.010
Urban Principal Arterial: Interstate	0.065	0.070	0.086	0.086	0.091	0.127	0.017
Urban Principal Arterial: Other	0.076	0.089	0.099	0.100	0.113	0.129	0.012
Urban Principal Arterial: Other Freeways	0.070	0.078	0.093	0.092	0.103	0.145	0.014

Source: NDOT's ATR data for years 2006 through 2010.

4.7. Determining Future Year D_{30} Values

Similar to the adjustment of K_{30} values, the D_{30} values may also need adjustment of the values obtained directly from the ATR. The D_{30} value obtained from the ATR may need adjustments to reflect the future year conditions of the project location. This adjustment may be needed regardless of whether the D_{30} is obtained from an ATR in the project location or the D_{30} is obtained from an ATR that is available at a location similar to the project location; the need for adjustment depends on the expected future year conditions.

4.7.1. Adjusting D_{30} values

To determine if a D_{30} value is acceptable for traffic forecasting purposes, the following four steps are necessary:

Step 1: The analyst is to select an ATR that best represents the subject roadway and obtain the D_{30} from that ATR.

Step 2: The analyst is to determine if the D_{30} value is within the acceptable range of demand D_{30} values by referencing Table 4-4.

Step 3: If the roadway is unconstrained, then the analyst is to consider the use of the D_{30} for future conditions; or alternately, if the D_{30} needs to be adjusted, the analyst is to apply adjustments following the guidelines explained later in this section.

Step 4: If the site is "constrained," Demand D-factor is to be used. Demand D-factor is estimated based on the summary statistics of unconstrained sites with similar roadway characteristics. The analyst is to select the appropriate D_{30} value by analyzing the traffic characteristics and comparing them with unconstrained traffic count locations. The analyst should be aware that a D_{30} value of less than 0.52 will not be acceptable for future conditions analysis without significant justification.

On highways with more than two lanes, on two-lane roadways where important intersections are encountered, or where additional lanes are to be provided later, knowledge of the hourly traffic volume in each direction of travel is essential for design.

For the same AADT, a multilane roadway with a high percentage of traffic in one direction during the peak hours may require more lanes than a roadway having the same AADT with a lesser percentage. During peak hours on most rural highways, anywhere from 55 to 70 percent of the traffic is in one direction. For two multilane highways carrying equal traffic, one may have a one-way traffic load that is 60 percent greater than the other during the peak hours. As an example, consider a rural roadway designed for 4,000 vph total for both directions. If during the design hour the D-factor is equally split (or 2,000 vph in each direction), then two lanes in each direction may be adequate. If 80 percent of the DHV is in one direction, at least three lanes in

each direction would be required for the 3,200 vph, and if the 1,000 vehicles per lane criterion is rigidly applied, four lanes in each direction would be required.

Traffic distribution by directions during peak hours is generally consistent from year to year and from day to day on a given rural roadway, although there are exceptions on some highways serving recreational areas. The measured D_{30} may be assumed to apply to the DHV for the design year for which the roadway is designed, except for urban highways. For urban highways and for roadways transitioning from rural to urban conditions, as the land use changes, the D-factor tends to the lower end of the roadway type. Ultimately, urban roadways may reach a value of 50 percent where traffic flows equally in both directions. For design purposes however, the lowest acceptable D-factor value is 0.52.

4.7.2. Acceptable D_{30} Values

Table 4-4 shows the recommended range of D_{30} values, by the type of roadway, to be used for traffic forecasting. The values in Table 4-4 are taken from NDOT's ATRs for the years 2006 through 2010. Note that the D_{30} values shown in NDOT's summary statistics are represented as a percentage. If the adjusted D_{30} for a specific project is outside the range prescribed in Table 4-4, then the justification for the unusual number must be included in the traffic forecast memorandum. Justification for all decisions relating to the D_{30} must be documented, especially as each relates to high or low values.

Table 4-4 Recommended D_{30} values for Traffic Forecasting

Roadway Type	Minimum D_{30}	15th Percentile of all D_{30}	Median D_{30}	Average D_{30}	85th Percentile of all D_{30}	Maximum D_{30}	Standard Deviation of D_{30}
Rural Major Collector	0.500	0.519	0.560	0.586	0.664	0.846	0.084
Rural Minor Arterial	0.504	0.530	0.610	0.621	0.729	0.782	0.086
Rural Minor Collector	0.510	0.542	0.590	0.587	0.626	0.684	0.055
Rural Principal Arterial: Interstate	0.500	0.515	0.544	0.552	0.593	0.693	0.040
Rural Principal Arterial: Other	0.503	0.515	0.537	0.556	0.609	0.770	0.050
Urban Collector	0.509	0.579	0.603	0.598	0.629	0.634	0.033
Urban Minor Arterial	0.500	0.515	0.549	0.573	0.645	0.690	0.059
Urban Principal Arterial: Interstate	0.508	0.517	0.530	0.539	0.571	0.627	0.027
Urban Principal Arterial: Other	0.503	0.520	0.565	0.572	0.637	0.712	0.050
Urban Principal Arterial: Other Freeways	0.504	0.523	0.563	0.564	0.612	0.684	0.046

Source: NDOT's ATR data for years 2006 through 2010.

4.8. Nonstandard K_{30} and D_{30} Values

If K_{30} and D_{30} values lower than NDOT's 15th percentile values are to be used, or if D_{30} values lower than 0.52 are to be used, then prior approval of NDOT is required before continuing the traffic forecasting process.

4.9. Documenting Traffic Forecasts

As noted, the adopted methodology and underlying assumptions involved in estimating future K_{30} and D_{30} values is to be clearly documented in the traffic forecast memorandum. All rationale behind any adjustments made to the initial K_{30} and D_{30} values as well as the final values are also to be documented in the traffic forecast memorandum.

Chapter 5
Traffic Forecasting with Travel Demand Models

This chapter provides guidance on how to apply the outputs from a travel demand model when developing traffic forecasts. As such, this chapter presents the following:

- An overview of travel demand models;
- The travel demand models that are available in the State;
- The process to evaluate model output, methods for reviewing the accuracy of travel demand model outputs; and
- The information needed for the traffic forecast memorandum.

5.1. Overview of Travel Demand Models

Regional travel demand models are widely accepted planning tools that produce forecasts of travel based on future estimates of population and employment. The primary purpose of a regional travel demand model is to provide system-level traffic forecasts used to identify transportation needs and future travel conditions. The resulting system travel demand forecasts provide a basis for the more detailed evaluation required for specific project developments.

Travel demand models can be useful tools in developing the traffic projections. However, since travel demand models are "planning" versus "design" tools, the system-level traffic projections must be properly evaluated for reasonableness and consistency in light of current conditions and those indicated by trends (see Chapter 6 of these Guidelines).

Travel demand models are typically developed and maintained by MPOs or local jurisdictions. A regional travel demand model is calibrated and validated for the model calibration year, using empirical traffic data from local origin and destination travel studies, traffic counts, transit boarding volumes, journey-to-work and American Community Survey data from the US Census, and other available travel behavior data. Calibration involves the adjustment of travel demand model parameters so that predicted travel matches observed travel in the model calibration year. Validation involves testing the predictive travel demand model data against additional empirical data for the model calibration year. Calibration/validation is an iterative process until the model's system-wide results fall within an acceptable range of error.

A travel demand model is then used to forecast future volumes using population and employment projections and the planned transportation network for a future year. The travel demand model parameters are not to be modified from the model calibration year set-up. The travel demand model for the model calibration year may be updated to create a base year model. The base year is as close as possible to the existing year and the base year travel demand model is validated using traffic volumes. This base year model is the basis for traffic forecasts.

Figure 5-1 illustrates the process of traffic forecasting based on travel demand model output, which is expanded upon in the subsequent sections of this chapter. Assumptions for typical

types of projects are provided, however, the analyst is cautioned concerning generalizations because some projects could require (or warrant) a higher level of accuracy due to project-specific circumstances.

The methodology of using travel demand model outputs for traffic forecasting is to be used for planning, environmental analysis, and design projects. For operational analysis projects, because the analysis years are usually within five years into the future, NDOT's hourly count data are to be the primary source for traffic forecasting. The traffic forecasting process, in this case, would involve conducting a historical trend projection analysis, which is explained in Chapter 6 of these Guidelines.

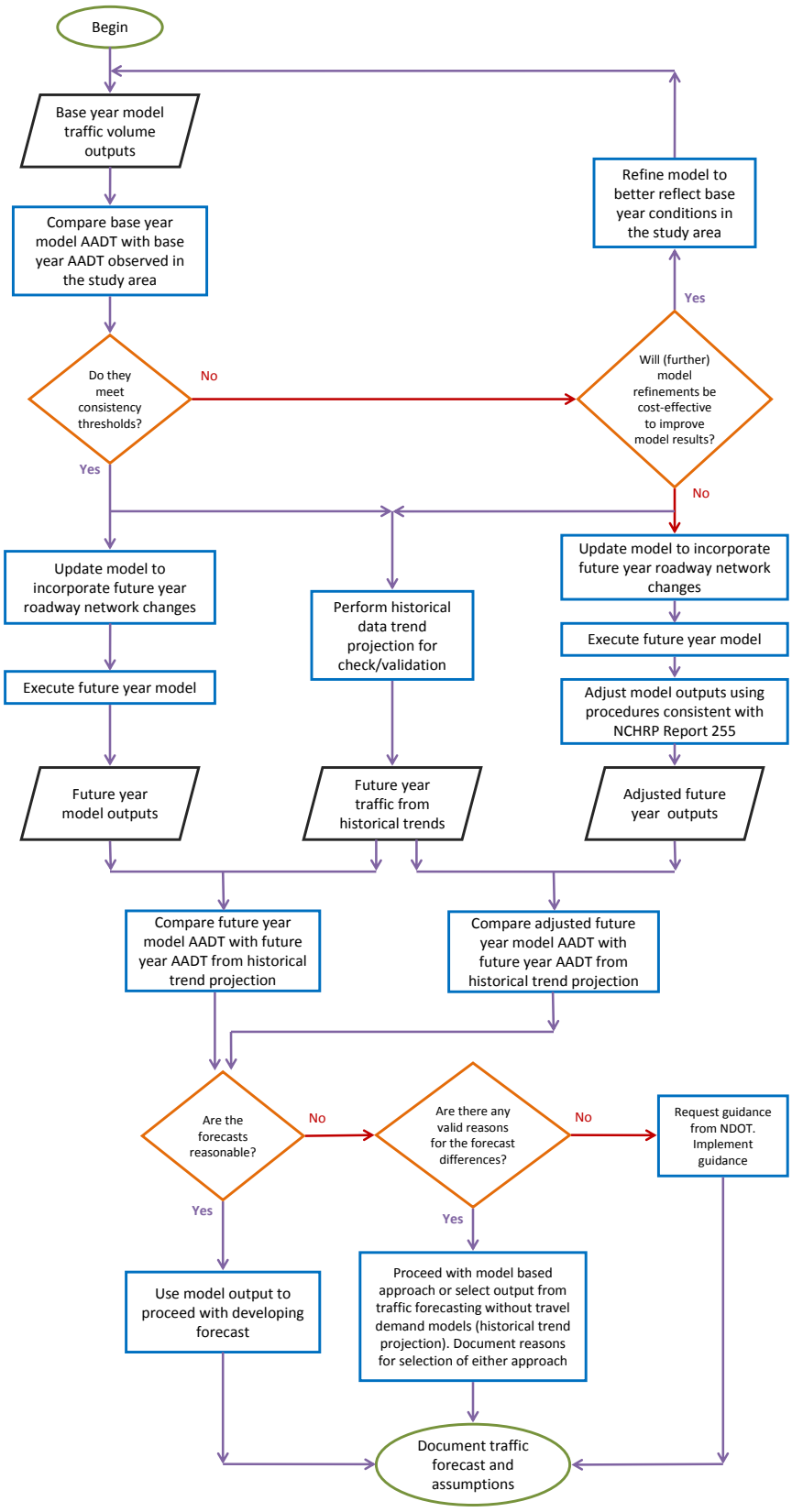


Figure 5-1 Traffic Forecasting with Travel Demand Models

5.2. Selecting a Travel Demand Model

Travel demand models are usually developed, maintained, and used by MPOs to establish regional or system-level traffic forecasts. These forecasts help to identify transportation needs of the region in the development of long range plans. In the State, travel demand models are available from the following MPOs:

- Regional Transportation Commission (RTC) of Southern Nevada;
- RTC of Washoe County;
- Carson Area MPO; and
- Tahoe Regional Planning Agency.

In addition to the travel demand models from these MPOs, a travel demand model is also available from the Lyon County Planning Commission.

Each of the travel demand models listed are regional in nature (county-wide), and selecting the most appropriate model is based upon the project's geographic limits. If the project location is outside the limits of these travel demand models and traffic projections for the project location are not available from the travel demand models, other approaches may be used for traffic forecasting (see Chapter 6 of these Guidelines). Because the availability of these travel demand models may vary, NDOT or the appropriate local agencies with jurisdiction in the region is to be contacted to verify availability of the model. Also, NDOT is developing a statewide travel demand model; this model is based on the available regional travel demand models. As such, it is standard practice to apply the individual MPO travel demand models, rather than the derived statewide model, for traffic forecasting purposes. In some cases, a travel demand model may be developed for areas where travel demand models do not currently exist. In such cases, these models should be developed under the direction and guidance of local agency staff and NDOT.

The model outputs from each of these travel demand models might not be AADT, the analyst is recommended to obtain the details of the model outputs from the agency responsible for that model. Relevant MOCF is to be applied to convert the model output to AADT, refer Section 5.5.2 for detailed information on estimating MOCF. In addition to the daily volume forecasts, the travel demand model might also provide peak period link volumes. Even in these cases, it is recommended that the analyst use the daily volumes to continue with the forecasting process rather than the peak period volumes.

5.3. Reviewing the Accuracy of a Travel Demand Model

After selecting a travel demand model for traffic forecasting, the next step is to review the model's base year traffic output within the study area to ensure that the travel demand model is able to produce accurate estimates of the base year traffic. Generally, an adopted or approved travel demand model is in an acceptable condition for regional planning purposes. However, if the travel demand model is not up to the desired standard in the study area, model refinements

are necessary to update the travel demand model to an acceptable standard for project or corridor-specific traffic forecasting purposes. The travel demand model is to be evaluated, refined, and validated, as appropriate, to ensure that it can accurately forecast future traffic volumes within the study area. The process also includes a review of available land use, socioeconomic, and transportation network data to be used in the travel demand model, and this review is to be documented and approved prior to its use.

5.3.1. Evaluating the Base Year Conditions

Reviewing the base year travel demand model ensures that the model is capable of replicating base year conditions and, as an extension, future year conditions in the study area. Validating the base year travel demand model allows the analyst to compare base year counts to the modeled volumes. It is important to establish the travel demand model's output in comparison with the field data available. Because travel demand models can vary significantly, the agency responsible for developing and maintaining the travel demand model must be contacted to establish the exact model output. As noted, any modifications made to the travel demand model output and the calculation of the MOCF must be documented in the traffic forecast memorandum.

5.3.2. Refining the Base Year Travel Demand Model

When evaluating the travel demand model for base year conditions, if the model outputs are found to vary from the field count data, base year refinements are necessary to ensure that the travel demand model best reflects the actual conditions in the study area. The following is a series of refinements that are commonly used to accomplish this.

- The network is to be updated to ensure proper representation of roadways through the inclusion of parallel roadway links, collector, and other secondary roadways within the study area. Acceptable refinements include changes in roadway type, area type, and the number of lanes.
- The TAZs centroid connectors and their location are to be examined and adjusted if necessary.
- The socioeconomic base year data in the TAZs is to be reviewed within the study area. Trips generated by prominent activity generators are to be compared to actual traffic counts. If discrepancies are found from observed conditions, then coordination with the MPO must occur to obtain consent and approval to make TAZ-related socioeconomic modifications.

The following sections further detail the list above. Additionally, any refinement must include just cause, and any refinement made to the travel demand model network or socioeconomic assumptions must be clearly documented in the traffic forecast memorandum.

5.3.2.1. Base Year Socioeconomic Land Use Data Refinements

The base year land use data is to be analyzed within the study area for accuracy and consistency with local comprehensive plans. When doing this, local planning agencies and MPOs are to be contacted to verify the socioeconomic land use data. Furthermore, all existing TAZs are to be analyzed based on the size and the number of trips each TAZ generates within the study area. Trip end summaries for zones of interest in the study area are also to be evaluated for reasonableness. It may be necessary to refine the existing TAZ structure to obtain a better assignment, although special care must be taken to correctly code the new centroid connectors. Though some data may be refined, the analyst must be aware that population, employment, and other totals for the entire travel demand model cannot be changed. These totals must continue to reflect the adopted RTP totals.

5.3.2.2. Base Year Network Refinements

The travel demand model's base year network within the study area is to be evaluated to ensure that all major roadways are coded appropriately. Additional roadways may need to be added to the network to provide better loading points for newly created TAZs/centroid connectors, as well as to allow for an improved path building process. The coding of all roadways within the study area is to be verified with regards to their roadway type and number of lanes.

5.3.2.3. Base Year Count Refinements

An analysis is to be conducted to identify whether a sufficient amount of count data is available within the study area. If critical links are missing counts, then additional counts are to be obtained. If any roadways have been added to the network, the availability of counts is to be checked for these added roadways. An analysis is also conducted to add cutlines, which may require additional counts, within the study area for quicker analysis of the accuracy of the distribution patterns. These additional counts would have to be adjusted to the base year of the study, as well as to the units the travel demand model uses (axle adjustments, AADT, ADT, AWDT, etc.). It should be noted that this approach may be a costly endeavor and may not always be feasible or desirable, based on the production schedule of certain projects.

5.3.3. Determining the Necessity and Feasibility of Further Refinements

After the appropriate base year travel demand model refinements have been incorporated, the modified travel demand model is assessed for accuracy. The accuracy of the model is to be evaluated to identify if the travel demand model outputs are consistent with real world conditions. This accuracy assessment is to be conducted as explained in Section 5.3.4. If the travel demand model outputs are found to be accurate and consistent with the real world conditions within the study area, the analyst may proceed to Section 5.4 of these Guidelines to apply the travel demand model for future year conditions. However, if the travel demand model is found to be inconsistent even after the base year refinements, the analyst is to evaluate the feasibility and cost-effectiveness of further refinements to the base year travel demand model. If

further refinements are feasible, the travel demand model is updated, and an accuracy assessment is conducted again. Figure 5-1 provides the series of steps involved in base year travel demand model refinements, determining the necessity and feasibility of further refinements and the relevant subsequent steps.

5.3.4. Recommended Accuracy Levels (Consistency Thresholds)

After refining the travel demand model to improve its ability to reflect base year conditions, the model outputs are tested against consistency thresholds. If the travel demand model outputs meet the consistency thresholds, then the travel demand model can be applied for the future year conditions, and the model outputs can be used for the traffic analysis. If the travel demand model outputs do not meet the consistency thresholds, then the model outputs are to be adjusted based on the industry standard NCHRP Report 255 procedures before proceeding to the traffic analysis process. Table 5-1 and Table 5-2 list the consistency thresholds that are required to be met.

Table 5-1 lists the percent deviation thresholds. This prescribes the extent by which the travel demand model volume can differ from the field count and still be accurate enough to proceed with the traffic forecasting process without adjusting the model outputs. Conceptually, model-simulated link volumes are expected to be accurate enough to correctly determine the required number of lanes for roadway design. This means that the acceptable error must be no more than the service volume (at the design LOS) for one lane of traffic. This reference service volume is a higher percentage of total traffic for low volume roads than for high volume roads. The percent deviation between the NDOT counts and travel demand model volumes for each link is calculated using the following formula where “i” corresponds to a link/segment in the roadway network and “n” is the total number of links/segments, as expressed in the following equation.

$$\text{Percent Deviation}_i = \left(\frac{\text{Count}_i - \text{Model Volume}_i}{\text{Count}_i} \right) \times 100$$

Percent deviation values are to be calculated separately for each link across the cultines and for each link along the project corridor. These percent deviation values are to be compared against the maximum allowable percent deviation thresholds (Table 5-1) for the AADT range that the subject links correspond to.

Table 5-2 lists the acceptable Coefficient of Variation of Root Mean Square Error (CV[RMSE]) thresholds for identifying the consistency between the travel demand model outputs and the base year counts. The CV(RMSE) between the NDOT counts and travel demand model volumes for each AADT range are calculated using the following formula where “i” corresponds to a link/segment in the roadway network and “n” is the total number of links/segments, as expressed in the following equation.

$$CV(RMSE) = \left(\frac{\sqrt{\frac{\sum_{I=1}^{n} (Count_i - Model\ Volume_i)^2}{n}}}{\frac{\sum_{I=1}^{n} Count_i}{n}} \right) \times 100$$

CV(RMSE) values are to be calculated separately for each AADT Range, by considering each link across the cultines and each link along the project corridor that correspond to that AADT range. The calculated CV(RMSE) values are to be compared against the maximum allowable CV(RMSE) threshold (Table 5-2) for that AADT range.

The basis for comparison and the specific criteria are as follows.

- Base year (travel demand model) runs are compared with the base year ground counts along cutlines and along the project corridor on a link-by-link basis. This comparison indicates where specific network coding changes may be required. Traffic volumes that are assigned to a link in the study area and traffic volumes that significantly vary from the ground counts could indicate a coding problem. Table 5-1 and Table 5-2 list the maximum desirable errors.
- Agreement between travel demand model and counted volumes must not be forced by altering the travel demand model to significantly affect other portions outside the study area and the network validity. Care is needed to ensure that "lack of fit" is not simply moved from one link to another.

As listed in Table 5-1 and Table 5-2, comparisons of the travel demand model volumes and counts are to be made for all links at cutlines and made for all links along the project corridor. All of the thresholds listed in Table 5-1 and Table 5-2 must be met for the travel demand model outputs to be considered "consistent" with base year counts. Steps to refine the base year travel demand model were explained in previous sections and these steps are applied so that the model outputs may be consistent with counts. If travel demand model outputs are inconsistent with base year counts even after refinements and if further refinements are deemed infeasible, NCHRP Report 255 adjustments are to be applied to the future year model outputs, which is explained further in Section 5.5.1.

Table 5-1 Consistency Thresholds: Percent Deviation Thresholds for every Link across Cutlines and all Project Corridor Links

AADT Range	Maximum Allowable Percent Deviation
< 50,000	± 10%
50,000 - 249,999	± 7.5%
≥ 250,000	± 5%

Table 5-2 Consistency Thresholds: CV(RMSE) Thresholds for every Link across Cutlines and all Project Corridor Links

AADT Range	Maximum Allowable CV(RMSE)
< 5,000	45%
5,000 – 9,999	35%
10,000 – 14,999	30%
15,000 – 19,999	25%
20,000 – 49,999	20%
> 50,000	10%

For the purpose of illustration, the travel demand model outputs for the region near Pyramid Way, Washoe County, are used here and the accuracy of the model outputs is evaluated. The travel demand model outputs from the 2008 RTC Washoe Interim Consensus Forecast (ICF) Base Model are compared with field counts to determine whether the model outputs satisfy the consistency thresholds.

This location falls under the purview of the travel demand model developed by the RTC of Washoe County. Figure 5-2 shows a portion of the year 2008 model output and the link volumes for a few segments; the models outputs are in 100's of AWDT. Hence, the model outputs (AWDT) were first converted to AADT by applying the MOCF (the methodology of estimation of MOCF for a model is explained in Section 5.5.2).

Table 5-3 and Table 5-4 show the Model AADT and the actual AADT obtained from field counts for each link along the project corridor. Table 5-3 shows the calculated percent deviation for each link along the project corridor. Similarly, Table 5-4 shows the calculated CV(RMSE) corresponding to each link along the project corridor estimated by AADT range.

Note that this illustrative accuracy assessment did not look at links across cutlines, the comparison of travel demand model outputs with field counts should be done at all links across cutlines too.

From Table 5-3 and Table 5-4, it can be seen that only one of the links meets the percent deviation thresholds and none of the links meet the CV(RMSE) thresholds. Travel demand model outputs are deemed inconsistent even if one of the links is found to exceed the consistency thresholds. Thus, it was determined that the model outputs were not consistent with the existing field counts and NCHRP Report 255 adjustments were deemed necessary. The application of these adjustments is explained in Section 5.5.1.

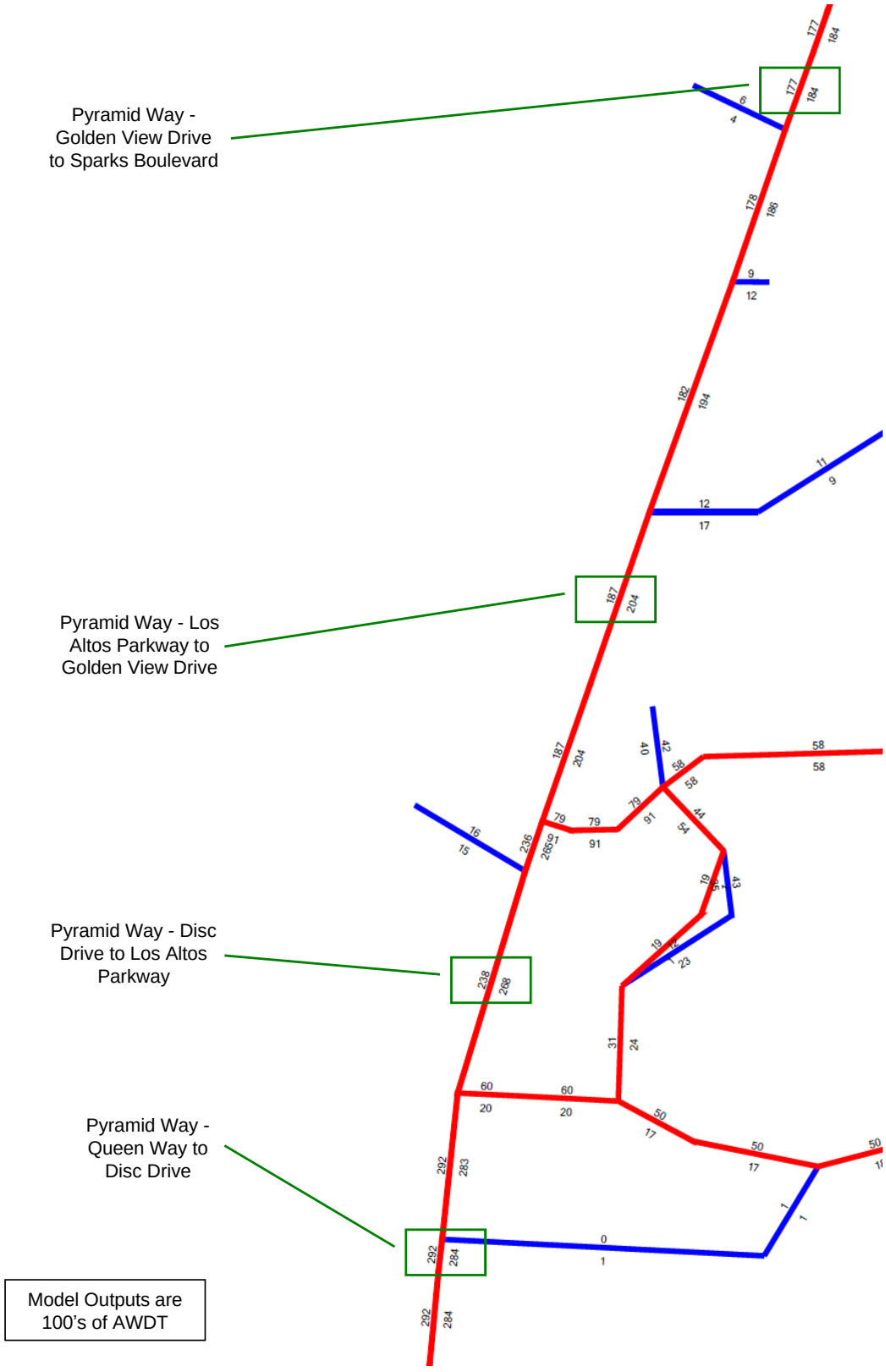


Figure 5-2 Sample Year 2008 Travel Demand Model Output Plot

Source: RTC Washoe

Table 5-3 Sample Percent Deviation Comparison along all Project Corridor Links

Segment	Field Count Source	Model AADT	Actual AADT	Percent Deviation	Meets Consistency Thresholds?
US-395: North of Parr	NDOT Station #418 (2008 volume)	73,453	66,260	11%	No
US-395: South of Parr	NDOT Station #468 (2008 volume)	79,336	69,334	14%	No
Pyramid Way: Queen Way to Disc Drive	NDOT Station #340 (2008 volume)	54,662	43,594	25%	No
Pyramid Way: Disc Drive to Los Altos Parkway	2007 tube count	48,019	37,805	27%	No
Pyramid Way: Los Altos Parkway to Golden View Drive	2007 tube count	37,106	31,792	17%	No
Pyramid Way: Golden View Drive to Sparks Boulevard	2007 tube count	34,259	27,054	27%	No
Pyramid Way: Sparks Boulevard to Dolores Drive	2007 tube count	53,429	38,398	39%	No
Pyramid Way: Dolores Drive to La Posada Drive	2008 tube count	46,976	34,119	38%	No
Pyramid Way: La Posada Drive to Sunset Springs Lane	2007 tube count	26,003	18,368	42%	No
Pyramid Way: Sunset Springs Lane to Calle De La Plata	2007 tube count	17,272	12,778	35%	No
Sun Valley Boulevard: South of Dandini Boulevard	NDOT Station #344 (2008 volume)	25,338	23,188	9%	Yes
Sun Valley Boulevard: North of Dandini Boulevard	NDOT Station #345 (2007 volume)	39,953	32,859	22%	No

Source: Jacobs, Pyramid Highway US 395 Connection

Table 5-4 Sample CV(RMSE) Comparison along all Project Corridor Links

AADT Range	Segment	Model AADT	Actual AADT	CV(RMSE)	Meets Consistency Thresholds?
10,000-14,999	Pyramid Way: Sunset Springs Lane to Calle De La Plata	17,272	12,778	35%	No
15,000-19,999	Pyramid Way: La Posada Drive to Sunset Springs Lane	26,003	18,368	42%	No
20,000-49,999	Pyramid Way: Queen Way to Disc Drive	54,662	43,594	37%	No
	Pyramid Way: Disc Drive to Los Altos Parkway	48,019	37,805		No
	Pyramid Way: Los Altos Parkway to Golden View Drive	37,106	31,792		No
	Pyramid Way: Golden View Drive to Sparks Boulevard	34,259	27,054		No
	Pyramid Way: Sparks Boulevard to Dolores Drive	53,429	38,398		No
	Pyramid Way: Dolores Drive to La Posada Drive	46,976	34,119		No
	Sun Valley Boulevard: South of Dandini Boulevard	25,338	23,188		No
	Sun Valley Boulevard: North of Dandini Boulevard	39,953	32,859		No
>50,000	US-395: North of Parr	73,453	66,260	13%	No
	US-395: South of Parr	79,336	69,334		No

Source: Jacobs, Pyramid Highway US 395 Connection

5.4. Applying the Travel Demand Model for Future Year Conditions

After reviewing the travel demand model for base year conditions, the model is ready to determine the future year traffic forecasts. However, the future year travel demand model has to reflect any refinements to the base year travel demand model. In addition, the network needs to accurately reflect future year conditions. This section explains the methodology to prepare the travel demand model to reflect future year conditions.

5.4.1. Modifying Future Year Network and Land Use

When forecasting interim and design year traffic, it may be necessary to incorporate any refinements in socioeconomic land use and/or changes in the network that is not reflected in the approved interim and design year data sets. Similar to the incorporation of base year travel demand model refinements, these changes are not to be made without the coordination and approval from the agency responsible for the travel demand model. Changes made to the travel demand model must be consistent with the methodology prescribed by the agency responsible for the travel demand model and are to be fully documented in the traffic forecast memorandum in a manner that would allow another individual to make the same changes and obtain the same results. This material is then reviewed with NDOT and the agency responsible for the travel demand model to obtain consensus on the results.

5.4.2. Evaluating Future Year Conditions

In order to forecast traffic for a given year, appropriate future year data inputs are required. For each of the future analysis years, the following travel demand model inputs are to be summarized:

- Transportation network, and
- Socioeconomic/land use data.

Each of these factors is to be updated to reflect the approved elements of the MPO's financially feasible long range plan along with the planned development mitigation infrastructure improvements anticipated to be in place in each analysis year. Because the timing of land use and network changes is not usually a known quantity, it may be appropriate to use the modeled data in a regression analysis with the historical data in order to obtain an AADT for any given year.

5.5. Executing the Travel Demand Model and Evaluating Outputs

After the travel demand model has been appropriately updated to reflect the future year conditions, the next step is to execute the model. Guidelines regarding the execution of a travel demand model are to be obtained from the agency responsible for the travel demand model and must be followed accordingly. For the sake of evaluating outputs, the outputs from the travel demand model are compared with results from a historical trend projection analysis. Care is

necessary when evaluating the travel demand model outputs to ensure that the model outputs are the same type as the results from the historical trend projection. For example, if the travel demand model outputs are AWDT and the historical trend projection uses AADT, then the model outputs must first be converted to AADT.

5.5.1. Adjusting Travel Demand Model Output using NCHRP Report 255 Procedures (If Necessary)

The following is to be applied only if the base year travel demand model was found to be inconsistent with real world conditions, and further model refinements were deemed necessary. Correspondingly, this section explains the NCHRP Report 255 guidelines for adjusting the travel demand model outputs in such cases, so that the future year model outputs are relevant and accurate.

In general, there are three procedures described in NCHRP Report 255 for adjustment of link volumes obtained from computerized travel demand volume forecasts. These three methods are the ratio adjustment method, the difference adjustment method, and the combination adjustment method. The purpose of each method is to adjust the future year link assignments to account for possible assignment errors.

For the purpose of illustration, travel demand model outputs are used for the region near Pyramid Way in Washoe County. This location falls under the purview of the travel demand model developed by the RTC of Washoe County. The travel demand model outputs from the 2008 RTC Washoe Interim Consensus Forecast (ICF) Base Model and the Year 2030 No-Build scenario are used to illustrate the adjustments.

Figure 5-2 shows a portion of the 2008 travel demand model output and the link volumes for a few segments. The model outputs are in 100s of AWDT. Table 5-5 lists examples of the application of these procedures to adjust travel demand model outputs. In this example, adjustments have been made to the travel demand model output AWDT, but the procedures described may also be applied to the model outputs after being converted to AADT (i.e., after applying the MOCF to the model outputs).

5.5.1.1. Ratio Adjustment Method

The ratio adjustment method can be described as a growth factor method where the growth between the base year's and future year's travel demand model outputs is applied to the field measured traffic counts. This method can generate erroneous or problematic results if the field traffic count is significantly greater than the travel demand model reported traffic volume or vice versa. In such a case, NCHRP Report 255 recommends using the difference adjustment method.

In Table 5-5, the ratio adjustment method has been applied as follows:

$$\frac{\text{Future year model volume}}{\text{Base year model volume}} \times \text{Base year count}$$

5.5.1.2. Difference Adjustment Method

The difference adjustment method provides adjusted volumes on each link by the addition of the difference (or increment) between the base year travel demand model and future year travel demand model to the field measured traffic volume. This method can generate problematic results if the difference is less than zero, which may lead to a (impossible) negative adjusted value for future traffic. In such a case, NCHRP Report 255 recommends using the ratio adjustment method.

In Table 5-5, the difference adjustment method has been applied as follows:

$$\left(\text{Future year model volume} - \text{Base year model volume}\right) + \text{Base year count}$$

5.5.1.3. Combination Adjustment Method

The combination adjustment method suggests taking the average of the values obtained by the ratio adjustment method and the difference adjustment method. If either of the ratio adjustment or difference adjustment method is found to produce erroneous or problematic results, then it is recommended not to use the combination adjustment method. Rather, the analyst is to use the method that provides the most reasonable results.

In all, the analyst is to apply engineering judgment on a case-by-case basis when choosing the most suitable method of adjustment. It is also acceptable to apply the most suitable method on a link-by-link basis, if the analyst determines that such an application will yield the most reasonable results.

Table 5-5 Sample NCHRP Report 255 Adjustments to the Travel Demand Model Output

Roadway Segment	Year 2008: Actual AWDT	Year 2008: Model Output AWDT	Year 2030: Model Output AWDT	Year 2030 Model AWDT after NCHRP Report 255 Adjustments		
				Ratio Adjustment Method	Difference Adjustment Method	Combination Adjustment Method
US-395: North of Parr	69,789	77,400	155,000	139,760	147,390	143,580
US-395: South of Parr	73,027	83,600	166,900	145,800	156,330	151,070
Pyramid Way: Queen Way to Disc Drive	45,916	57,600	63,200	50,390	51,520	50,960
Pyramid Way: Disc Drive to Los Altos Parkway	39,819	50,600	53,900	42,420	43,120	42,770
Pyramid Way: Los Altos Parkway to Golden View Drive	33,485	39,100	51,400	44,020	45,790	44,910
Pyramid Way: Golden View Drive to Sparks Boulevard	28,495	36,100	48,100	37,970	40,500	39,240
Pyramid Way: Sparks Boulevard to Dolores Drive	40,443	56,900	60,600	43,080	44,150	43,620
Pyramid Way: Dolores Drive to La Posada Drive	35,936	49,500	46,300	33,620	32,740	33,180
Sun Valley Boulevard - South of Dandini Boulevard	24,423	26,700	53,100	48,580	50,830	49,710
Sun Valley Boulevard - North of Dandini Boulevard	34,609	42,100	62,900	51,710	55,410	53,560

Source: Jacobs, Pyramid Highway US 395 Connection

5.5.2. Converting Travel Demand Model Output

If the output from the travel demand model is not AADT, the output must be converted to AADT in order to continue with the process of estimating DDHV. Accordingly, the following explains the calculation of appropriate conversion factors.

5.5.2.1. Developing Model Output Conversion Factors (MOCF)

For the purpose of illustration, the conversion of travel demand model outputs to AADT for the region near Pyramid Way in Washoe County is explained here. As noted in Section 5.5.1, this location falls under the purview of the travel demand model developed by the RTC of Washoe County, and the model plots from the 2008 RTC Washoe ICF Base Model were used to obtain the travel demand model volumes for roads in this region. Figure 5-2 shows a portion of the travel demand model output and the link volumes for a few segments. The model outputs are in 100s of AWDT.

AADT is the basic quantity for the calculation of DDHV, but the travel demand model outputs were AWDT, requiring the development of MOCF to convert the AWDT to AADT. Data from NDOT's short-term count stations and the consultant's short-term counts were used for the validation purpose. The travel demand model outputs were converted to AADT by applying the MOCF. The MOCF is calculated by dividing the existing count AADT by the existing count AWDT, as expressed in the following equation.

$$\text{MOCF} = \frac{\text{Existing Count AADT}}{\text{Existing Count AWDT}}$$

The AWDT for the NDOT count stations were obtained by averaging the observed daily volumes for Monday through Friday and adjusting with the seasonal factor. Table 5-6 lists the travel demand model output AWDT, actual AWDT, actual AADT from the field counts, and the calculated MOCF for the different roadway segments in the project location. Regardless of the travel demand model output, the MOCF can be estimated based on the procedure explained here.

Table 5-6 Sample Calculation of MOCF

Roadway Segment	Actual Count Source	Actual AWDT	Actual AADT	Actual AADT to Actual AWDT (MOCF)	Model Output (AWDT)	Converted Model Volume (Model AADT)
US-395: North of Parr	NDOT Station #418 (2008 volume)	69,789	65,210	0.934	77,400	73,453
US-395: South of Parr	NDOT Station #468 (2008 volume)	73,027	67,957	0.931	83,600	79,336
Pyramid Way: Queen Way to Disc Drive	NDOT Station #340 (2008 volume)	45,916	44,137	0.961	57,600	54,662
Pyramid Way: Disc Drive to Los Altos Parkway	2007 tube count	39,819	-	-	50,600	48,019
Pyramid Way: Los Altos Parkway to Golden View Drive	2007 tube count	33,485	-	-	39,100	37,106
Pyramid Way: Golden View Drive to Sparks Boulevard	2007 tube count	36,100	28,495	-	-	34,259
Pyramid Way: Sparks Boulevard to Dolores Drive	2007 tube count	56,300	40,443	-	-	53,429
Pyramid Way: Dolores Drive to La Posada Drive	2008 tube count	49,500	35,936	-	-	46,976
Sun Valley Boulevard: South of Dandini Boulevard	NDOT Station #344 (2008 volume)	24,423	22,863	0.936	26,700	25,338
Sun Valley Boulevard: North of Dandini Boulevard	NDOT Station #345 (2007 volumes)	34,609	34,083	0.985	42,100	39,953
			Average MOCF	**0.949**		

Source: Jacobs, Pyramid Highway US 395 Connection

5.5.2.2. Converting AWDT to AADT

The MOCFs were calculated corresponding to each of the NDOT short-term count stations in the project location. In the example (Table 5-6), five NDOT count stations were present in the project location. The MOCFs corresponding to each of these count stations were averaged to obtain a project-wide MOCF. This project-wide MOCF was applied to the travel demand model output AWDTs to obtain the AADT projections from the model. The travel demand model AADTs are calculated from the AWDTs using the following equation:

$$\text{Model AADT} = \text{Model AWDT} \times \text{MOCF}$$

The "Converted Model Volume" column of Table 5-6 lists the travel demand model outputs converted to AADT using the calculated MOCF.

This illustration explained the conversion of travel demand model output AWDT to AADT. But, this same procedure may be appropriately applied even if the travel demand model outputs are a different quantity.

5.5.3. Comparison of Model Forecasts with Historical Trend Projection Results

Once the travel demand model-predicted future year traffic volumes are available, a historical trend projection analysis is to be completed for comparison with the model results. A historical trend projection analysis is done based on one or more of the following: available historical traffic counts, population growth, employment, gasoline sales, or other appropriate growth indicators. While comparing the travel demand model output volumes with historical trend projection results, engineering judgment is to be applied in determining "reasonableness." The trend in the change of traffic from both the procedures is to be compared, and the rationale and justification behind the judgment are to be documented in the traffic forecast memorandum. If the comparison fails the test of reasonableness, the causes must be identified. An example of a traffic forecast that could be higher than the historical trend would be the addition of lanes or new land development in the study area. An example of a traffic forecast that could be lower than the historical trend would be a future congested roadway identified by the preliminary capacity analysis. These factors and other relevant factors are to be considered when preparing the historical trend projections. The methodology to complete a historical trend projection is explained further in Chapter 6 of these Guidelines.

Future year traffic volumes cannot be validated against existing traffic counts. The modeled volume changes for each year of analysis and for each alternative network are to be evaluated against the expected changes. Although expected changes cannot be accurately quantified, approximate changes are to be estimated. For example, if the region's growth is expected to continue, freeway volumes are expected to increase with some relationship to the trend. The percentage of change between years would be expected to be relatively constant unless some special factors affect the growth, such as improvement of parallel roadways.

The travel demand model-generated volumes for the future years are to be reviewed for logical traffic growth rates. The general growth trends and growth rates prevalent in the area can be identified by the historical trend projection analysis. The future year travel demand model volumes are compared against the appropriate historical count data. If an unexplained growth rate exists, a thorough review of the base and future year land use, socioeconomic data, and network coding must be performed. Logical reasons for any anomalies are to be documented in the traffic forecast memorandum. A careful comparison is required, especially for urbanized areas where growth may be higher along undeveloped corridors, although on an area-wide basis, it may be much lower. Care must be applied to ensure that similar types of traffic outputs are compared. For instance, if a travel demand model outputs AWDT and the historical trend projection is made for AADT, the travel demand model outputs are to first be converted to AADT before comparison (see Section 5.5.2 of these Guidelines).

Travel demand models frequently provide insight into traffic route selection that might not be readily apparent. However, if the travel demand model outputs are found to be unreasonable when compared to the historical trend projection results, valid reasons for the variation in the results must be identified. If valid reasons for the inconsistency cannot be determined, then guidance is to be requested from NDOT, and this guidance is to be followed in the traffic forecasting process. Valid explanations for differences between the historical trend and travel demand model forecast may include land use changes, new roadways, congested conditions, or other considerations that may not be reflected in either the travel demand model or the historical trend analysis projection. All of these issues must be taken into consideration when evaluating the traffic forecasts. As noted, complete documentation of the traffic projection process, including reasonableness evaluation, is to be included in the traffic forecast memorandum.

5.6. Obtaining Design Year AADT from the Travel Demand Model's Future Year AADT Estimates

In some cases, the travel demand model's future years may not match the design year of the transportation project. In these cases, the design year is usually within a couple of years of the travel demand model's future year. Subsequent to following the guidelines explained in the previous sections of this chapter, the AADT estimates that were prepared for the travel demand model's future year are to be used to obtain the project design year AADT.

Compound annual growth rates are to be estimated at each of the study locations, between the interim year and the future year AADT estimates. If AADT estimates are unavailable for an interim year, the compound annual growth rates are to be calculated between the base year and the future year AADT estimates. The compound annual growth rates are to be calculated using the following formula, where "r" is the desired compound annual growth rate being calculated and "n" is the number of years between the "interim year" and the "future year".

$$r = \left(\frac{\text{Future year AADT}}{\text{Interim year AADT}} \right)^{\frac{1}{n}} - 1$$

These compound annual growth rates are to be applied to the future year AADT estimates obtained from the travel demand model to estimate the design year AADT. Depending on whether the design year is before or beyond the travel demand model future year, the compound annual growth rates are to be applied according to either of the two following formulae.

If the design year is before the travel demand model future year, then

$$\text{Design year AADT} = \frac{\text{Future year AADT}}{(1+r)^n}$$

Or, if the design year is beyond the travel demand model future year, then

$$\text{Design year AADT} = \text{Future year AADT} \times (1+r)^n$$

In both these formulae, "r" is the compound annual growth rate calculated in the previous step and "n" is the number of years between the "future year" and the "design year".

For the purpose of illustration, consider the following case of the estimation of the design year AADT for a particular study location.

- Interim year (year 2025) AADT at a study location is 9,640
- Future year (year 2035) AADT at the same study location is 12,220
- The design year of the transportation project is year 2033 and AADT is to be obtained for this study location for the design year

Using the formulae listed above, the compound annual growth rate for the location between year 2025 and year 2035 is

$$r = \left(\frac{12220}{9640} \right)^{\frac{1}{10}} - 1 = 0.024$$

Applying this compound annual growth rate to estimate the design year AADT,

$$\text{Design year (year 2033) AADT} = \frac{12220}{(1+0.024)^2} = 11{,}654$$

Hence, the design year AADT = 11,654 = 11,500 (after rounding)

5.7. Documenting Traffic Forecasts

After the travel demand model results are validated and the traffic forecast is finalized, the next step is to document the forecast. Every assumption made in the traffic forecasting process and every decision made at the decision points shown in Figure 5-1 are to be documented in the traffic forecast memorandum following the guidelines listed in Section 1.7 and Section 1.8. The plots of the study area are to be maintained in the file. Tabulation of the forecasts for the interim and design year are also to be included in an individual section of the traffic forecast memorandum. Appropriate documentation of the methodology, calculation of MOCFs, model accuracy assessment and comparison against consistency thresholds, details of NCHRP Report 255 adjustments applied and reasonableness evaluation with historical trend projection analyses are to be included in the traffic forecast memorandum. Schematic diagrams of the project are to be developed as needed to clearly convey the forecasts. AADT, peak hour link volumes, peak hour turning movements, K_{30}, D_{30}, and T% should be documented.

Chapter 6
Traffic Forecasting without a Travel Demand Model

This chapter provides the methodology and procedures for developing traffic forecasts when a usable travel demand model is not available for the project location. The chapter presents:

- An overview of historical trend projection analyses to forecast traffic in an area without a travel demand model;
- The procedures for performing historical trend projection analyses; and
- Various other references that can assist when forecasting traffic in an area without a travel demand model.

The chapter concludes with a sample case of how to perform a historical trend projection analysis.

6.1. Overview of Historical Trend Projection Analyses

For areas without a travel demand model, traffic forecasts are normally based on historical trends of traffic count data, and growth rates may also be developed (if available) through gasoline consumption reports, census data, and working with the county, city, and their comprehensive plans. Future growth rates can be obtained using nearby metropolitan area growth projections, Statewide plan projections, and information from local comprehensive plans. When historical AADT data is used, a regression analysis is to be performed using the most recent ten years of data. Depending on the availability of data, the regression analysis is conducted using as much historical data as possible. Caution is needed to negate counts that might be obviously out of sync with other years. Some of the most commonly used growth trends are linear, logarithmic, and exponential, and the use of a particular trend depends on the historical traffic data and existing and expected land use characteristics of the project location and the level of “fit” of a particular trend for the available historical data.

It is important to consider the capacity of the roadway when creating the projection for future years. Projections are to show traffic demand and not be constrained because the roadway itself becomes constrained as traffic becomes congested. If the demand is for a six-lane roadway and a four-lane roadway is being designed, then the traffic forecast memorandum is to note that four lanes will not be adequate for a 20-year design. Subsequently, steps are to be taken to address the potential short fall. To arbitrarily constrain traffic does nothing to address or mitigate future congestion.

6.2. Procedures for Performing Historical Trend Projection Analyses

This section explains the methodology and steps to perform a historical trend projection analysis to forecast traffic in an area without a travel demand model.

6.2.1. Assembling the Data

When available and applicable, the analyst is to assemble the following items for preparing a traffic forecast where a travel demand model is not available (also see Section 6.4 of these Guidelines):

- Mapping or other roadway location drawings of the roadway requiring traffic projections (e.g., a project location map);
- Graphical representation of existing lane arrangements (e.g., aerial photography and intersection sketches);
- Resources for determining traffic growth trends, including:
  - Historical traffic count data (Existing year plus nine earlier years of mainline traffic is considered the minimum, but if ten years of data is not available, existing year plus four or more earlier years of mainline and/or intersection approach volumes are necessary), and
  - Current and historical population data (if available);
  - Gas sales records (if available);
- Traffic factors, including K_{30}, D_{30}, and T%;
- RTP or LGCP (land use and traffic circulation elements);
- Description of existing and future land uses that contribute traffic that would use the proposed roadway;
- Current HCM and relevant software;
- The opening year, interim year and design year;
- Adjacent or nearby metropolitan area growth projections; and
- Statewide plan forecasts.

6.2.2. Establishing Traffic Growth Trends

When establishing traffic growth trends, the analyst is to use the following approaches.

- Plot historical AADT at a convenient scale with traffic volume on the y-axis and year of count on the x-axis (leaving room for design year and traffic growth) (see Figure 6-1).
- Use least squares regression analysis combined with graphical representation of traffic growth trends. The R-squared statistic associated with the growth trend is to be reported.
- If historical count data are insufficient, prepare a similar analysis of alternative indicators that are available (e.g., gas sales data, population data).

Using historical data (>10 years) for the trend projection should, in most cases, ensure that the analysis results in a reasonable compound annual growth rate. Nevertheless, forecast volumes that correspond to an equivalent compound annual growth rate of less than 0.5% should be

sufficiently justified. In cases where an equivalent compound annual growth rate of less than 0.5% is estimated based on the historical trend projection, the analyst is to gather and take into consideration additional information as available, and consult with local land plans before recommending a suitable and reasonable compound annual growth rate. In the absence of sufficient justification and supplementary information, a nominal compound annual growth rate of 0.5% is the minimum acceptable value for determining the forecast traffic. This 0.5% minimum compound annual growth rate should not be treated as a default value. The analyst is strongly encouraged to conduct further analysis and then make a careful judgment if a rate higher than 0.5% is more appropriate.

6.2.3. Developing Preliminary Traffic Projection

When developing preliminary traffic projections, the analyst may either:

- Use empirically derived traffic growth trend equations to compute future year traffic volumes, or
- Use graphical methods to project traffic volume from growth trend history to the design year.

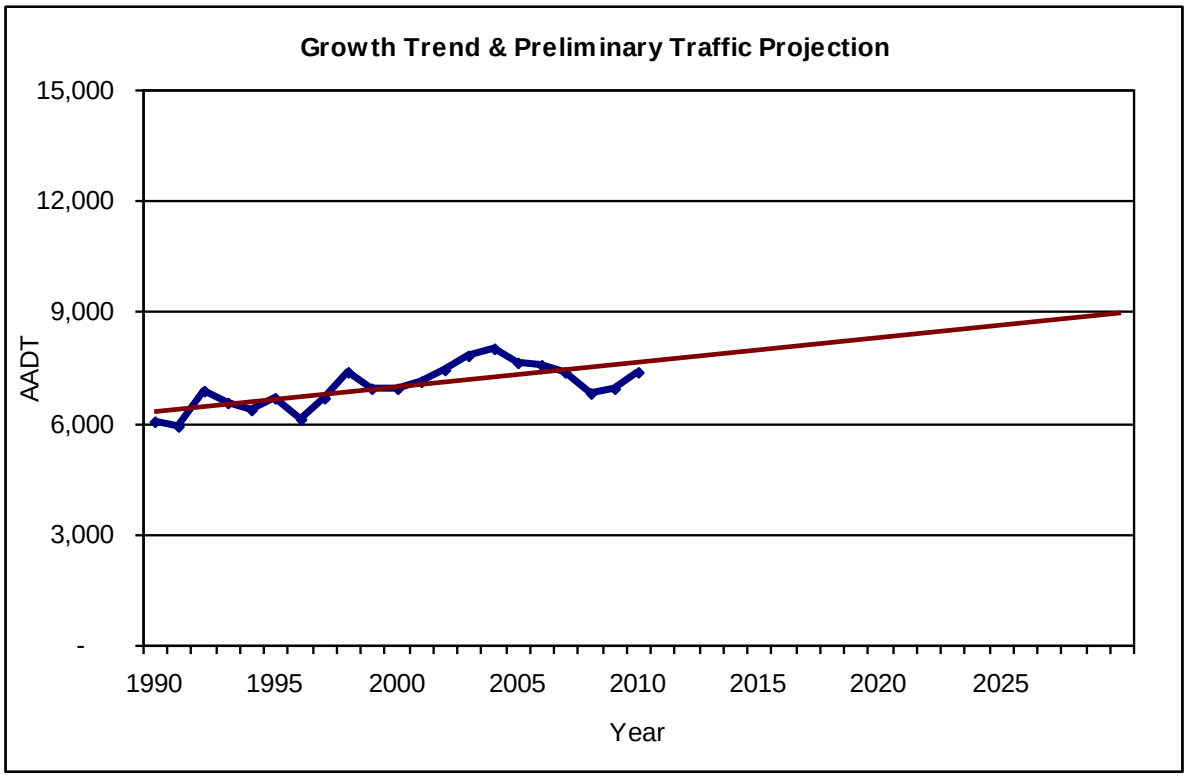


Figure 6-1 Establishing Growth Trend and Developing Preliminary Traffic Projection

6.2.4. Verifying Traffic Forecasts for Reasonableness

To verify traffic forecasts for reasonableness, the analyst is to apply the following.

- If design year geometric and traffic control design characteristics are firmly established (i.e., fixed by adopted plan(s) or constraints), determine the future capacity of the roadway section.
- If design is flexible enough to satisfy unconstrained demand, skip this step. Compare the projected demand traffic volume to the available capacity. A constrained volume may be given (e.g., a four-lane roadway is 15 percent over capacity today, and the project is for a six-lane roadway with trend analysis projections exceeding capacity for a six-lane roadway). The traffic forecast memorandum is to note that the roadway being designed will not be adequate for a 20-year design period.
- Review expected land use changes in the study area and determine whether projected traffic growth is consistent with the projected growth of population, employment, or other variables. If, for example, a new shopping center, office park, or tourist attraction is expected to be built prior to the design year, then projections based on historical traffic trends would underestimate the design year traffic. In such cases, ITE trip generation rates could be used to establish daily and peak hour trips for the new land uses. A logical distribution of resulting site generated trips to available roadways would be based on knowledge of local travel patterns and used to adjust the traffic forecast. Conversely, the closing of an existing traffic generator would be expected to cause a reduction of the traffic forecast.

6.2.5. Developing Traffic Forecast in Detail

When developing traffic forecasts in detail, the analyst is to keep the following in mind.

- Use K_{30} and D_{30} factors to develop directional design hour traffic projections in the peak periods as explained in Chapter 7 of these Guidelines. AM and PM forecasts usually involve reversing the peak direction of flow.
- Review the AM and PM design hour volumes for consistency with the trip generation activity patterns of the projected land uses in the study area and adjust if necessary. Such adjustments are made with reference to observed differences in travel characteristics, such as numbers of trips and directional splits that occur during AM and PM peak periods. Directional traffic counts collected at local land use sites may provide the necessary data. The ITE Trip Generation Manual may also be used to obtain the peak period trip generation characteristics of various land use/special generator sites.
- Estimate peak hour intersection turning movement volumes as explained in Chapter 8 of these Guidelines.

6.2.6. Preparing for Final Review and Documentation

The analyst is to consider the following during the final review and documentation step of the process.

- Perform final quality control review for reasonableness of projections. The assessment of reasonableness could be to examine traffic projections in comparison with observed traffic and historical trends, prospective roadway improvements, and land use projections. The quality control review is also to perform error checks to ensure that input traffic numbers have been correctly transcribed and traffic forecasting computations have been calculated correctly.
- Prepare the traffic forecast memorandum, which includes documenting procedures, assumptions, and results.
- Fill out the traffic forecasting guidelines checklist.

If the traffic forecasts for a project are prepared using the historical trend projection analysis techniques explained in this chapter, the analyst must document forecast traffic, assumptions, and the methodology involved. The documentation should also follow the guidelines explained in Section 1.7, Section 1.8 and Section 5.7 of these Guidelines.

6.3. Other Available Resources for Forecasting Traffic in an Area without a Travel Demand Model

In addition to historical traffic count data, the following list offers other resources that may assist in the preparation of traffic forecasts for areas without travel demand models and when verifying traffic forecasts in areas with travel demand models.

- *Highway Traffic Data for Urbanized Area Project Planning and Design*, NCHRP Report 255
- *Travel Estimation Techniques for Urban Planning*, NCHRP Report 365
- Property appraisal data from the Nevada Real Estate Division
- LGCP (land use, traffic circulation, and transportation elements) from the NDOT District Office/Local Government Office
- *Trip Generation Manual*, ITE (Current Version)
- Gas sales records
- Motor vehicle registrations from the Department of Highway Safety and Motor Vehicles
- MPO long range plans
- Statewide plan projections

When available, the following are examples of factors that are to be considered when making forecasts for areas where travel demand models are not available:

- Current and historical population data,
- Density,
- City size,
- LOS (existing),
- LOS standards,
- Transit alternatives,
- Automobile ownership,
- Household income,
- Residential/non-residential mix,
- Freeway diversion, and
- Other unique area considerations.

6.4. Historical Trend Projection Analysis: Sample Case

The following is an example of traffic forecasting that uses historical trend projection analysis of historical traffic count data. For illustration purposes, the historical data from NDOT count station #190042 in Lyon County are presented, and the preparation of traffic forecasts for the corresponding segment is explained. The forecast was prepared by developing an empirical traffic growth trend equation and by identifying the growth trend graphically. Figure 6-2 illustrates the identified growth trend and the growth trend equation obtained from a linear regression analysis. Historical data extending from 1990 to 2010 was obtained, and a linear projection of traffic was made to 2030. The growth trend that occurred between 1990 and 2010 was assumed to be applicable for forecasting existing traffic to 2030. Table 6-1 lists the annual traffic data from this station. Based on the linear regression analysis (shown in Figure 6-2), traffic on this segment is expected to increase from 7,400 AADT in 2010 to 8,961 AADT in 2030, which calculates to a 0.96 percent compounded annual growth rate. Figure 6-2 also includes the linear trend projection that was established for the historical traffic data.

A comparison was then made to population data for the purpose of validating the forecast traffic. Based on historical population data from the U.S. Census, the population for Lyon County was observed to have increased from 20,001 in 1990 to 51,980 in 2010, which calculates to a 4.89 percent compound annual growth in population. Also, according to population projections by the Nevada State Demographer, the population in Lyon County is expected to increase from 52,700 in 2011 to 70,592 in 2030. This calculates to a 1.55 percent compound annual growth in population. The recorded historical growth in traffic for this roadway segment has been observed to be less than the historical population growth, and this trend is consistent with projected traffic and projected population growth. Furthermore, the rate of traffic growth has been found to slow down for future years similar to the projected rate of population growth. Therefore, the trend in traffic growth, both past and future, has been consistent with the trend in population growth.

Table 6-1 Historical AADT for Use in Trend Projection

Year	Observed AADT
1990	6,015
1991	5,935
1992	6,840
1993	6,560
1994	6,350
1995	6,685
1996	6,085
1997	6,685
1998	7,380
1999	6,950
2000	6,950
2001	7,090
2002	7,410
2003	7,800
2004	8,000
2005	7,600
2006	7,550
2007	7,400
2008	6,800
2009	6,900
2010	7,400

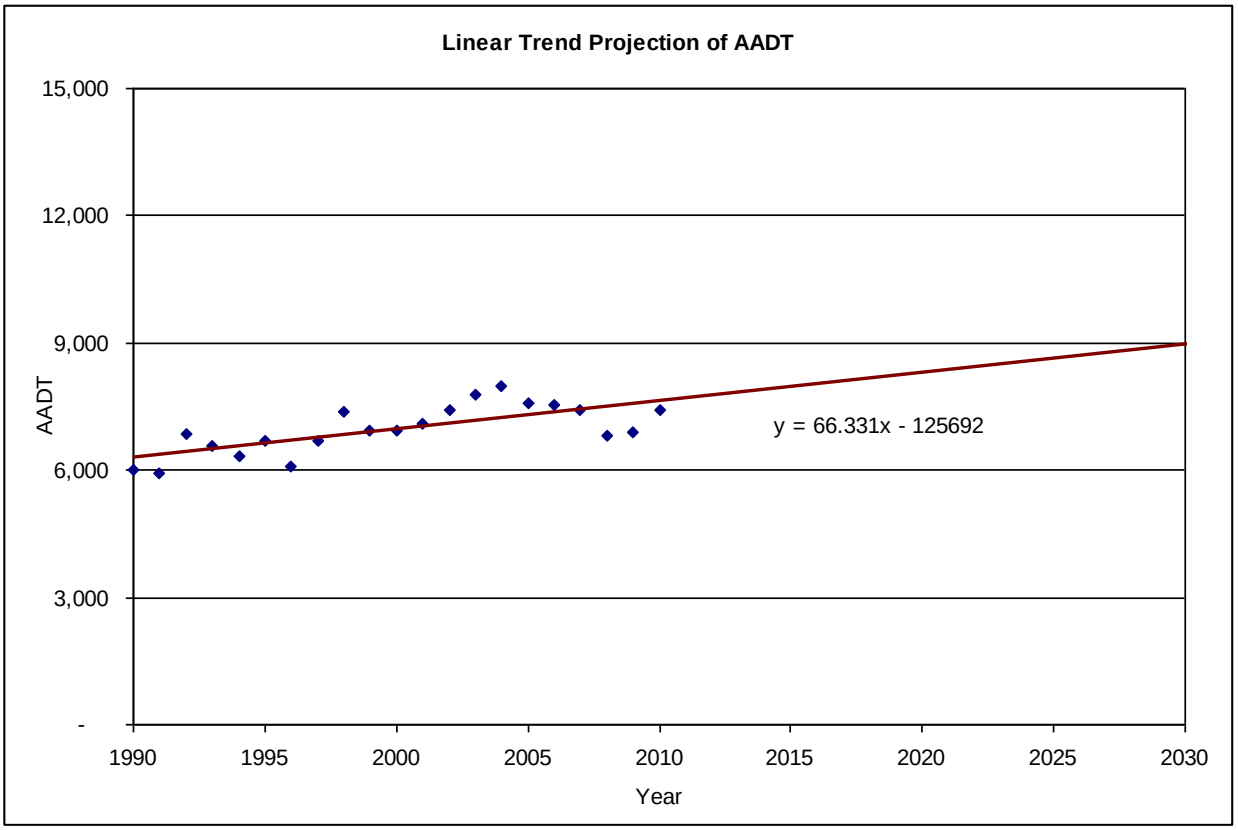


Figure 6-2 Traffic Growth Trend

Note that a traffic forecast reflects an evaluation of the effect of future traffic growth relative to historical trends, the addition of major development, the diversion of traffic to nearby roadways, and the impact of capacity constraints. In all, a traffic forecast is prepared using the best available resources and engineering judgment.

DDHV is usually the final metric used for analysis in many projects. This chapter provides the procedure for arriving at DDHV. In addition, the chapter includes:

- A general overview related to LOS operational analysis;
- Definition and guidance regarding volume estimates for constrained roadways; and
- Additional considerations when drafting the traffic forecast memorandum.

The chapter closes with an overview and sample case of the how to determine peak hours from DDHV.

7.1. Developing Directional Design Hour Traffic Volumes

As discussed earlier, project specific data are used to derive the K_{30} and D_{30} for obtaining DDHV from AADT. These factors are to be within the ranges established by NDOT from the ATRs (see Chapter 4 of these Guidelines for a list of the acceptable range of values). In most instances, there is adequate flexibility within the prescribed range of acceptable values to accommodate application to individual projects.

Design hour traffic is produced by applying K_{30} and D_{30} to AADT projections. The AADT projections may be the result of the travel demand model generated traffic projections (see Chapter 5 of these Guidelines), or the projections may be produced by other techniques, such as historical trend analysis (see Chapter 6 of these Guidelines).

As defined, the K_{30} converts the 24-hour AADT to an estimate of two-way traffic in the 30th highest hour of the year, which is required for design purposes and results in DHV. The K_{30} used for design is to represent unconstrained demand (i.e., it should be obtained from data measured at a location where the 30th highest hour traffic is not constrained by available capacity) (see Section 7.3 of these Guidelines for constrained roadways).

Also as discussed previously, D_{30} converts any DHV two-way traffic volume to an estimated DDHV. Appropriate D_{30} values are developed and updated in the same manner described previously. By convention, the D_{30} value always pertains to the peak direction of traffic flow during the design hour. Using both the K_{30} and D_{30} values, the estimated DDHV is obtained by the following equations.

$$\text{DDHV (Peak Direction)} = \text{AADT} \times K_{30} \times D_{30}$$

$$\text{DDHV (Off - Peak Direction)} = \text{AADT} \times K_{30} \times (1 - D_{30})$$

By applying the above approach, DDHV traffic forecasts are generated for roadway links and intersection turning movements as needed to satisfy requirements. Turning movement forecasts are to reflect the logical effects of future year land use and transportation network improvements on the traffic pattern at a given location. In general, if the pattern of land use and transportation

system characteristics is expected to change, turning movement patterns are also likely to change over time. Existing turning movements and travel demand model simulation results (when available) provide useful starting points for the turning movement forecasting process. The need for turning movement forecast refinements is determined by careful review of the chosen starting point. The analyst is to use K_{30}, D_{30}, and current turning percentages, if available, to calculate turning volumes during the design hour.

7.2. LOS Operational Analysis Guidelines

An LOS analysis is to be performed in accordance with the most current HCM procedures. The HCM procedures are acceptable methods for LOS determination as well as intersection and roadway lane arrangements. The LOS analysis could include, but is not limited to, intersections, mainline segments, HOV lanes, ramps, and weaving lanes. HCM software or equivalent software approved by NDOT may also be used. All LOS analyses, operational, and capacity-related assessments are to be completed under the direction and supervision of the NDOT Traffic Operations Division.

Project traffic using design traffic criteria is a forecast of the 30th highest hour traffic volume for the design year and is required by NDOT for all design projects.

7.3. Definition of a Constrained Roadway

Physical, environmental, or policy constraints may dictate that an existing roadway may not be expanded even if excess demand for that roadway exists. This type of roadway is called a constrained roadway. Physical constraints primarily occur when intensive land use development is immediately adjacent to roadways, thus making expansion costs prohibitive. Environmental and policy constraints primarily occur when decisions to not expand a roadway are based on environmental, historical, archaeological, aesthetic, or social impact considerations. Volumes on constrained roadways are often governed by the capacity of the constrained roadway rather than K_{30} and D_{30} values.

For constrained roadways, the following is also to be considered during the traffic forecasting process.

- If traffic forecasting is carried out with a travel demand model, the travel demand model would be coded to reflect the constrained number of lanes, and standard traffic forecasting procedures would apply. Traffic smoothing adjustments are, as with other travel demand model forecasts, to be reviewed in the development of model traffic forecasts.
- For historical trend projections, procedures outlined in the NCHRP Report 365 are to be considered. Per the report:

  > The underlying assumption of the redistribution procedure is that forecast-year volumes on parallel roadways should tend to be distributed

proportionally to the volumes as observed on the roadways in the base year. Further stated, if no capacity changes (e.g., widenings and new roadways) occur between the year observations are made and the forecast year, the forecast-year volumes on the links intercepted by the screenline are inclined to be proportional to the base year system. All capacity changes to the forecast year system are interpreted as new roadways, including widening of existing roadways (NCHRP 1998).

In other words, the existing capacities are used as guidelines for developing traffic forecasts. Adjustments are to be made to the distribution for the constrained roadway in relationship to the impact that the constrained capacity has on the overall existing distribution capacity and future capacity.

- The constrained condition might cause the constrained roadway to exceed accepted minimum LOS standards. Several iterative steps may be needed prior to finalizing DHV and DDHV so that project volumes will meet NDOT accepted standards. Use of standard K_{30} values are to be reviewed for applicability in converting a constrained roadway's AADTs into DHVs and DDHVs. The DHVs and DDHVs may be governed by the capacity of the constrained roadway rather than the K_{30} value.
- When a desired number of lanes cannot be achieved because of a determination that the subject roadway is constrained, an analysis is performed to identify whether an acceptable LOS could be obtained at the constrained roadway by reducing its traffic load. Methods for achieving such traffic reductions could include the following:
  - Improving a parallel roadway,
  - Increasing vehicle occupancy,
  - Providing transit alternatives,
  - Implementing congestion pricing strategies,
  - Offering staggered work hour programs, or
  - Applying restrictions to future growth.

  The congestion reduction strategies may require review of network configuration, available mode attributes, land use, trip generation, distribution, mode choice, and assignment components to revise previous system traffic forecasts. After the review, the DHVs and DDHVs are to be redeveloped.
- In the project development phase, it is critical to estimate the year when the constrained roadway will fail to operate at a desirable LOS. A simple procedure for obtaining the breakdown year involves obtaining existing and future year DDHV traffic projections for the constrained roadway. Trend analysis is applied to the data to obtain intermediate and additional traffic projections. The projected DDHVs are compared to the minimum LOS volume, and the approximate year of breakdown is identified (see Figure 7-1). It should be emphasized that actual future year LOS for an arterial roadway depends on the expected delay at signalized intersections and overall arterial speed.

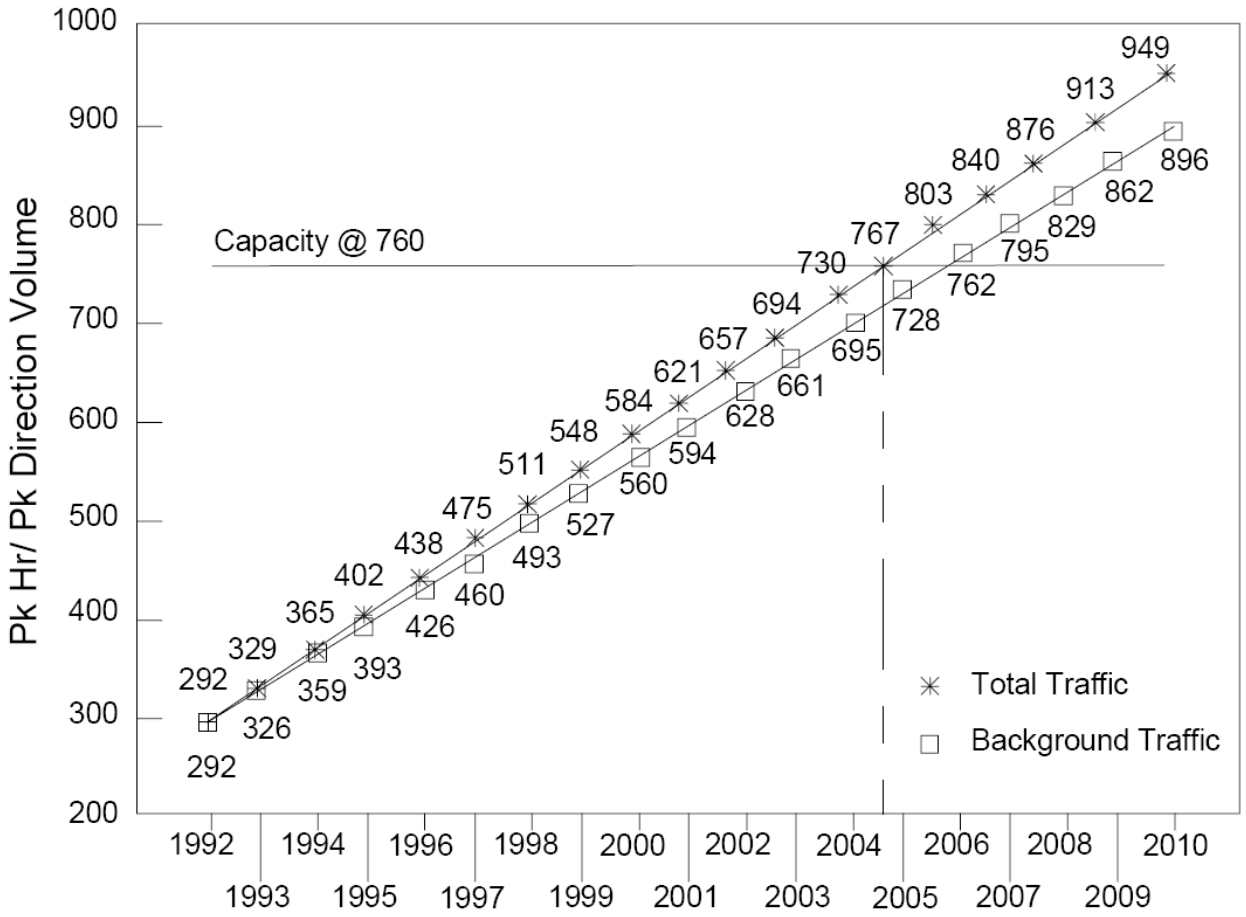


Figure 7-1 Constrained Roadway LOS Example Illustrating LOS Breakdown Year

Source: FDOT, Project Traffic Forecasting Handbook 2002

7.4. Determining Peak Hour Design Volumes from DDHV

For many transportation projects in the State, it may be necessary to forecast traffic for multiple peak hours of traffic of the future years. Most commonly, it may be necessary to forecast traffic for AM and PM peak hours, but there might also be cases where a midday peak hour sees the highest traffic volume. As a result, the assignment of the DDHV to an AM, midday or PM peak hour in the future years is required. To accomplish this, short-term traffic counts and the existing lane configuration can be examined to determine whether the AM, midday or PM peak hour during a typical weekday is the critical time period. The DDHV is then applied by convention to the critical peak hour. For example, if the PM peak hour is found to be the critical time period, then the DDHV is assigned to the PM peak hour peak direction (e.g., northbound). To determine the other peak hour peak direction volume, the ratio of the peak direction volumes between the two peak hours is taken and applied to the DDHV. This ratio of the peak direction volumes between the two peak hours can be obtained from the typical weekday volumes from the short-term traffic counts.

Using the same example as above, it is assumed that the peak direction in the critical PM peak hour is northbound. Also assume that the AM peak hour is found to be other critical period, and the peak direction in the AM peak hour is found to be southbound, and the proportion of southbound AM traffic volume to northbound PM traffic volume is 0.95 from the short-term count. Then, 0.95 of the DDHV is assigned to the AM peak southbound direction. To determine the traffic forecast for the AM peak off-peak direction, the short-term count is again referenced. The ratio between the peak direction and off-peak direction volumes for the AM period for the typical weekdays from the short-term count is then applied to obtain the off-peak direction volume during the AM peak hour.

If the midday peak hour volumes were found to be either the critical period or the other critical period, the procedure explained above can be applied accordingly to assign the DDHV and to obtain the other volumes.

7.5. Determining Peak Hour Design Volume: Sample Case

For this sample case, the DDHV for the year 2037 at Interstate 80, east of the USA Parkway Interchange, was calculated to be 1,677 vph. The corresponding off-peak direction volume was calculated to be 1,481 vph. A project requires AM and PM peak hour design volumes for the future year 2037 conditions. NDOT short-term count station #311035 located on Interstate 80 east of the USA Parkway interchange was examined, and the information shown in Table 7-1 was obtained from this count station.

Table 7-1 Existing Peak Hour Directional Volumes

Peak Hour	Eastbound Volume	Westbound Volume
AM peak hour	474	982
PM peak hour	1104	614

Note: All volumes are average typical weekday

Both eastbound and westbound directions have the same number of lanes, and therefore, it was determined that the PM peak hour was the critical time period, and the eastbound direction was the peak direction. The DDHV is, therefore, assigned to the PM peak hour as follows:

- 2037 PM peak hour eastbound volume equals 1,677 vph, and
- 2037 PM peak hour westbound volume equals 1,481 vph.

During the AM peak hour, the westbound direction was found to be the peak direction based on the NDOT short-term count data. The proportion of AM westbound volume (982) to PM

eastbound volume (1104) for the typical weekday was calculated from the NDOT short-term count data using the following equation.

$$\frac{\text{AM Westbound Volume}}{\text{PM Eastbound Volume}} = 0.89$$

Therefore, the AM peak hour westbound volume in 2037 is calculated to be 0.89 multiplied by 1,677, which equals 1,493 vph.

For the AM peak hour, the ratio between the peak and off-peak direction volumes (474 and 982) was calculated for the typical weekdays from the NDOT short-term count data using the following equation.

$$\frac{\text{AM Eastbound Volume}}{\text{AM Westbound Volume}} = 0.48$$

Therefore, the AM peak hour eastbound volume in 2037 is calculated to be 0.48 multiplied by 1,493, which equals 717 vph.

After rounding, the design year 2037 volumes are reported as follows:

- PM peak hour eastbound volume equals 1,680 vph;
- PM peak hour westbound volume equals 1,480 vph;
- AM peak hour westbound volume equals 1,490 vph; and
- AM peak hour eastbound volume equals 720 vph.

7.6. Documenting Traffic Forecasts

As noted throughout these Guidelines, when drafting the traffic forecast memorandum, this guidance presented herein complements what has been listed in the previous chapters. The draft traffic forecast memorandum is to include all supporting documents used for the traffic forecasting process, including the documentation of the traffic parameters AADT, K_{30}, D_{30}, DDHV, and T%.

Chapter 8
Estimating Intersection Turning Movements

Intersection turning movements are an essential requirement when conducting an operational analysis for a project. This chapter provides a methodology for estimating intersection turning movements and explains techniques for balancing turning movements. The chapter specifies the recommended tool (Turns W32) in addition to a number of other techniques/tools that can be used to estimate intersection turning movements.

8.1. Estimating Intersection Turning Movements

Future year estimates of peak hour intersection turning movements are required for intersection design, traffic operations analysis, and site impact evaluation. Travel demand models, if available for the study area and if used for the forecasting process, may be able to provide forecasts of intersection turning movement volumes. However, turning movements obtained from travel demand models, even after they have been refined for project-level forecasts, may note erroneous results because of the regional nature of such models. Moreover, it is usually difficult to generate peak hour volumes directly from a travel demand model for every possible intersection within a given study area. Travel demand models are also not available in most rural areas, which would require the analyst to apply other methods to estimate intersection turning movements. Accordingly, various methods and procedures have been developed to estimate peak hour turning movement volumes from peak hour traffic volumes. Most of these methods rely heavily on existing intersection turning movement count data and professional judgment to estimate future turning movements. While the travel demand models may not provide accurate turning movement volumes, these turning movement volumes may be an appropriate starting point in the iterative process to develop acceptable turning movement volumes.

A review of the methods currently available for use in developing intersection turning movements indicates that many of the methods can be categorized as “intersection balancing” methods. Generally speaking, the degree of accuracy that can be obtained from “intersection balancing” methods depends on the magnitude of incremental change in land use and travel patterns expected to occur between the base year and future year conditions. These balancing techniques are used to adjust existing counts as well as travel demand model-generated counts. The assignment of future turn paths is estimated, and often the departure and arrival between intersections on the same link will require manual balancing. The algorithms used for the balancing may not be capable of achieving the desired tolerance. Existing counts need to be balanced because the turning movements occurring at some driveways may not be included in traffic counts. The driveways that may not be counted are often commercial strip centers, gas stations, and other curb cuts that influence the traffic at intersections. The roadway network coded in the travel demand model generally includes all freeways, arterials, some collectors, and local roadways. However, some collectors and local roadway that are not coded may be the key roadways serving the study area. To account for the missing roadways and missing

driveway information, balancing techniques are used to generate turning movement traffic volumes.

To date, most algorithms are somewhat interrelated and involve the application of an iterative procedure that balances future year turning movements based on existing turning movement counts, approach volumes, and/or turn proportions. These balancing methods can be used for peak hour volumes, future traffic movements, or any other application that requires balancing intersection movements.

The following sections offer an overview of some of the techniques used for estimating turning movements, including the input data required and the relative ease of applying each technique. The pertinent methods entail the methods described in the NCHRP Report 255, the methods suggested by H. J. Van Zuylen (1979), and the methods applied by Hauer (1981) and Schaefer (1988).

8.2. TurnsW32

The TurnsW32 tool is the recommended tool for estimating turning movement volumes in the State. TurnsW32 was developed by Dowling Associates to compute forecast turning volumes using the techniques described in NCHRP Report 255. This process is often referred to as the Furness process of estimating turning movement, which is also how it is referred to in the program. The subsequent section explains the user interface of the TurnsW32 tool and offers guidance in applying the tool to estimate turning movements.

8.2.1. TurnsW32 Methodology

TurnsW32 computes forecast turning volumes from existing turning movement volumes and forecasted future approach and departure volumes. Based upon future trip “ins” and “outs” (obtained from the travel demand model) along each leg of the intersections, TurnsW32 runs several iterations to calculate future traffic volumes by turning movement. The iterative procedure alternately balances the approach flows and departure flows until the results converge (up to a user-specified maximum number of iterations).

The following steps are involved in using the TurnsW32 program.

- **Step 1:** Enter observed turning volumes, and alternatively enter estimated percentages of future year’s assigned inflows. If the future estimated percentages are used, then the totals on each approach must equal 100. (The departure totals will not equal 100, except by coincidence). When observed turning volumes and estimated turning percentages are not available, the analyst may enter "1" for the volume of each permitted movement, this can be used to obtain the turning movement volumes for intersections along new roadways.

- **Step 2**: Enter forecast approach and departure volumes. (These volumes may either be obtained from the travel demand model or from the forecasts made by historical trend projections.) At any intersection, the inflows must equal the outflows. The program also offers the analyst an option to “lock in” a predetermined turn volume for one or more movement. Locking in a turn volume ensures that this volume is unmodified during the iterative process of estimating turning movements.

The Furness calculation screen of the TurnsW32 program allows the analyst to enter data as explained below.

8.2.2. TurnsW32 Program Interface

TurnsW32 is a typical Microsoft Windows program with typical user interface options. This section explains the core menu options of the TurnsW32 program that are concerned with data input and generating the required outputs. For illustration purposes, data was entered for a hypothetical intersection (see Figure 8-1, Figure 8-2, and Figure 8-3). The “Manual data entry” is the basic method that allows the analyst to enter data for each intersection and is discussed further in these Guidelines. However, for advanced features of the program, the analyst is to refer to the technical documentation that accompanies the TurnsW32 program. (The following explanation about the program’s features is adapted from the technical documentation of the TurnsW32 program.)

The “manual data entry” command is available from the “Options” menu of the program. Selecting this brings up the “Furness screen” for manual entry of intersection turning movement volumes as well as approach and departure volumes. The analyst is also presented with options to name the intersection for which the data is entered (see Figure 8-1).

8.2.2.1. Intersection Data

The upper half of the Furness screen contains the basic intersection information and turning movement count data used by the program (see Figure 8-2). Intersection numbers are entered in the blue shaded boxes, and the center box must have a node number because all of the intersection's information and traffic data are referenced by this number. The other node numbers, representing the adjacent intersections, are optional. Existing (known) turning movement counts are entered in the boxes with movement arrows. For "T" intersections, the analyst is to enter “0” for movements that do not exist. For more accurate results, counted (rather than estimated) turning movement volumes are to be entered. If counted turning volumes are not available, enter the estimated turning percentages of the future year's approach volumes and click on the "Turn %-ages" option button. (If this procedure is used, the totals on each approach must equal 100, although the departure totals will not equal 100, except by coincidence). When actual volumes and estimated turning percentages are not available, the analyst may enter "1" for the volume of each permitted movement and then click on the "Count data" option button.

8.2.2.2. Approach/Departure Data

The lower half of the Furness screen provides the option to enter the approach and departure volumes (see Figure 8-3). Forecast approach and departure volumes are entered in the unshaded boxes around the outside of the intersection display. The volumes are entered clockwise starting with the southbound approach volume, then the northbound departure volume, etc. During the Furness calculation process, if the computed approach and departure totals are not equal, a balancing dialog box is displayed giving the analyst a choice on the method to resolve the issue. The methods presented to the analyst are the following.

- **Balance Manually:** The analyst supplies the corrections needed to balance the entering and leaving totals.
- **Balance to Highest Total:** The lowest total (either approach or departure) will be factored up to match the highest total.
- **Balance to Lowest Total:** The highest total (either approach or departure) will be factored down to match the lowest total.
- **Balance to Average of Entering and Leaving Totals:** The approach and departure volumes will be factored so that their totals both equal the average of the unbalanced approach and departure totals.
- **Balance to Entering Total:** The departure volumes will be factored so that their total equals the total approach volumes.
- **Balance to Leaving Total:** The approach volumes will be factored so that their total equals the total departure volumes.

In most cases, the “Balance Manually” option might provide the best results because the analyst would be able to apply engineering judgment based on the knowledge of the existing and expected conditions near the intersections. Hence, the analyst is recommended to balance the peak hour volumes manually before entering them in TurnsW32.

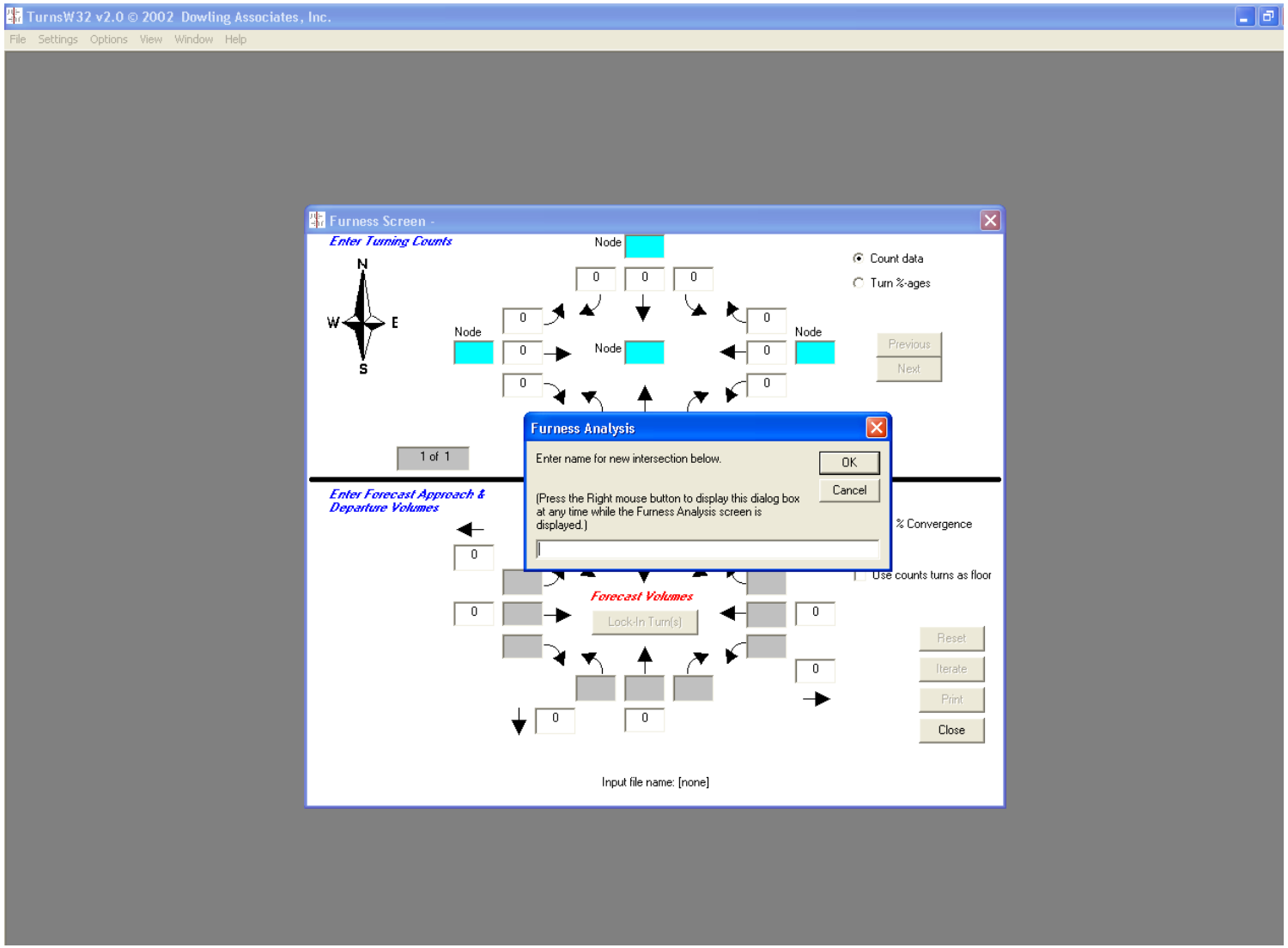


Figure 8-1 Manual Data Entry and the Furness Screen

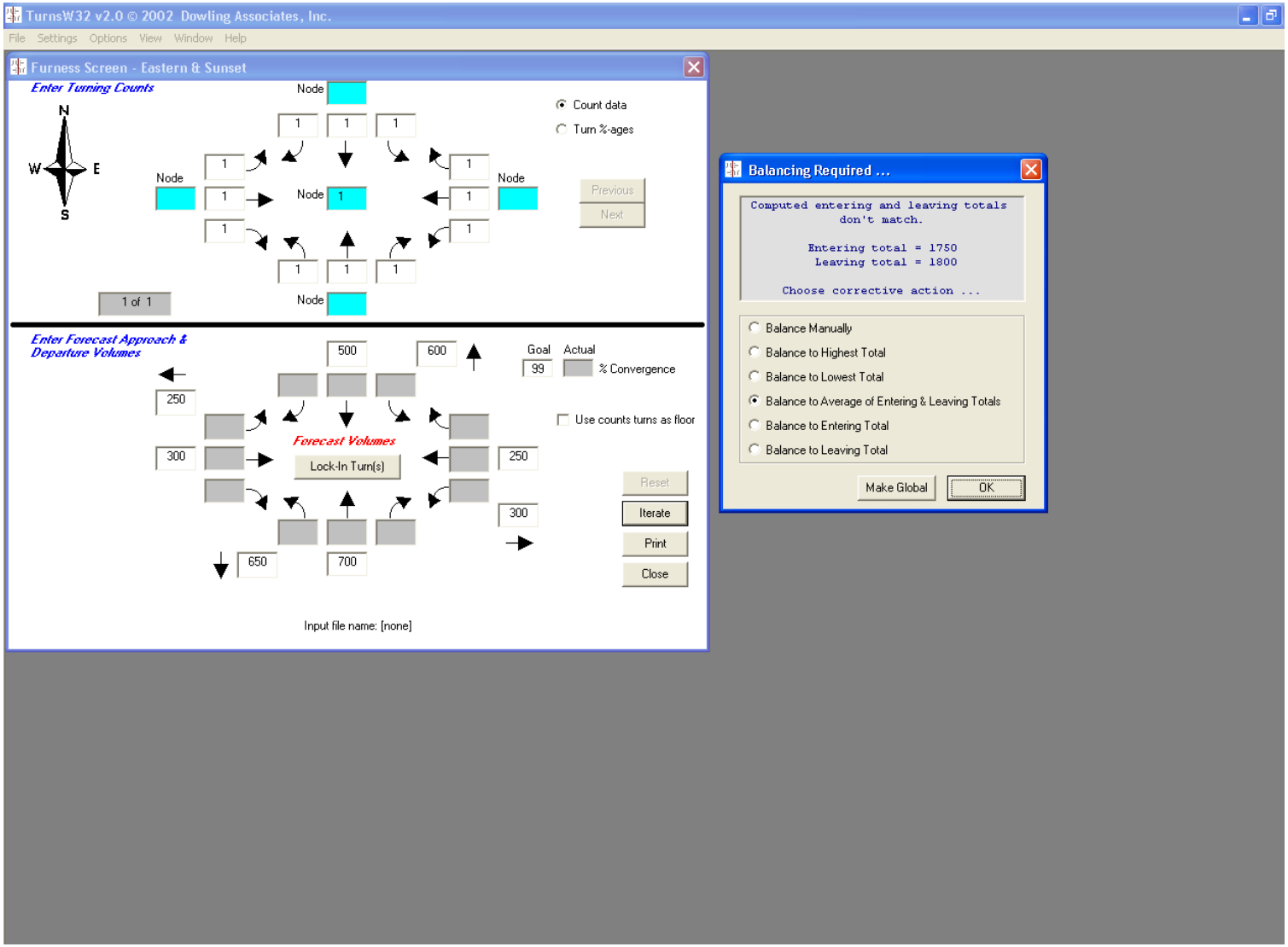


Figure 8-2 Furness Screen and Iteration Settings

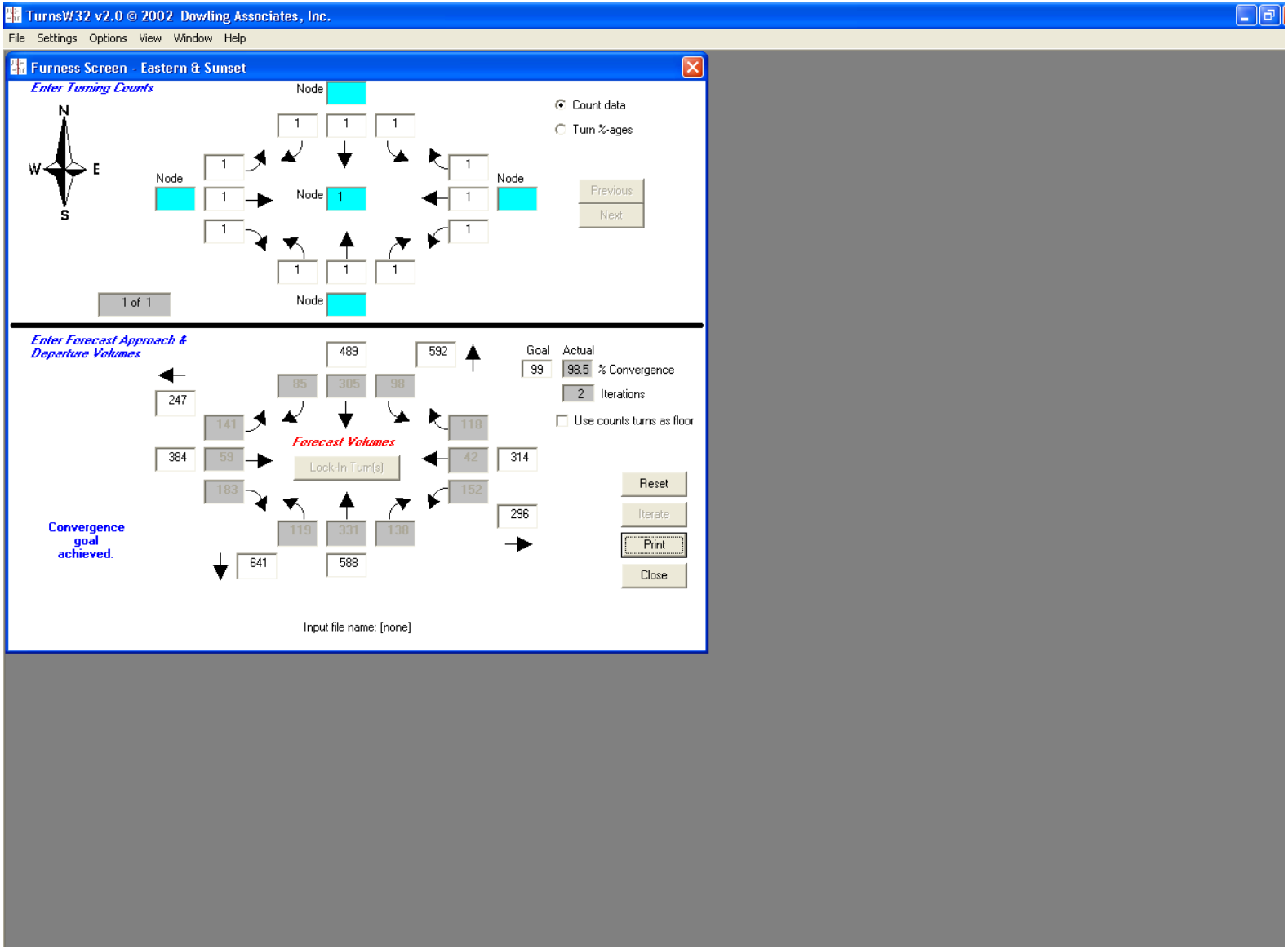


Figure 8-3 Results Screen

8.2.2.3. Settings & Options

The settings used in the Furness computation process are also displayed in the lower half of the Furness screen (see Figure 8-2). The following are some of the settings and options that are displayed in the Furness screen.

- **Convergence settings:** The percent convergence goal for the Furness process is entered in the respective data box in the upper right of the lower half of the screen (to the nearest whole percentage). The actual convergence result of the Furness process is displayed in the box to the right.
- **Use counts turns as floor:** This check box keeps the Furness calculation process from estimating future turning volumes that are less than the counted values entered in the upper half of the screen. The count volumes become the floor below which the Furness calculation will not go.
- **Lock-in turn(s):** This button allows the analyst to enter forecast volumes for individual turning movements that will be locked-in during the Furness process. (Note that locking-in movements reduce the degrees of freedom in the Furness calculation process and could result in a situation where convergence is not possible.)
- **Iterate button:** This button starts the Furness calculation process, using the current data for the intersection. As the process runs, the results are displayed in the shaded boxes, which also display the results when the process ends. Note that this button is not activated unless the computed approach and departure volumes are displayed.
- **Reset button:** This button resets the display to the values that were present before the Furness iteration process was run.

8.2.2.4. Results

After entering all the required input data, choosing the desired settings and options, and clicking the “Iterate” button, the turning movement volumes that result from the Furness calculation process are displayed in the lower half of the Furness screen (see Figure 8-3).

8.3. Other Tools/Techniques

At this time, NDOT does not accept Lotus 1-2-3 based tools for estimating intersection turning movements.

The following is an explanation of some of the other available tools and techniques for estimating intersection turning movements from forecast daily traffic volumes that may be accepted for use by NDOT.

8.3.1. TURNS5-V02

The TURNS5-V02 program enables the analyst to obtain turning movements estimates by operating a Microsoft Excel spreadsheet. The program only requires basic knowledge of Microsoft Windows and Microsoft Excel. However, the analyst should have a thorough knowledge of basic traffic engineering principles and be familiar with development of traffic forecasts by non-automated processes. The use of TURNS5-V02 is acceptable to NDOT for development of turning movement volumes, and the program has the following characteristics.

Required Input Data

- Existing year AADTs
- "First guess" turning movement proportions for AADTs
- Growth rates to be used or travel demand model year AADTs
- K-factor and D-factor

Output Produced

- Balanced daily and design hour turning movement forecasts
- Existing year, opening year, interim year, and design year forecasts

8.3.2. TMTOOL

The TMTool was developed by FDOT District Four, and it consists of a single Microsoft Excel spreadsheet with an input, output, and calculations tab. The TMTool may be used for existing and planned intersections, and the main spreadsheet (TMTOOL.xls) is set up for intersection turning movement forecasts where detailed information is available. The use of TMTOOL is acceptable to NDOT for development of turning movement volumes, and tool has the following characteristics.

Required Input Data

- Turning movement distributions
- Base year daily approach volumes
- Future year growth factors
- K-factor and D-factor

Output Data

- Balanced AM and PM peak hour turning movement forecasts
- Base year and up to three future year forecasts

8.3.3. Manual Method

The manual method consists of a simple calculation technique for obtaining balanced turning movement volumes from approach volumes at three-legged and four-legged intersections. Appendix B offers an example of this methodology. Manual methods for development of turning

movement volumes may be acceptable to NDOT in certain situations, and the method has the following characteristics.

Required Input Data

- Approach volumes
- Possibly K-factor and D-factor

Output Data

- One set of balanced turning movement forecasts

8.3.4. Growth Factor Technique

To establish future year turning movement forecasts, the growth factor method relies on the application of projected growth factors to existing year traffic data. The technique has the following characteristics.

Required Input Data

- Existing turning movement counts
- Future year growth factors
- Possibly K-factor and D-factor

Output Data

- Daily and/or peak hour turning movement forecasts
- One set of turning movement forecasts

8.3.5. Methods from the NCHRP Report 255

The NCHRP Report 255 suggests three methods for estimating intersection turning movements:

- The ratio method,
- The difference method, and
- The iterative method.

The first two methods assume that relative and absolute differences between the estimated and observed turn volumes will remain constant over time. Therefore, future turn volumes generated from models are adjusted according to “ratios” or “differences” calculated from estimated and observed base year turn movement volumes. The iterative procedure requires base year counts of intersection approaches. The iterative method employs the traditional Fratar method, which has been widely used in practice to balance trip tables.

The iterative method is based on an incremental procedure of applying implied growth between base year and future year to actual traffic counts. Growth rates are derived from the travel demand model. The iterative procedures would require observed turning movements for all intersections under study. This method is not applicable to new intersections for which base

year counts are not available. The Fratar method would produce reasonable results for either developed areas or areas expected to experience moderate growth in land use. Notably, TurnsW32 uses the NCHRP Report 255 methods as the basis for developing turning movement volumes.

8.4. Summary

The differences inherent to each of the described turning movement methods primarily involve the amount of data input and the information that is generated. These methods could also be used for areas without a travel demand model (e.g., rural areas) where some information on existing (and/or historical) travel and expected growth are available. However, estimates would have to be made for the future approach volumes. Also, existing turning movement data would have to be used judiciously relative to the expected growth characteristics of the area of the roadway improvement.

Overall, the TurnsW32 program is the recommended tool for use because of its simplicity and the available options in the program. At this time, NDOT does not accept Lotus 1-2-3 based tools for estimating intersection turning movements. As noted throughout, any balancing method used by the analyst for estimating intersection turning movements are to be documented in the traffic forecast memorandum, which would include methodology, assumptions, and rationale.

Chapter 9
Truck Traffic Forecasting

This chapter provides the methodology for truck traffic forecasting in instances where historical truck traffic data is available as well as in instances where data is not available for the project location. This chapter also explains the process by which to estimate T% and document truck traffic forecasts.

9.1. Truck Traffic Forecasting Methodology

Estimation of future truck volume is often based on truck traffic history. Several factors can influence future truck volume, such as land use changes, economic conditions, and new or competing roadways. Similar to the general trend in traffic growth, truck volume may decrease, remain constant, or increase, all of which is often illustrated as a straight line, an accelerating rate (exponential trend), or a decelerating rate (logarithmic trend).

Truck traffic data is collected by means of vehicle classification counts. The purpose of vehicle classification is to estimate the composition of traffic by vehicle types, and this data can be used to estimate T%. Vehicle classification data are collected in accordance to the FHWA Classification Scheme “F” and the 13 vehicle types illustrated on Figure 3-1. When suitable truck traffic data by class of vehicles is available, truck forecasts are also to be prepared by each class of vehicles. Similar to the NDOT count stations available for measuring total traffic, truck volumes are measured by a combination of continuous and short-term classification stations. Data from the continuous vehicle classification stations are available for current and previous years where data had been collected. Data from the short-term classification stations are collected on a three-year cycle, and approximately one-third of the data is available for the most recent data collection year, with the remaining two-thirds distributed over the previous two years. Truck AADT values for roadway segments are published by NDOT in their Annual Traffic Reports.

In general, the amount of historical truck data available from NDOT is not as extensive as the general traffic data, but this is expected to change in the future. As such, the methodology for truck traffic forecasting depends on the availability of truck data for the project location. It is recommended that the analyst contact NDOT’s Traffic Information Division regarding availability of historical data for the project location.

Figure 9-1 illustrates the truck traffic forecasting methodology.

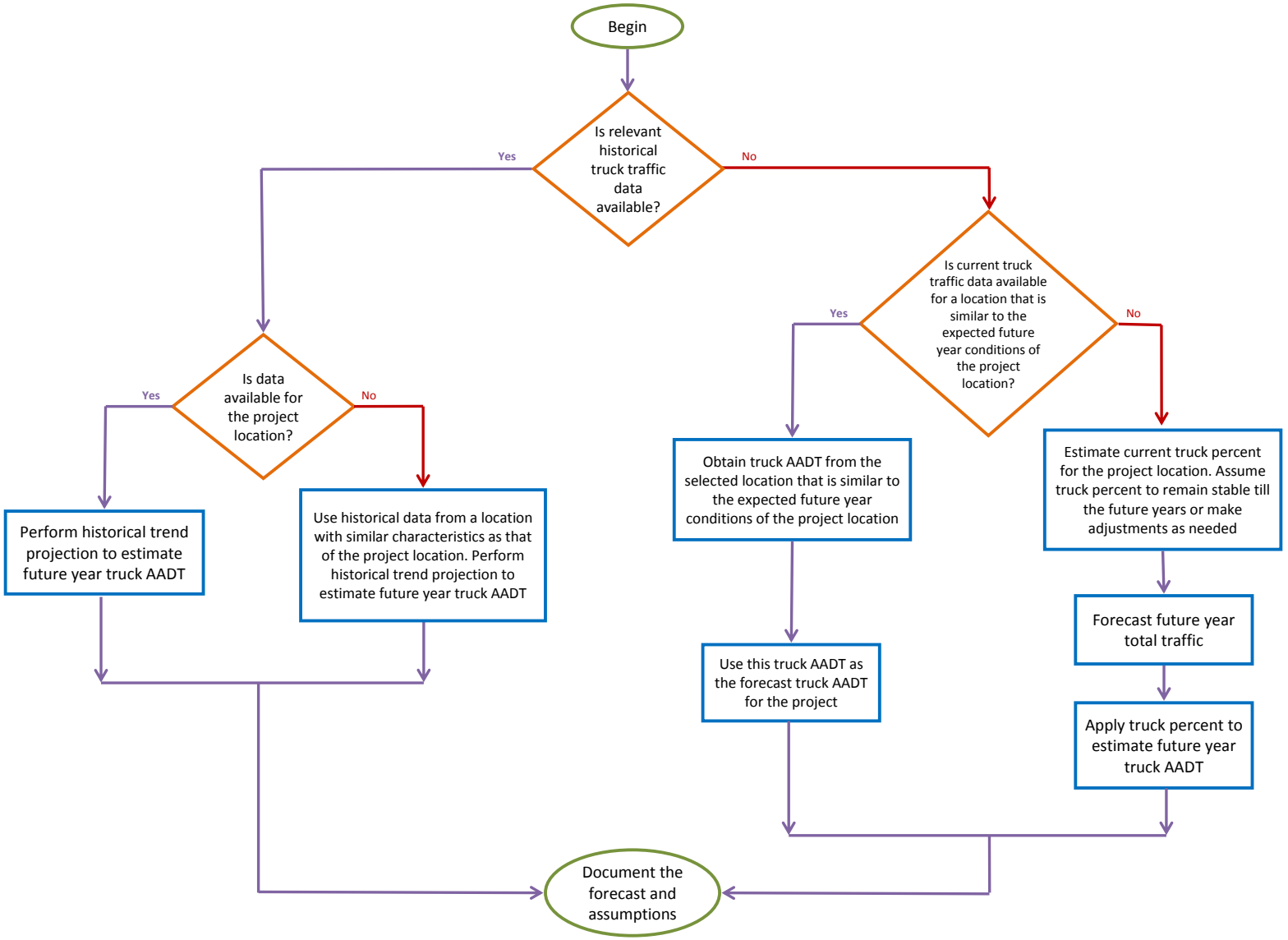


Figure 9-1 Truck Traffic Forecasting

9.2. Truck Traffic Forecasting Procedures

There are four methods for truck traffic forecasting that can be applied based on the availability of data and the nature of the project location. The following are to be applied in the order listed below.

- A historical trend projection analysis using historical truck AADT data is the recommended approach for forecasting future truck traffic when historical truck AADT data is available for the project location.
- If historical truck data is unavailable for the project location, the availability of data for a location with similar characteristics to that of the project location is to be examined.
- If historical data is unavailable for the project location, and a location with similar characteristics cannot be identified, the analyst is to use current truck traffic data from a location similar to the expected future year conditions of the project location.
- If, after all of these options have been exhausted, suitable truck traffic data is still unavailable for forecasting, the analyst may apply the "truck traffic as a constant percentage of total traffic" method.

In all, it is recommended that the analyst apply engineering judgment when forecasting truck traffic as the extent of historical data available for the regression analysis may be less, resulting in unreasonable projections. The forecast truck AADT is to be examined for reasonableness and compared with the change in trend of other quantities, such as population, economic activity, and transportation demand for commodities.

9.2.1. Truck Traffic Forecasting if Historical Truck AADT Data is Available for the Project Location

A historical trend projection analysis is conducted if suitable historical truck traffic data is available for the project location. The procedure of forecasting truck traffic using historical data is similar to the procedure documented in Chapter 6 of these Guidelines. The historical trend projection analysis is conducted using the most recent five years of truck AADT data, at a minimum. But the analysis is to be conducted with as much historical data as possible. The most commonly used growth trends are linear, logarithmic, and exponential. The use of a particular trend depends on the historical data and the level of "fit" of a particular trend for the available historical data.

The steps involved in this process are:

- Assembling the data;
- Establishing a truck traffic growth trend;
- Developing the preliminary truck traffic projection;
- Verifying the forecast for reasonableness;

- Developing a truck traffic forecast in detail;
- Conducting a final review and documenting the process.

For a detailed explanation of each step, refer Chapter 6 of these Guidelines.

9.2.2. Truck Traffic Forecasting if Historical Data is Not Available for the Project Location

If historical truck AADT is not available for the project location, then the next step is to identify the availability of data for a location that has similar characteristics as that of the project location. If data is available for a similar location, a historical trend projection is to be conducted similar to the procedures described in the previous section. The use of historical data from a different location for forecasting truck traffic must be documented in the methodology memorandum and the traffic forecast memorandum. NDOT's consent must be obtained before proceeding with the forecast.

9.2.3. Truck Traffic Forecasting if Historical Data is Not Available and a Location with Similar Characteristics Cannot Be Identified

Historical trend projection analysis for a project location may be unfeasible because of a lack of sufficient historical data. In such a case, the analyst should try to identify locations that have characteristics similar to the expected future year conditions of the project location. The existing truck traffic from this similar location can then be used as the future year truck traffic for the project location. However, the current truck traffic from a chosen location is to be used as future year truck volumes only if there are strong indicators that the future year project location would closely resemble the current conditions of the chosen location. For this reason, the analyst is advised to be extremely cautious when using this method, and all justification and supporting data when applying the method must be clearly documented in the methodology memorandum and the traffic forecast memorandum. NDOT's consent must be obtained before proceeding with this approach.

9.2.4. Truck Traffic Forecasting if No Suitable Truck AADT Data is Available

If suitable truck traffic data is simply unavailable, the following method may be used to forecast truck traffic. The method is based on the assumption that the truck traffic remains a constant percent of the total traffic at a location over the years analyzed. If information regarding the changing nature of truck traffic is available, adjustments are to be made to the assumed T%.

- **Step 1:** The first step in the estimation of future truck traffic is to identify the truck percent at the project location for the present day. NDOT's vehicle classification data provide the composition of traffic by vehicle types, and these classification counts may be used to calculate the T%. T% may be calculated for a specific roadway segment by dividing the truck AADT (if available) by the total AADT for that roadway

segment. Truck AADT may be obtained from NDOT's Annual Vehicle Classification Report, and the total AADT may be obtained from NDOT's short-term count stations or ATRs. NDOT also publishes the typical percent T% for each functional class of roadway in the State in their annual traffic reports. If the truck AADT is not available for the project location, this T% reported for the functional class of the roadway can be used.

- **Step 2:** The second step is to forecast the total traffic at the project location for the future years (years for which truck forecast is needed). The forecast can either be made with a travel demand model (see Chapter 5 of these Guidelines) or without a travel demand model (see Chapter 6 of these Guidelines). If the forecast total traffic is a quantity other than AADT, this quantity is first to be converted to AADT.
- **Step 3:** Once the future total traffic is available, the third step is to apply the T% to the forecast traffic to obtain the future year truck traffic.

9.3. Estimating Truck Percent (T%)

As noted, T% is the percentage of truck traffic for 24 hours (one day), and it is calculated as follows,

$$\text{T\%} = \frac{\text{Truck AADT}}{\text{Total AADT}}$$

If truck traffic was forecast using the historical trend projection analysis, the result of the analysis would be the future truck AADT. In this case, T% may be calculated using the above equation. In contrast, if truck forecasting was done as per the "truck traffic as a constant percentage of total traffic" method, the T% for the future years is assumed based on the existing year and is readily available, although adjustments to the assumed T% may be necessary to account for changing traffic conditions.

9.4. Peak Hour Truck Volumes and Peak Hour Truck Percent

The peak hour truck volume is the volume of truck traffic during the hour of the day that observes the highest truck traffic volumes. If suitable truck data is available, future peak hour truck volumes are estimated based on the forecast daily truck volumes and the observed proportion of daily truck traffic occurring in the peak hour of truck traffic ($T_{P\text{-}D}$). The underlying assumption here is that the proportion of peak hour truck volumes and daily truck volumes would remain fairly constant over the years. If information is available regarding the change in the proportion of peak hour truck volumes to the daily truck volumes, $T_{P\text{-}D}$ is to be adjusted accordingly.

$T_{P\text{-}D}$ is to be calculated based on observed truck volumes.

$$T_{P-D} = \frac{\text{Observed peak hour truck volume}}{\text{Observed daily truck volume}}$$

$$\text{Future peak hour truck volume} = \text{Future daily truck volume} \times T_{P-D}$$

Once the peak hour truck volumes are obtained, the peak hour truck percent can be calculated based on the peak hour total volume.

9.5. Documenting Truck Traffic Forecast

The availability of historical data for the project location and the adopted methodology for forecasting the truck traffic must be clearly documented in the traffic forecast memorandum. Any assumptions and adjustments made to the forecast must be included, and the rationale behind these changes must be explained in the traffic forecast memorandum. The relevant forecast factors, such as the future year truck AADT and T%, must be documented in the traffic forecast memorandum.

Appendix A

Appendix A offers guidance for identifying ATRs at locations with characteristics similar to that of the project location. In addition to NDOT's functional class assignment of roadways, classification of the project location could begin by analyzing seasonal traffic trends followed by area type, number of lanes, weekly traffic trends, and AADT. The subclasses within a number of these more general classes are listed below.

Based on Seasonal Traffic Trends	
Sub Class	**Description**
Interstate Urbanized	Stations located on any section of urbanized (areas of population greater than 50,000) interstate.
Interstate Non-Urbanized	Stations located on any section of non-urbanized interstate.
Commuter	Stations characterized by small seasonal changes in traffic patterns and commuting between city pairs (also to be applied to non-State streets in urbanized cities).
Agriculture	Stations characterized by late summer and fall harvest peaks.
Recreational Summer	Stations characterized by high summer peaks in recreational areas.
Recreational Summer/Winter	Stations characterized by both summer and winter peaks in recreational areas.
Recreational Winter	Stations characterized by high winter peaks in recreational areas.
Summer	Stations characterized by a smaller summer increase in traffic patterns when compared to Recreational Summer (also to be applied to non-State streets in small cities).
Summer < 2,500 ADT	Stations with less than 2,500 ADT characterized by a smaller summer increase in traffic patterns when compared to Recreational Summer (also to be applied for many rural off-system county roads).

Based on Area Type	
Sub Class	**Description**
Urbanized	Stations located within areas of population greater than 50,000.

Based on Area Type	
Sub Class	**Description**
Urban Fringe	Stations influenced by an urban area, such as an MPO area.
Small Urban	Stations located within areas of population between 5,000 and 49,999.
Small Urban Fringe	Stations influenced by a small urban area.
Rural	Stations located on routes outside of areas with population less than 5,000.
Rural Populated	Stations located in cities with a population of less than 5,000 (also to be applied for unincorporated communities).

Based on Weekly Traffic Trend	
Sub Class	**Description**
Weekday	Traffic volume trends are greatest on weekdays; typical for commuter trend and urban areas.
Weekend	Traffic volume trends are greatest on weekends; typical for recreational trend.
Steady	Traffic volume trends are steady throughout the week without significant peaks on the weekend or weekdays.

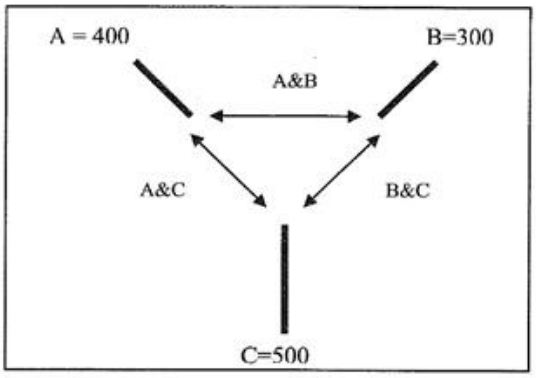
Appendix B

Estimating Intersection Turning Movements (an example of the manual method): Appendix B offers a simple calculation technique for obtaining balanced turning movement volumes from approach volumes at three-legged and four-legged intersections.

E.1 Calculation of Turns at "T" or "Y" intersection from End Volumes

Given: Two-way AADT on each leg of a "T" or "Y" intersection
A=400, B=300, C=500

Round all volumes: Current years to nearest 20, future years to nearest 200 (This example assumes current year)



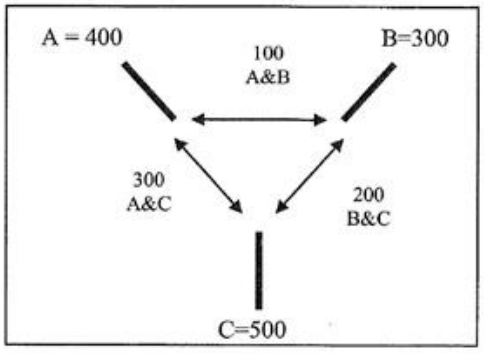
Rule: To find the two-way volume moving between two legs of a three-legged intersection, add the two-way volumes on the two legs concerned and subtract the two-way volume on the third leg, then divide by 2

Find: Two-way turning volumes

$$\text{between A \& B} = \frac{A + B - C}{2} = \frac{400 + 300 - 500}{2} = 100$$

$$\text{between B \& C} = \frac{B + C - A}{2} = \frac{300 + 500 - 400}{2} = 200$$

$$\text{between A \& C} = \frac{A + C - B}{2} = \frac{400 + 500 - 300}{2} = 300$$



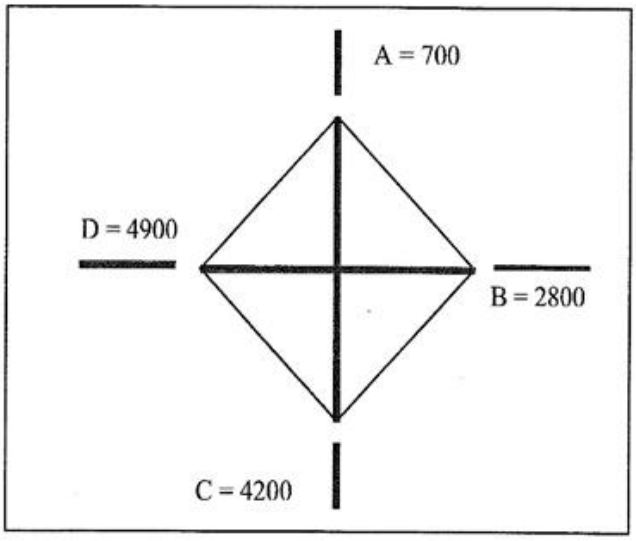
E.2 Approximation of Turns from End Volumes

Given: Two-way AADT on each leg of a four-legged intersection

Find: The two-way turns and through AADT between A&B, A&C, A&D, B&C, B&D, C&D

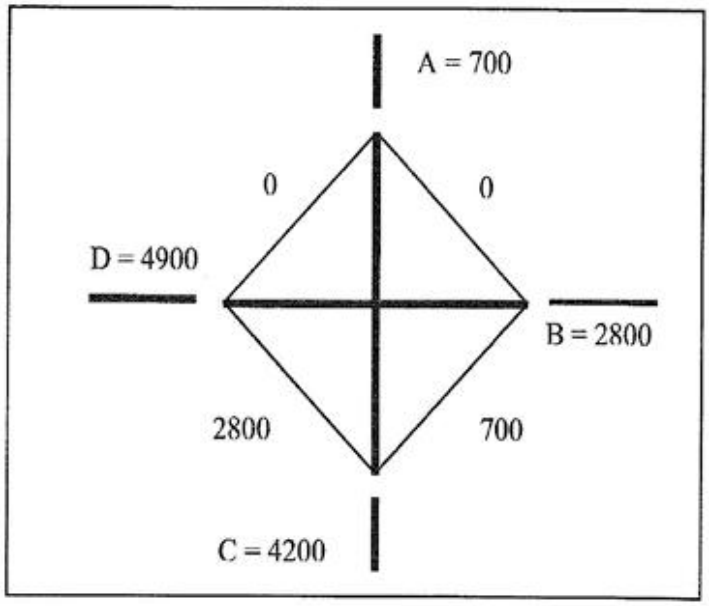
Round all volumes: Current year to nearest 20, future years to nearest 200
(This example assumes current year)

1. From the larger of A or C subtract the smaller of A or C
   4200 – 700 = 3500
2. From the larger of B or D subtract the smaller of B or D
   4900 – 2800 = 2100
3. From the larger difference subtract the smaller difference, Divide the remainder by 2
   3500 – 2100 = 1400
   1400 / 2 = 700
   This is the first diagonal-turn-volume-difference



4. From the larger difference subtract the last calculated value.
   3500 – 700 = 2800
   This remainder is the second diagonal-turn-volume-difference.
5. Position the last two calculated diagonal-turn-volume-differences so that the original end volume are satisfied if the two other turning movements are zero

6. Approximate the turns which were taken as zero by prorating the smaller end volume to the other three legs.



A is smallest = 700, so base = B + C + D
= 2800 + 4200 + 4900 = 11900

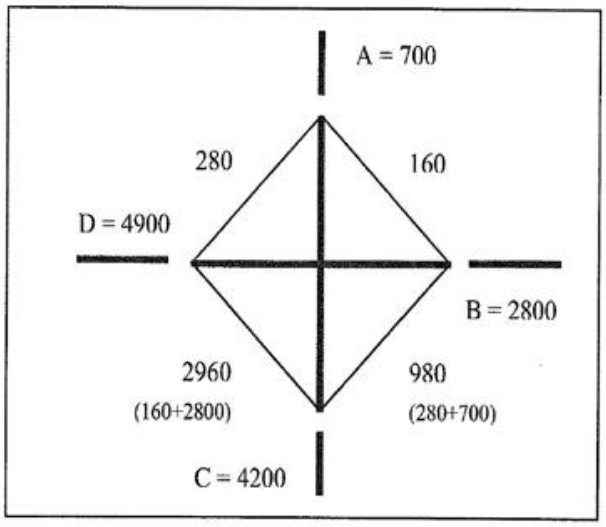
Proration constant for "A"

$$K_A = \frac{A}{B+C+D} = \frac{700}{11{,}900} = 0.0588$$

Turns between A&B = $K_A \times B$
= 0.0588 × 2800 = 164
(20 Round) → 160

Turns between A&D = $K_A \times D$
= 0.0588 × 4900 = 288
(20 Round) → 280

7. To the approximated minor turns add the opposite diagonal-turn-volume-difference to obtain the remaining turn volumes.
   280 + 700 = 980
   160 + 2800 = 2960



8. From the end volumes subtract the turn volumes to obtain the through volumes

   700 – 280 – 160 = 260
   2800 – 160 – 980 = 1660