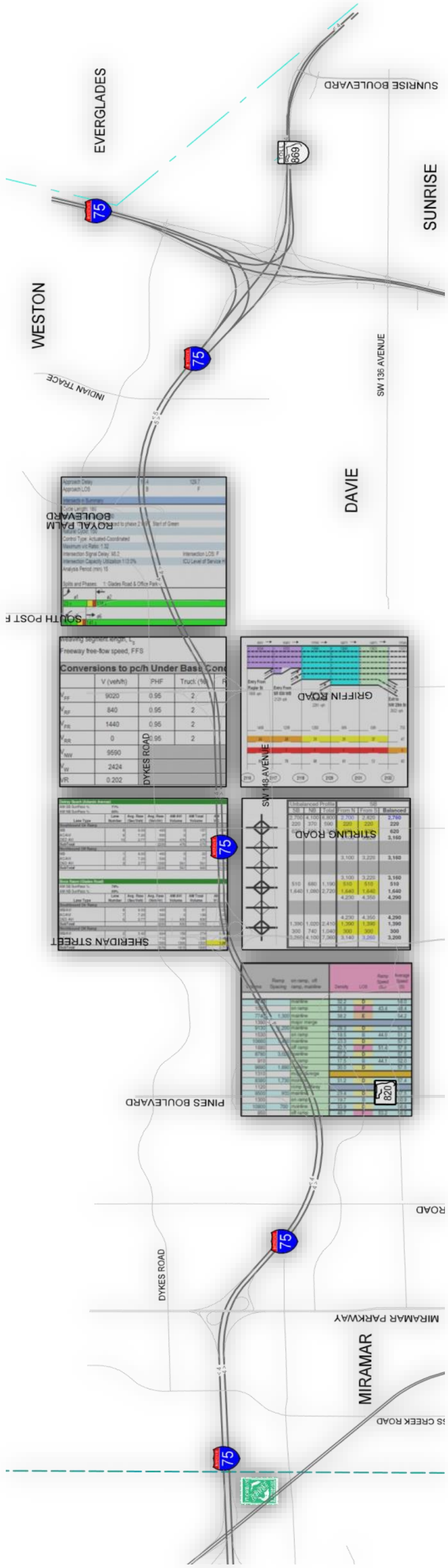
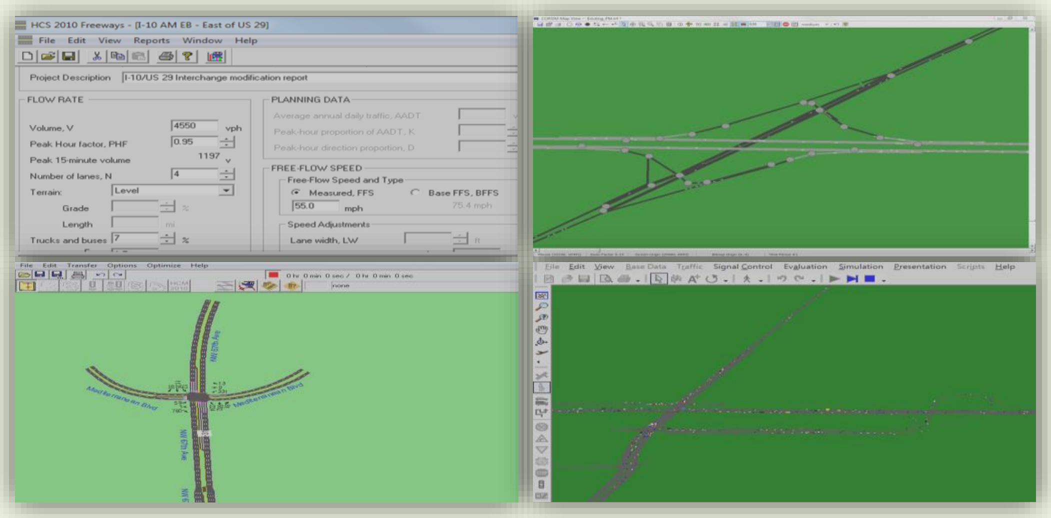
Florida Department of
TRANSPORTATION




HCS 2010 Freeways - [I-10 AM EB - East of US 29]

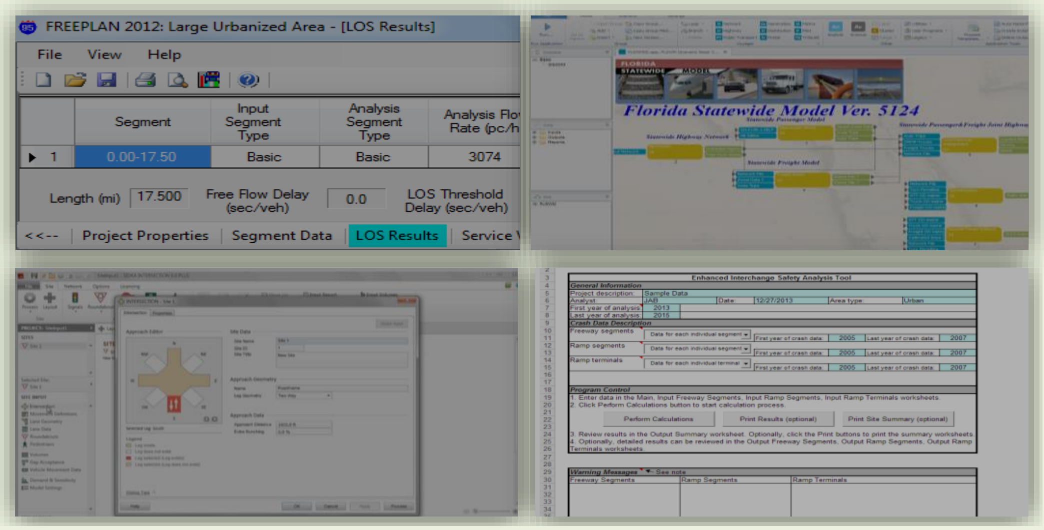
Project Description: I-10/US 29 Interchange modification report

FLOW RATE
Volume, V: 4550 vph
Peak Hour factor, PHF: 0.95
Peak 15-minute volume: 1197
Number of lanes, N: 4
Terrain: Level
Trucks and buses: 7 %

FREE-FLOW SPEED
Measured, FFS: 55.0 mph

Traffic Analysis Handbook

A Reference for Planning and Operations


FREEPLAN 2012: Large Urbanized Area - [LOS Results]

Segment	Input Segment Type	Analysis Segment Type	Analysis Flow Rate (pc/h
1 0.00-17.50	Basic	Basic	3074

Length (mi): 17.500
Free Flow Delay (sec/veh): 0.0

Systems Planning Office

2014

March 2014

FLORIDA DEPARTMENT OF TRANSPORTATION

TRAFFIC ANALYSIS HANDBOOK

Florida Department of Transportation
Systems Planning Office, Mail Station 19
605 Suwannee Street
Tallahassee, Florida 32309
ATTN: State Interchange Review Coordinator

Table of Contents

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List of Abbreviations

2D	Two-dimensional
3D	Three-dimensional
AADT	Annual Average Daily Traffic
ADT	Average Daily Traffic
ANOVA	Analysis of Variance
APAC	Aerial Photography Archive Collection
CADD	Computer Aided Drafting and Design
CBD	Central Business District
CC	Coefficient of Correlation
CMFs	Crash Modification Factors
CORSIM	CORridor SIMulation
D	Directional Distribution
DOS	Degree of Saturation
DRI	Development Regional Impact
EPA	Environmental Protection Agency
FDOT	Florida Department of Transportation
FFS	Free Flow Speed
FGDL	Florida Geographic Data Library
FHWA	Federal Highway Administration
FSUTMS	Florida Standard Urban Transportation Model Structure
FTI	Florida Transportation Information

FTO	Florida Traffic Online
GEH	Geoffrey E. Havers
GSVT	Generalized Service Volume Tables
HCM	Highway Capacity Manual
HCS	Highway Capacity Software
HOV	High Occupancy Vehicles
HSM	Highway Safety Manual
ICU	Intersection Capacity Utilization
IHSDM	Interactive Highway Safety Design Model
ISATe	Enhanced Interchange Safety Analysis Tool
ITS	Intelligent Transportation System
K	Proportion of Daily Traffic Volume in the Peak Hour
LGCIP	Local Government Capital Improvement Plans
LOS	Level of Service
LRTP	Long Range Transportation Plans
MAPE	Mean Absolute Percentage Error
ML	Managed Lanes
MOEs	Measures of Effectiveness
MPOs	Metropolitan Planning Organizations
MRM	Multiple Resolution Modeling
MUTCD	Manual on Uniform Traffic Control Devices
MUTS	Manual on Uniform Traffic Studies
NRMSE	Normalized Root Mean Square Error
O-D	Origin-Destination
PD&E	Project Development and Environment
PHF	Peak Hour Factor
PPM	Plan Preparation Manual
QA/QC	Quality Assurance/Quality Control
RBC	Ring Barrier Controller
RITIS	Regional Integrated Transportation Information System
RMSNE	Root Mean Square Normalized Error
RSA	Road Safety Audits
SERPM7	Southeast Florida Regional Planning Model Version 7

SHS	State Highway System
SIDRA	Signalized & Unsignalized Intersection Design and Research Aid
SLD	Straight Line Diagram
SPFs	Safety Performance Functions
T	Truck factor of Percentage of Heavy Vehicles
TEM	Traffic Engineering Manual
TEV	Total Entering Volume
TMCs	Turning Movement Counts
TSM	Turnpike State Model
V/C	Volume to Capacity Ratio
VAP	Vehicle Actuated Programming
VISSIM	Verkehr In Staedten SIMulation
VMT	Vehicle-Miles Traveled

Chapter 1
Introduction

Traffic analysis is the process of evaluating the effect of traffic demand and supply on the performance of a transportation facility in relation to meeting goals and objectives of the facility. Demand is the amount of traffic load that intends to use the facility while supply is the capacity of the facility to handle the demand. The goals and objectives not only provide guidance to the transportation planning process, but also are used to evaluate the implementation and operation of the facility. The goals can be categorized as related to mobility, reliability, accessibility, safety, economy, or environmental preservation.

There are different levels of traffic analysis which can be grouped as:

- Generalized (sketch-level) planning analysis.
- Conceptual planning and preliminary engineering analysis.
- Design analysis.
- Operational analysis.

Since safety of a transportation facility is correlated with the traffic demand, safety consideration is as important as operational (mobility, reliability and accessibility) efficiency of the system. As such, safety must be integrated as appropriate in all traffic analysis levels to address safety issues for all users, including pedestrians and bicyclists. This can be achieved by incorporating relevant safety performance measures early on in the analysis process.

Traffic analysis tools are procedures, methodologies and computer models used to carry out traffic analyses. These tools differ in their computational capabilities, input requirements and output measures. Consequently, proper application of each tool to solve traffic problems is a challenge to the transportation practitioners and decision-makers in obtaining reasonable traffic analysis results for the projects. This challenge eventually affects the cost and time to perform transportation projects. Guidance on the uniform and consistent application of the traffic analysis tools is therefore needed to overcome this challenge.

1.1 Purpose

This handbook provides guidance and general requirements for the uniform application of traffic analysis tools on roadway corridors, interchange, and intersection analyses. The techniques and accepted procedures for analyzing project traffic within the Florida State Highway System (SHS) are documented in this handbook. Additionally, the handbook guides traffic analysts, reviewers, and decision-makers through development of documentation and deliverables necessary to complete the traffic analysis process.

This handbook provides guidelines for uniform and consistent applications of traffic analysis tools in Florida

Specifically, this handbook:

- Provides guidelines toward a consistent and unified approach to the traffic analysis process that conforms to Florida Department of Transportation (FDOT) expectations.
- Guides the traffic analyst to select appropriate traffic analysis tool(s) and comparable performance measures of effectiveness (MOEs).
- Documents FDOT's requirements for traffic analyses.
- Provides a streamlined review process for accepting and approving traffic analysis and making informed decisions regarding the existing and proposed transportation investments.

The guidance provided in this handbook is based on documents previously published elsewhere such as technical reports, research reports, and manuals, as well as information collected from traffic analysis projects in Florida and FDOT's experience on working and reviewing traffic analysis methodologies and reports. The guidance was prepared with a consideration that not all traffic analyses are the same. As such, the handbook is not intended to be prescriptive nor an FDOT standard, and its application can be adjusted based on the context and size of the project as well as capabilities of the Districts and reviewing entities. To obtain reasonable traffic analysis results there should always be a balance between project complexity, its goals and objectives; time and budget available; and measures of system performance that will be used to assess the project.

1.2 Goals

It is expected that the information contained in this handbook when used and adapted to site specific conditions will:

- Improve consistency and effectiveness of the traffic analysis process.
- Streamline selection and application of analytical tools and traffic simulation models around the state.
- Improve documentations and transparency of the assumptions, input values, calibrated parameters, and outputs from traffic analyses.
- Facilitate portability of microscopic traffic simulation models from one phase of the project development to another.
- Ultimately streamline the project delivery process.

1.3 Intended Use

This handbook has been designed to be consistent with the Federal Highway Administration (FHWA) Traffic Analysis Toolbox program. The FHWA's toolbox provides general criteria to perform traffic analyses; whereas, the FDOT Traffic Analysis Handbook provides Florida specific guidelines.

The primary intended users of this handbook are the transportation practitioners preparing traffic analyses which are to be accepted or approved by FDOT or FHWA and reviewers of such efforts. Applicable traffic analyses to this handbook include corridor studies, interchange access requests (IARs), and project development and environment (PD&E) studies. For traffic studies that are not covered by this handbook which include but not limited to traffic signal warrant studies, travel time studies, and speed studies, the analyst should refer the FDOT Manual on Uniform Traffic Studies (MUTS)[1]. For guidance on conducting traffic impact studies, the analyst should refer the FDOT Transportation Impact Handbook[2].

The handbook guides the reviewer to the items that need to be checked and verified before accepting the work performed by the analyst. This handbook does not address the details of every aspect of traffic analyses but rather provides guidance the analyst will use when conducting traffic analyses in Florida.

This handbook does not constitute a training manual. Rather, it assumes the user has sufficient knowledge, experience and expertise in traffic analysis and is familiar with relevant traffic analysis tools available in the industry. Additionally, when the standards, methods or procedures are documented elsewhere, the handbook refers to those publications.

Users of this handbook should have sufficient knowledge of traffic flow and traffic analysis tools.

Guidelines provided in this handbook do not explicitly cover facilities with a managed lane (ML) component. Managed lanes include facilities where operational strategies are implemented based on accessibility, vehicle eligibility, and/or pricing. Additionally, this handbook does not cover multiple resolution modeling (MRM) approaches. MRM concept integrates regional travel demand models and microscopic simulation (microsimulation) models to perform time-dependent traffic assignments. FDOT is currently evaluating several MRM tools for use on traffic analyses on the SHS. Such guidelines will be published as a supplement to this handbook as soon as they are established.

1.4 Handbook Organization

The chapters of the handbook give guidance on conducting traffic analysis as follows:

- **Chapter 1: Introduction** – contain an overview of the handbook including purpose, goals and intended use.
- **Chapter 2: Traffic Analysis Methodology** – provides guidelines to prepare methodology to conduct the traffic analysis.
- **Chapter 3: Analysis Area Boundary Limits** – provides guidance on establishing the limits of traffic analysis.

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[1] http://www.dot.state.fl.us/trafficoperations/Operations/Studies/MUTS/MUTS.shtm
[2] http://fdottransportationimpacthandbook.com/

- **Chapter 4: Analysis Tools Selection**– contains general guidelines on selecting proper traffic analysis tools.
- **Chapter 5: Collecting and Analyzing Data** – provides guidance on data requirements, resources, collection techniques and procedure.
- **Chapter 6: Analyzing Traffic using Analytical Tools** – contains additional guidelines on the use of deterministic tools that are used to perform traffic analysis.
- **Chapter 7: Microscopic Simulation Analysis** – provides guidance to the use of traffic microsimulation tools, specifically CORSIM and VISSIM. Key steps that are to be followed when performing microsimulation are also provided.
- **Chapter 8: Alternative Analysis** – contains guidelines for developing and evaluating project alternatives.
- **Chapter 9: Analysis Documentation** – contains guidelines for preparing documentations for traffic analysis.
- **Appendices** – contains a list of technical references that were used to prepare this handbook and Tool Selection Worksheet.

1.5 Distribution, Updates and Contact

This document is available online at: FDOT Maps and Publications website or Systems Management website under Interchange Access Request. For updates, and questions regarding this Handbook, please contact:

Florida Department of Transportation
Systems Planning Office, Mail Station 19
605 Suwannee Street
Tallahassee, Florida 32309
ATTN: State Interchange Review Coordinator

Users of this handbook are encouraged to submit questions and requests for modifications to the State Interchange Review Coordinator at the above address. The handbook will be updated every three years or earlier as needed. Users of this handbook are encouraged to check the website prior to use to obtain any latest process and technical requirements.

1.6 Recommended References

Users of this handbook should review the FHWA Traffic Analysis Tools Program[3] (Volumes I, II, III and IV and VI) for detailed explanations of traffic analysis covered in this handbook. Additional technical references are listed in **Appendix A**.

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[3] Traffic Analysis Tools Program, Federal Highway Administration (FHWA), Washington, DC, 2003. http://ops.fhwa.dot.gov/trafficanalysistools/index.htm

Chapter 2
Traffic Analysis Methodology

The traffic analysis component of a project can be substantial in terms of time, resources and complexity. To streamline proper use of analysis approach and tools for the project the methodology[4] of the traffic analysis should be prepared. The analysis methodology is used to document how the analysis will be accomplished to meet project goals. A properly prepared methodology provide the base for the entire analysis process by identifying the issues to be solved, data requirements, performance measures, schedule, and analysis deliverables. The content of the analysis methodology should be tailored to the context and complexity of the project. The methodology elements discussed in this chapter can also be used by project managers to prepare the scope of traffic analysis. The reviewers of the traffic analysis report may use the methodology development process as an opportunity to raise critical issues and concerns so they can be resolved and incorporated in the analysis.

2.1 Methodology Elements

The methodology of the traffic analysis effort should include:

- Project description
- Traffic analysis objective
- Analysis boundary limits
- Analysis tool(s) selection and analysis approach
- Data requirements and data collection plan
- Project traffic forecasting
- Performance measures of effectiveness (MOEs)
- Project alternatives analysis
- Traffic analysis report and technical documentation
- Estimation of level of effort

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[4] Methodology elements discussed in this chapter include elements of the technical analysis approach memos or methodology memorandums of understanding that are prepared by the analyst and approved by the reviewing entity prior to beginning the analysis. These elements can also be incorporated in the project scope by project managers.

Very early at the project onset, the traffic analysis methodology should be discussed and agreed upon between the lead agency, FDOT, the analyst, and other project stakeholders. A pre-analysis field review is essential to become familiar with the analysis location. However, the field review may not be necessary for sketch-level planning analyses where lower levels of effort and details are desired. The field review should include key members of the project team. Additional meetings such as analysis scoping meeting may be required to reach full agreement and to clearly define and document every aspect of the traffic analysis methodology.

> Traffic analysis methodology has to be agreed to by all parties involved in the project

Prior to completing the methodology document the analyst should determine the schedule and budgetary constraints for the analysis effort. Additionally, all improvement concepts to be evaluated should be known along with their evaluation criteria.

2.2 Project Description

The project description is used to introduce the project. It includes general context and background information. Both vicinity map and project location map are included in the project description.

2.3 Traffic Analysis Objective

Traffic analysis objective(s) should clearly identify the following:

- The performance problem or goal which the analysis seeks to answer.
- The intended use and decision-makers of the traffic analysis results.

> The objectives of a project's traffic analysis have to be clear, specific, measurable and realistic

The objectives should be clear, specific, measurable and realistic, considering the resources and time that are available for their achievement. It is important to establish specific and measurable objectives that are directly tied to traffic operational and safety performance measures. Broad analysis objectives should be avoided as they tend to obscure the project needs and negatively impact decision-making. Additionally, the traffic analysis objectives should be in conformity with the project purpose and need statement.

It is noteworthy that safety performance measures should be integrated into the traffic analysis process. This is important because a facility that is free of traffic incidents would result in higher operational efficiency. Like operational MOEs, safety performance measures could identify the location and magnitude of the transportation problems and they could also provide means of developing effective crash countermeasure strategies.

2.4 Analysis Boundary Limit

The analysis boundary limit defines the traffic study are in both space and time domains. The space dimension is affected by the physical characteristics of the project while the time dimension is affected by hourly variation of the traffic on the project. Analyst's knowledge of the location and operation of the existing facility or proposed improvement is requisite for defining proper analysis boundary limit. Therefore, prior to defining the analysis boundary, the analyst should review and understand both spatial and temporal characteristics of the facility.

In determining the analysis boundary limit, the following should be considered:

- Characteristics of the project and the required level of analysis.
- Geographic location of network being studied.
- Size and topology of the network and availability of multiple routes.
- Classifications of the roadways forming the network being studied.
- Existing traffic controls and traffic management strategies.
- Future network conditions that are being planned in the long range transportation plans (LRTP), local government capital improvement plans (LGCIP) or approved Development Regional Impact (DRI) within the vicinity of project.
- Hourly variations of traffic in the project area.
- Bottleneck (capacity constraints) locations, their activation and dissipation periods, and queue extents caused by them.

Residual queues can have a significant effect on the results of the analysis. As such, the analyst should make sure that the analysis incorporates any residual queues observed in the field to the extent possible. If it is impossible to collect an initial queue estimate, the analysis time period should be extended to start on the period with demand less than capacity and no residual queue. Incorporating residual queues may require multi-hour analyses.

The analyst is responsible to determine and incorporate any improvements beyond the project area in the analysis boundary limit if they impact the project. Failure to consider such impacts may affect analysis results.

To streamline the review process, the analyst should coordinate with the traffic analysis reviewing and approving entities when establishing limits of the analysis. Guidance on establishing the limits of traffic analysis is further provided in **Chapter 3**.

2.5 Traffic Analysis Tool and Analysis Approach Selection

Traffic analysis tools can be categorized as deterministic or stochastic (or non-deterministic). Deterministic tools are tools in which no randomness is applied in their computational methods. These tools are also called analytical tools. Most of analytical tools are based on Highway Capacity Manual (HCM) methodologies. Stochastic tools employ randomness in their computational methods to model real world traffic conditions. Microsimulation tools are stochastic and thus they are effective in evaluating heavily congested conditions, complex geometric configurations, and system-level impacts of transportation improvements that are beyond the limitations of deterministic tools.

Proper selection of analysis tool and approach determines the success of any traffic analysis effort. The analyst should possess sufficient traffic analysis knowledge including understanding of the strengths and weaknesses of the traffic analysis tools in order to select proper analysis tools that meets the project needs. The analyst should be aware that no single tool can analyze or model all project conditions. It is recommended that the analysis effort correlate the project complexity, traffic analysis level and magnitude of the traffic problem being analyzed. Thus, use of very sophisticated tools and approaches should match the complexity of the problem being solved. The following factors are normally considered when selecting analysis approach and tools to carry out the analysis:

- Type of the project and level of analysis
- Required performance MOEs
- Traffic operating conditions such as queue formation and degree of saturation
- Facility type and geographic context of the analysis
- Assumptions and limitation of the available analytical tools
- Presence of traffic management strategies, specialized traffic control and intelligent transportation system (ITS) features
- Interoperability with other analysis software or traffic management strategies
- Resources and budgetary constraints

Projects on urban arterials that require signal optimization would require signal optimization tools to determine optimal signal settings.

The analyst should determine appropriate analysis tools and their versions based on the above mentioned factors and guidance provided in **Chapter 4**. The reasons for selecting such tools should be justified and stated clearly in the analysis methodology.

Reasons for selecting analysis tools should be documented in the analysis methodology

2.6 Data Requirements and Data Collection

Data requirements for any traffic analysis depend on the analysis level of detail, analysis type, analysis tool, and targeted performance measures. Variables affecting operation of the system (the vehicle, the environment, and the driver) should be assessed and collected as appropriate to meet the analysis objective. At minimum, assumptions, input data and calibration data (when simulation is proposed) must be identified.

It is required to document all assumptions with concise reasoning to enable reviewers understand them

Required data should be categorized as available from existing sources or to be field-measured with appropriate collection means outlined. The quality of the existing data should be verified to determine its fitness to the analysis method. Such verification can involve checking recent GIS files, maps or drawing. Additionally, sample data may be collected during field reviews to verify the accuracy of the existing data.

Existing data collected within the last 12 months should be used whenever possible. This data should represent a typical day (Tuesday, Wednesday or Thursday) of the week. However, data can be collected from other days of the week that are known to have highest volumes depending on the use of the facility or purpose of the project. The data should be screened for and exclude those days where weather, incidents, and holidays influence the traffic.

When microsimulation analysis is proposed, the methodology should identify calibration performance data along with their collection requirements. Key locations where calibration data is to be collected should be included so that the analyst and reviewers can agree on the simulation scenarios and calibration data needs. It is important to note that local knowledge and field observations of the traffic operating characteristics is requisite in establishing calibration locations.

Clear identification of the data required to support the analysis methodology helps to minimize project costs. Specific budgetary items should be included in the project plan to fund data collection. Regardless of the level and type of the analysis, data collection plan should be designed carefully. However, when the data collection is proposed to utilize the current FDOT procedures, the analyst should only reference the procedures. Data collection requirements are discussed in detail in **Chapter 5**.

2.7 Project Traffic Demand Forecasting

The project analysis methodology should include the demand forecasting procedure for future year analysis. Also included in the analysis methodology are the design year, interim years, and opening year for traffic analysis.

Development of demand volume projections should follow the guidelines and techniques published in the 2012 FDOT Project Traffic Forecast Handbook and the FDOT's Project Traffic Forecasting Procedure Topic No. 525-030-120. The analysis should identify the adopted regional (MPO) travel demand model to be used in the analysis along with its version, base year and planning (horizon) year. Depending on the location of the project and type of the analysis, the Florida Statewide Model or the Turnpike State Model (TSM) can also be used. For the limitation of the demand volume projection, the analyst should review NCHRP project number 08-83[5].

A most recent adopted travel demand model should be used. It is important that data used in the subarea model (model at the project boundary) reflects the most up-to-date assumptions about the highway network, socio-economic and land use. If it is determined the model would require incorporating recent changes in input data, documentation of the updates and the validation procedure should be provided. The procedure for subarea model validation and reasonableness checking should be consistent with the FDOT Florida Standard Urban Transportation Model Structure (FSUTMS) Standards.

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[5] NCHRP 08-83 Analytical Travel Forecasting Approaches for Project-Level Planning and Design

If no travel demand model is available, historical traffic data may be used to forecast future year traffic demand utilizing trend analysis. Other socio-economic data such as gas sale records, land use maps and population data may be used to estimate the traffic growth rate. Trend analysis may also be used on a project that is not significantly enough to cause traffic diversion and project traffic volume is shown to follow historical trend. Resurfacing and widening projects typically would not cause substantial traffic diversion.

When future traffic is projected without a demand model, traffic factors such as K (proportion of daily traffic in the peak hour), D (directional distribution), and T (percentage of heavy vehicles) should be used consistent with the 2012 FDOT Project Traffic Forecast Handbook.

2.8 Performance Measures of Effectiveness (MOEs)

Numerical outputs from the traffic analysis are the MOEs which are metrics used to assess the performance of a system. MOEs are also used to compare and contrast the system performance under various design or improvement alternates. The analyst should be aware of and able to identify any limitations of the MOEs to the measurement of performance of the system being evaluated.

The methodology should identify all operations and safety MOEs that will be used to measure the performance of the system to fulfill the objective of the analysis and alternatives being evaluated. It is important to describe the MOEs as field-measured or analytically established. Additional project-related MOEs to be used in the alternatives analysis can be obtained from relevant local and regional agency guidelines.

> All MOEs that describe the objectives of the analysis should be identified in the methodology

Level of Service (LOS) is readily recognizable indicator of traffic operations and has been widely used by different agencies when evaluating the traffic operations performance of facilities. However, LOS alone does not necessarily give insight about the overall performance of the facility. Thus additional quantifiable measures should be included in the analysis to better assess the performance of the system or network being analyzed. It is recommended that the analyst seek input from project stakeholders when establishing MOEs for the project.

LOS criteria for projects on the SHS are to be selected based on the FDOT LOS policy (FDOT procedure No. 525-000-006). Projects on local agency facilities may use the agency's LOS standard.

When the proposed analysis approach requires calibration, the methodology should outline how calibration process will be performed and what calibration performance measures will be used. All calibration and validation parameters and the locations where they will be checked should be identified. The analysis methodology should also identify the desired calibration margins of error or tolerances that will be met.

2.9 Project Alternatives

All alternative improvements that have been developed for the project and will require traffic analysis should be described in the analysis methodology. Discussion of how (and why) the alternatives will be developed should be brief, yet clear. The amount of details provided should be commensurate with the proposed level of analysis. Graphical illustrations of all alternatives considered should be provided when alternatives are known. The "No-Build" alternative must be considered as one of the project alternatives. No-Build alternatives include not only maintenance, but also committed improvements with programmed funding to the analysis location. A description of how the alternatives will be evaluated and screened should be included.

2.10 Traffic Analysis Report and Technical Documentation

Documentation requirements for a traffic analysis should be established as part of the traffic analysis methodology. The methodology of the traffic analysis should describe how the results will be presented to the intended audience such as policy makers and the public. Documentation is also necessary to enable a reviewer to independently confirm analysis assumptions, analysis methodology, input data, outputs, and if necessary reproduce the same results presented by the analyst. As such, the methodology should include check points to provide for interim technical reviews and approval of the analysis efforts. The number of check points and interim documents necessary to support traffic analysis should be proportional to the size of the project and complexity of the analysis. Specific documentation requirements for traffic operational analyses are provided in **Chapter 9**.

2.11 Estimation of the Level of Effort

The methodology of the traffic analysis may include an estimate of the work effort required to meet project objectives. The estimate of work effort should identify both personnel, budget, and scheduling requirements which include key milestones and decision points required to deliver a traffic analysis report. When microsimulation approach is proposed, the methodology may include the model development proposal which could help project stakeholders comprehend the realistic level of effort to carry out the analysis.

Efforts that involve modeling of complex areas with extreme congestion should be carefully estimated. Such efforts have to include the time and resources required to test and validate the analysis results. Generally, for most projects involving deterministic and analytical tools, the traffic analysis could be completed in less than three (3) months. Time to complete traffic analyses that require microsimulation tools could be longer than three (3) months depending on the complexity of the project, number of alternatives being evaluated and project schedule. Ideally, one analyst at a time can code, calibrate, and run the microsimulation on the computer. However, there are some situations where a skeleton (master network) model may be built and later split into subarea models that could be coded by different analysts. The subarea models can then be pasted back into the skeleton network. As such, ability of the software package to split the network should be explored prior to coding the model.

Additionally, since calibration of microsimulation tools is a time consuming process, its staffing requirements, budget and schedule should be set properly to meet project time and money constraints. Level of effort estimates for microsimulation should include time and resources for error checking (model verification) for alternative analysis. Estimates of level of effort should also include time for reviews of the analysis methodology, preliminary data, analysis outputs, and analysis reports.

2.12 Traffic Analysis Methodology Checklist

A checklist of the traffic analysis methodology development content is shown in **Table 2-1**. This checklist is a guidance that should be used by the analyst when preparing the methodology memorandum. The checklist may also be used by project managers when preparing scope for the traffic analysis. Following of this checklist does not guarantee acceptance of the analysis methodology and/or results.

Table 2-1 Traffic Analysis Methodology Content Checklist

Financial Project ID: ______________ **Federal Aid Number:**______________

Project Name: ____

State Road Number: ______________ **Co./Sec./Sub.** _____________ **Begin Project MP:** ______________ **End Project MP:** __________________

Item	**Description**	**Check**	**Remarks**
Traffic analysis objective	Discuss briefly and concisely objective, purpose and need. Include location map.	☐	
Technical Guidance and Standards	Describe technical standards, procedures, and guideline to be followed to conduct analysis. Include quality assurance/control commitment.	☐	
Analysis area boundary limit	Describe both spatial and temporal boundary limits. Include a legible and scaled area map showing all study intersections and interchanges	☐	
Analysis tool(s) selection and analysis approach	Describe the approach to be used to perform traffic analysis. List analysis tool(s) to be used along with their versions.	☐	
Data requirements and data collection plan	Describe data collection plan, include methodology, sources, techniques, schedule, and quality assurance plan. Identify calibration and validation data requirements and include calibration data collection means	☐	
Project traffic forecasting	Summarize methodology for projecting traffic forecast. List design year/planning horizon, opening and interim years	☐	
Analysis output	Describe performance measures of effectives (MOEs) that will be evaluated. Explain how the selected approach and tools will report the MOEs. If calibration and validation are required, briefly explain approach and MOEs as well as locations to be calibrated and targets for acceptance.	☐	
Project alternatives	Describe existing/No-Build conditions, and improvement (build) alternatives to the extent possible. Use graphics to illustrate build alternatives. Describe alternative screening criteria	☐	
Traffic analysis report and technical documentation	Describe required documentation requirements commensurate with the complexity of the analysis	☐	
Estimate of work effort	Include an estimate of the level of analysis effort	☐	

Preparer's Name:________________________________ **Date:**______________ **Reviewer's Name:**________________________________ **Date:**______________

Chapter 3
Analysis Area Boundary Limits

Boundary limits for the analysis area are established to accurately capture the prevailing traffic operating characteristics. This chapter provides guidance on establishing both spatial and temporal boundary limits of the traffic analysis.

3.1 Spatial Boundary Limit

Spatial boundary limit is derived from an area of influence or study area which is the geographic breadth of the traffic analysis. The area of influence depends on the type and location of the project type and the prevailing traffic operating characteristics. Proper identification of the area of influence increases the level of accuracy of the traffic analysis tool in replicating real world traffic characteristics. The analyst should initially conduct a field reconnaissance to determine an extent of the problem and identify any hidden bottlenecks. Hidden bottlenecks are formed when the existing demand at a segment or point is constrained by upstream bottlenecks. In such conditions, correction of upstream bottleneck by the improvement would normally shift the bottleneck to a downstream capacity constrained location.

> Presence of traffic bottleneck affects the spatial boundary limit

Additionally, DRIs in the vicinity of the project area should be analyzed to determine its inclusion in the area of influence.

The area of influence for the analysis performed in urban areas typically includes at least the first adjacent interchange or signalized intersection. The variation of operating characteristics observed in urban areas can necessitate the extension of the area of influence. When traffic congestion is prevalent, the location, type, magnitude and causes of congestion should be determined prior to establishing the area of influence for the analysis. The establishment of the spatial boundary limits of analysis should therefore consider factors that would affect traffic operational and safety performance of the project such as:

- Bottleneck (capacity constraint) that affects traffic flow into or out of the area of influence in both existing and future conditions.
- Queues that extend beyond the predefined area of influence.
- Major systems interchanges that affect the lane-changing behavior (merge/diverge or weaving operations) through the area of influence.
- Adjacent intersections that affect formation of vehicle platoons in the area of influence. For example presence of a coordinated signal system.

Area of influence for projects located in rural areas is established on a case by case basis depending on their degree of isolation from other segments or facilities.

For projects involving interchange access requests, the analyst should consult the FDOT Interchange Access Request User's Guide[6]. Coordination with the approving agency of the analysis is strongly recommended when establishing the analysis boundary limits.

The following general guidelines may also be considered when identifying the area of influence for projects involving microsimulation:

Freeway Projects – Projects involving freeways in urban areas may require a longer area of influence due to variations in the network topology, land use characteristics and driving behaviors. Existing or proposed traffic conditions downstream and upstream of the area of influence may affect the outcome of the analysis of the study area. As such, the analyst should examine and consider the following as appropriate to replicate existing operating characteristics:

- Extent congestion (or queuing) upstream or downstream of the analysis area of influence.
- Ramp connections that affect weaving within the area of influence.
- Areas where traffic flow entering the area of influence is metered by toll plazas, ramp meters, and upstream traffic signals.
- Other relevant operational situations as evidenced by data or field observations.

Arterial Projects – The area of influence for arterial roadways and other surface streets depends upon the road network configuration, frequency of traffic signals, and the level of congestion within the project area. The following guidelines should be considered when establishing the area of influence:

- Boundaries should extend far outside the project location enough to replicate existing traffic conditions within the area of influence. Inclusion of at least one signalized intersection beyond the area of influence is typically necessary to increase accuracy of the model in replicating existing operating characteristics.
- Boundaries should be located at logical points in the road network from the existing traffic operations perspectives, such as on a section of road with approximately random or uniform traffic arrivals. For instance, the random arrivals might be due to a distant (0.5 miles or more) upstream signalized intersection, while the uniform arrivals might be due to heavy traffic turning onto the arterial from the upstream signalized intersection or intervening unsignalized streets and driveways, resulting in traffic uniformly arriving at the traffic signal throughout the cycle. If the project is within an arterial with signal coordinated system, the analysis boundary should be extended to include the effect of coordinated signals.
- Boundaries should not be extended unnecessarily, as this would increase analysis efforts and may reduce attention to the project location.

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[6] FDOT Interchange Access Request User's Guide

Spatial boundary limit of the analysis affect the analysis approach. For instance, an analysis with small spatial boundary limit on urban areas would favor microscopic analysis techniques. Broader spatial boundary limits tend to favor a combination of travel demand models and other macroscopic analysis techniques.

3.2 Temporal Boundary Limits

Knowledge of variability in traffic demand is needed to properly determine temporal boundary limits

Temporal boundary limit is the length of traffic analysis period. Analysis period is selected such that the effect of traffic demand variation is captured and included in the analysis. Capacity analyses typically focus on the peak hour where demand to use the facility is high. Typically, hourly volumes are higher prior to the onset of the peak hour than during the peak hour in oversaturated traffic conditions. As such, peaking characteristics of the facility should be examined before establishing the analysis period. Peaking characteristics can be obtained from examining hourly and daily variations of the traffic demand. The analyst should consult local permanent count station data to gain an understanding of the traffic demand variations. Additional field observations and queue analysis may be conducted to confirm the demand variations.

The traffic operating characteristics in undersaturated conditions are homogenous and thus 15-minute analysis period is used consistent with HCM methodology. In undersaturated conditions, vehicles interactions are minimal so drivers can choose their own desired speed. As such, extending the analysis period beyond 15 minutes in undersaturated conditions will not affect the performance measure significantly. Traffic flow during the analysis period is deemed undersaturated when all of the following assumptions hold: (a) the arrival flow rate is less than the capacity of the facility, (b) no residual queue present from a previous breakdown of the facility, and (c) downstream conditions do not affect the traffic flow. If any of these conditions is violated, the traffic flow is considered oversaturated.

For locations where traffic flow is oversaturated, a single 15-minute traffic analysis period is typically not sufficient. A multiple-period analysis is required under these conditions to capture the effect of demand that is not served by the facility from one 15-minute to the next. The multi-period analysis should account for the residual queues (unmet demand) from one period by using them as initial queue in the subsequent period. It is important to note that the first and last periods of the multiple-period analysis should be undersaturated.

Analysis period on congested facilities can be more than one hour when demand to use the facility exceeds the capacity over a period longer than one hour. This condition is called peak spreading. Peak spreading typically occurs when congestion is very severe. Existing 24-hour traffic volume profiles should be evaluated to determine the periods where peak demand spreads over multiple hours. Directional volumes should be analyzed because of the possibility to have volume in one direction at capacity while volume in the opposite direction well below capacity. When the peak traffic spreads out, the analysis period must include duration of traffic congestion as well as uncongested periods before (congestion build-up) and after (congestion dissipation) the peak period. Inclusion of uncongested periods is essential to capture the effects of traffic breakdown as the result of congestion spread beyond the time during which the demand exceed capacity.

In future year analyses where congestion is expected but none currently exists, the analyst should review the results of the analysis to determine the presence of unmet demand. When unmet demand is observed, the analyst should extend the analysis period to include uncongested periods before and after the period where demand exceed capacity.

Chapter 4
Analysis Tool Selection

Since traffic analysis tools have different computational capabilities and assumptions, one set of tools should be applied consistently to perform traffic analysis in a particular project. As such, to obtain cost-effective, yet reasonable analysis results at a desired level of confidence, guidance for selecting proper analysis tools is provided in this chapter.

4.1 Traffic Analysis Tools

The following are tools that are mostly used to perform traffic analysis in Florida:

- *Florida's GSVT*

  Florida's Generalized Service Volume Tables (GSVT) are sketch-planning level tools developed to provide a quick review of capacity and LOS of the transportation system. The tables provide the most representative statewide service volumes and capacities for the state of Florida.

- *Cube*

  Cube Voyager is used to perform future travel demand forecasting based on existing transportation network conditions and future projections of household and employment characteristics. It uses the gravity model and capacity restrained assignment. Cube is run on the FSUTMS which is a set of standardized software programs, data formats and operating procedures that were developed to perform travel demand forecasts for Metropolitan Planning Organizations (MPOs) LRTP. FSUTMS replicates MPOs area wide travel patterns. It should be noted that some of the MPOs' models in the State, such as the Southeast Florida Regional Planning Model Version 7 (SERPM 7), are moving away from the gravity model and incorporates the Destination Choice Model for trip distribution.

- *LOSPLAN*

  LOSPLAN is a suite of three software programs that perform level of service and capacity analyses for generalized and conceptual planning applications. The three programs are ARTPLAN, for signalized arterial facilities, FREEPLAN, for freeway facilities, and HIGHPLAN, for two-lane and multilane highway facilities. The LOSPLAN calculations are based largely on the analysis methodologies of HCM, but also incorporate enhancements based on the FDOT research.

- *Highway Capacity Manual (HCM)/Highway Capacity Software (HCS)*

  The Highway Capacity Manual (HCM) is the most widely used document in the transportation industry that contains a set of methodologies and application procedures for evaluating the capacity and quality of service of various transportation facilities. It is a tool for analyzing existing facilities and for the planning and design of future systems. HCM is built from more than 60 years of research work and represent a body of expert transportation consensus. Highway Capacity Software (HCS) is a computer program that implements the HCM methodologies. Both HCM and HCS analyze capacity and LOS for uninterrupted-flow and interrupted-flow roadways. Other travel modes covered by HCM and HCS are pedestrian, bicycle, and transit. Results from traffic model created by HCS can be directly animated in CORridor SIMulation (CORSIM) software.

- *SIDRA INTERSECTION*

  SIDRA (which stands for Signalized & unsignalized Intersection design and Research Aid) INTERSECTION is an analytical model mostly used to analyze roundabout operations in the United States. SIDRA can also be used to analyze signalized and unsignalized intersections, single-point urban interchanges, and signalized midblock crossings for pedestrians. Unlike HCM which uses lane group concept in intersection analysis, SIDRA has a capability of performing lane-by-lane analysis at the intersection. Additionally, SIDRA can be used to evaluate the effect of metering signals on roundabout performance.

- *Synchro/SimTraffic*

  Synchro is a macroscopic analysis tool which is used to design, model and analyze signalized and unsignalized intersections. Synchro is also used to model arterial segments. The software optimizes traffic signal timings for an isolated intersection, an arterial or a network. It uses three methods to analyze signalized intersections: Intersection Capacity Utilization (ICU), HCM Signalized Method and Synchro Percentile Delay. SimTraffic is a microsimulation tool which models individual vehicles interactions and provide animation of the model in a network. SimTraffic uses direct input from Synchro to perform microscopic traffic simulation. SimTraffic can model signalized and unsignalized intersections and highway segments. When a 3D Viewer application is used, the analyst could convert a two-dimensional (2D) model from SimTraffic to a three-dimensional (3D) animation. Additionally, Synchro has capability of building input files for CORSIM where detailed microsimulation analysis can be performed.

- *CORSIM*

  CORSIM stands for CORridor SIMulation. It is a microscopic traffic simulation tool. CORSIM supports several tools for analyst's convenience of preparing input data. These tools are: TRAFED, TSIS Next, Streets Editor, Freeways Editor, TRANSYT-7F, Synchro, HCS-Urban Streets, and HCS-Freeway Facilities. CORSIM models individual vehicle movements using car-following and lane-changing logics in a time-step simulation. Time-step simulation enables each vehicle to be individually tracked through the network, and MOEs collected on every vehicle. Driver behavior characteristics are assigned to each vehicle. Random processes are introduced to reflect real-world operating conditions. The variation of each vehicle's behavior is simulated in a manner reflecting real-world operations. Driver behavior parameters can be calibrated to simulate local existing conditions. CORSIM come pre-configured with TRAFED and TRAFVU tools. TRAFED is a graphical user interface-based editor used to create and edit traffic networks while TRAFVU is the visualization utility that displays the network and animates simulated traffic flow. An arterial system modeled using Synchro can be imported into CORSIM.

- *VISSIM*

  VISSIM stands for the German words "Verkehr In Staedten SIMulation". It is a microsimulation tool that is used to analyze and model vehicular traffic, transit and pedestrian flows. VISSIM has an option of recording videos of simulation runs in 3D mode. VISSIM can be applied to analyze different transportation problems such as signal prioritization and optimization; dynamic traffic assignments; freeway operations; traffic management strategies; pedestrian flows; and interaction of different transportation modes. It simulates the traffic flow by moving the driver-vehicle units. It also uses a car-following and lane-change logic which allow drivers from multiple lanes to react to each other. This software provides a number of calibration parameters that allow for model calibration to better match local conditions. Additionally, VISSIM has a module which can build models from Synchro by directly importing Synchro's geometry, volumes and signalization data.

Table 4-1 provides a summary of the applications of these tools in different levels of analysis.

Table 4-1 Uses of Traffic Analysis Tools

Analysis Type	Level of Detail	Level of Analysis	Analysis Tool
Sketch Planning	Analyzing system elements to obtain general order-of-magnitude estimates of performance based capacity constraints and operational control	Generalized Planning	GSVT, LOSPLAN, HCM/HCS
Deterministic	Analyzing broad criteria and system performance based on geometric and physical capacity constraints; operational systems such traffic control and land use	Conceptual Planning & Preliminary Engineering; Design; Operation	LOSPLAN, HCM/HCS, Synchro, SIDRA
Travel Demand Modeling	Analyzing regional travel demand patterns, land use impacts and long range plans. Outputs of demand models are applied in analytical and microscopic analysis	Conceptual Planning	Cube Voyager
Microscopic Simulation	Analyzing system performance based on detailed individual user interactions; geometry and operational elements	Preliminary Engineering; Design; Operation	CORSIM, VISSIM, SimTraffic

4.2 Which Tool is Appropriate?

Early on the traffic analysis methodology development process, determination of the tool which satisfies the project traffic analysis objectives to the extent possible should be made. In making such determination, the analyst should be aware of the required level of analysis effort, degree of detail and limitations of all tools in performing such analysis. For example, generalized

> The decisions to select a tool should be based on the analysis objective and project specific constraints

planning analysis should not be performed by using sophisticated tools which involve microsimulation. However, the analyst should refrain from selecting a simple analysis tool (solely based on familiarity or lack of resources) that may not fit the analysis objective. **Figure 4.1** demonstrates the relation between the levels of analysis, effort and degree of accuracy among different traffic analysis tools used by FDOT.

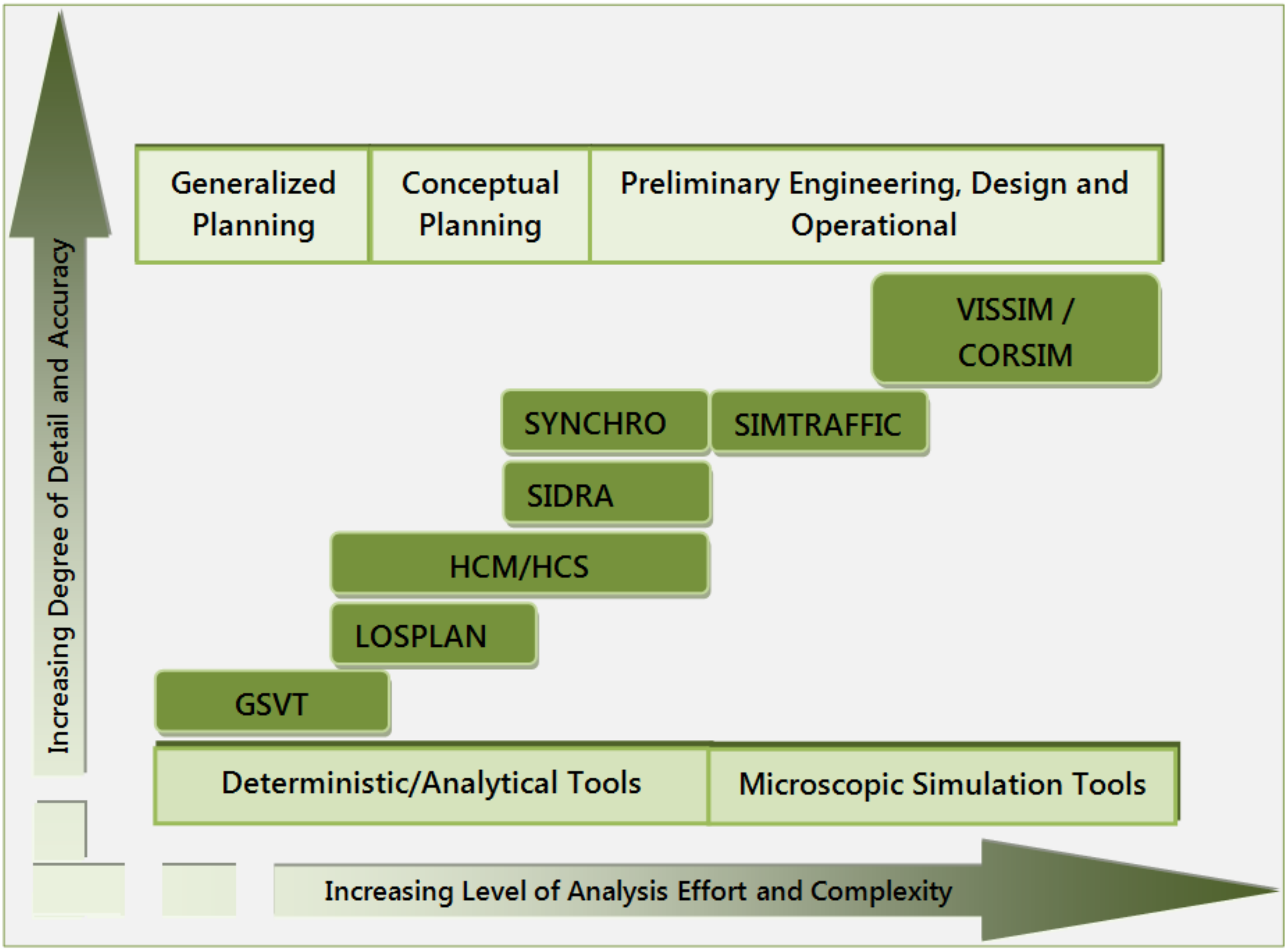

Figure 4-1 Traffic Analysis Tools

Selection of inappropriate tools could be detrimental because of the possibility to make poor transportation investments decisions. When the analysis approach requires a more detailed level of analysis and is constrained by budget, the analyst should consider and discuss with the Project Manager and the reviewing entity about the tradeoff between increasing resources limits against the risk of poor investments.

A good approach to selecting an appropriate traffic analysis tool is to review past experiences of the available tools to perform similar analyses in order to verify and select the tools that have produced high-quality results. Using this approach would help the analyst understand and overcome any limitations of the tools. Schedule and budget constraints should also be considered when selecting appropriate analysis tools.

For a detailed procedure for selecting traffic analysis tools, the analyst should review FHWA Traffic Analysis Toolbox, Volume II: Decision Support Methodology for Selecting Traffic Analysis Tools. A tool category selection worksheet that can be used in the tool selection process is reproduced and attached in the **Appendix B**.

It is recommended that microsimulation tools be used for preliminary engineering, design and operation analyses only when HCM-based tools are not appropriate. Use of microsimulation should be supported and justified by existing data. **Table 4-2** presents a summary list of example applications of traffic analysis tools to analyze the performance of different facilities.

Prior to selecting microsimulation tools, the analyst should thoroughly review existing conditions to justify their use. Such justification should be explicitly included in the methodology of analysis. At least one of the following conditions must be valid for the analyst to consider microsimulation:

- Conditions that violate or limit the basic assumptions of analytical tools such as higher levels of saturation and complexity of the network or corridor
- Conditions that are not covered by analytical tools such as traffic routing, queues that overflows to the system analyzed, or prolonged congestion periods
- When analysis objective requires evaluation of vehicle performance, user behavior, multiple what-if scenarios, effect of application of a technology or an operational strategy like managed lanes, and ramp metering

Analysis of an isolated location, point or a segment where influence from adjacent segments is marginal and congestion is not prevalent should always be performed by HCM-based tools such as HCS, Synchro or LOSPLAN. Additionally, where congestion does not exist (LOS D or better), HCM should be used to analyze freeway facilities (connected basic segment, weaving area, ramp merge/diverge areas) and urban street facilities (combination of automobile, pedestrian, transit, and bicycle) from a complete corridor perspective. Analytical applications that fall beyond the limitations of HCM and HCS on urban networks should be done using Synchro/SimTraffic software. Such conditions include intersection and arterial street analyses which require design of signal program and timing plan, signal optimization, queue analysis or exchange of data with other traffic analysis software or traffic control equipment.

> Always use HCM-based tools for isolated point or segment analyses and when congestion is not prevalent

Table 4-2 Traffic Analysis Software by System Element

Facility	Level of Analysis	Project Need	Performance MOE	Recommended Software
Limited Access	Generalized Planning	Determining a need for additional capacity	LOS	GSVT, LOSPLAN
	Conceptual Planning	Determining number of lanes	LOS	LOSPLAN, HCS
	Preliminary Engineering and Design	Determining how the facility will operate	LOS, density, speed, Travel time	HCS CORSIM, VISSIM
	Operational	Determining how well the facility operates	LOS, density, speed, Travel time	HCS CORSIM, VISSIM
Interchanges	Conceptual Planning	Determining capacity of the weaving segment	Flow rate, LOS	HCS
	Preliminary Engineering and Design	Determining capacity of the weaving segment or ramp merge/diverge	Density, speed, LOS	HCS
		Evaluating effect of a queue backup from the ramp terminal to the weaving operation	Queue length	SYNCHRO, VISSIM, CORSIM
		Analyzing weaving from ramp terminal to the nearest signalized intersection	Speed, density	VISSIM/CORSIM
		Evaluating the operation of the entire interchange	Density, speed,	SYNCHRO, CORSI, VISSIM
	Operational	Evaluating weaving operation	LOS, density	HCS, SYNCHRO, VISSIM, CORSIM
Urban Arterials	Generalized Planning	Determining a need for additional capacity	LOS	GSVT, LOSPLAN
	Conceptual Planning	Determining number of lanes	LOS	LOSPLAN, HCM/HCS
	Preliminary Engineering and Design	Determining how the facility will operate	Speed	HCS
		Optimizing signals	Control delay, queue, V/C ratio	SYNCHRO/SIMTRAFFIC
	Operational	Coordinating traffic signals	Travel time, speed	SYNCHRO
		Evaluating existing signal timing plans	Travel time, speed	HCS, SYNCHRO
		Checking the effect of technology application or traffic demand management strategy	Travel time, speed	SYNCHRO/SIMTRAFFIC, VISSIM,CORSIM
Rural two-lane highways and Multilane highways	Generalized Planning	Determining a need for additional capacity	LOS	GSVT, LOSPLAN
	Conceptual Planning	Determining number of lanes	LOS	LOSPLAN, HCS
	Preliminary Engineering and Design	Determining how the facility will operate	LOS	HCS
	Operational	Determining how well the facility operates	LOS	HCS
Intersections	Conceptual Planning	Determining a need for additional intersection capacity	LOS, V/C, delay	HCS
	Preliminary Engineering and Design	Designing isolated intersection	LOS, V/C, delay	HCS, SYNCHRO
		Analyzing closely spaced intersections	LOS, V/C, delay, queue length	SYNCHRO/SIMTRAFFIC
		Analyzing unconventional (or complex) intersection	LOS, V/C, delay, queue length	CORSIM, VISSIM
		Analyzing multimodal interactions	LOS	VISSIM, HCS
	Operational	Evaluating the performance of signalized intersection	LOS, V/C, control delay, queue, ,Phase Failure	HCS, SYNCHRO
Roundabouts	Conceptual Planning	Evaluating the need for roundabout	V/C, LOS	SIDRA, HCS
	Preliminary Engineering and Design	Analyzing roundabout	V/C, LOS	SIDRA, HCS, SYNCHRO
	Operational	Evaluating the performance of roundabout	V/C, LOS, delay	SIDRA, HCM, SYNCHRO

Table 4-2 Continues

Facility	Level of Analysis	Project Need	Performance MOE	Recommended Software
Networks & Systems	Planning	Forecasting system-wide future demand	vehicle-miles traveled, V/C	GSVT, LOSPLAN, CUBE, HCS
	Preliminary Engineering and Design	Evaluating the performance of the entire network/system	Speed, travel time, LOS, vehicle-miles traveled	SYNCHRO/SIMTRAFFIC, CORSIM, VISSIM
	Operational	Evaluating the performance of the entire network/system	Speed, travel time, LOS	SYNCHRO/SIMTRAFFIC, CORSIM, VISSIM
Multimodal Transportation District (MMTD)	Planning	Planning level assessment of different modes	LOS	GSVT, LOSPLAN, HCS
	Design and operational	Evaluate alternative multimodal improvements	Travel time, LOS, queue	VISSIM
		Assessing quality of service on a multimodal corridor	Travel time, LOS, queue, transit reliability	HCS, VISSIM

If simulation is required, the simulation tool should be selected carefully. It should be noted that that there is no single microsimulation tool that can perfectly analyze all types of traffic problems. Each microsimulation tool that is available in the market has strengths and limitations. FDOT recommends CORSIM and VISSIM to be appropriately used to perform traffic microscopic analysis on interstate and freeway corridors. SimTraffic can be used on urban arterials analysis. Factors that can be considered when deciding to use CORSIM or VISSIM for traffic microsimulation may include:

- Prior applications and available data
- Network size limitations
- Suitability of the software package to simulate the special phenomenon that is to be investigated, e.g., pedestrian movements, transit, etc.
- Knowledge of calibration and validation parameters from previous completed projects
- Visualization capabilities and input data formats
- User interface control and flexibility of coding network
- Compatibility and integration with other traffic modeling tools, e.g. travel demand models

This list is not exhaustive and it remains responsibility of the analyst to use good engineering and planning judgment when selecting microscopic traffic simulation tools to analyze traffic.

While this handbook provides guidelines on selecting and using appropriate traffic analysis tools on different analysis levels, use of alternative tools other than those discussed in this handbook may be necessary depending on the project local circumstances, software limitations and scale of analysis. When alternative tools are proposed, the analyst should provide adequate documentation to enable the reviewer to understand the model development process so as to independently confirm model inputs and outputs and verify calibration process. **Appendix B** of the FHWA Traffic Analysis

Toolbox Volume II contains a Tool Selection Worksheet (9-page worksheet) that can be used as part of the documentation to justify the use of alternative tools.

4.3 Safety Analysis Tools

Quantitative safety evaluations can be performed using the following tools:

- *Highway Safety Manual(HSM)*

  Highway Safety Manual (HSM) consists of a set of procedures and methodologies to support objective-based, data driven, and systematic approach to quantify safety performance of a highway. The HSM is intended to assist agencies in their effort of integrating safety into the decision-making process. Whether the inception of the project is derived by safety or not, HSM can be used to evaluate meaningful safety performance measures in the project development process that will aid the decision-making process.

  The safety evaluation process of the HSM is a continuous-cyclical process which starts with network screening where the safety performance of individual sites is compared with the safety performance of similar sites to determine its acceptability. The next step is diagnosis where crash causation factors are examined and their countermeasures are identified. The countermeasure step involves selection of treatments to mitigate or address the safety issues. Economic appraisal and project prioritization are the next steps of the evaluation procedure where economic viability of the countermeasures is analyzed and countermeasures are ranked in terms of potential maximum benefits. The safety effectiveness evaluation step monitors the implemented countermeasures to determine their performance. Additionally, HSM has crash predictive models which vary by facility and location type. The prediction models use Safety Performance Functions (SPFs), Crash Modification Factors (CMFs) and Calibration Factor to estimate crashes for a specific year on particular location.

  HSM has spreadsheet tools[7] to predict average crash frequency for rural two-lane two-way roads, rural multilane highways, and urban and suburban arterials as per Part C of the HSM.

  The tools that support HSM procedures and methodologies to quantify highway safety include SafetyAnalyst, Enhanced Interchange Safety Analysis Tool (ISATe), Interactive Highway Safety Design Model (IHSDM), and Crash Modification Factors Clearinghouse.

  - SafetyAnalyst includes tools to implement the roadway safety management procedures (Part B) of the HSM.
  - IHSDM is a suite of software analysis tools that are used to evaluate the safety and operational effects of geometric design decisions on highway projects. IHSDM supports HSM Part C (Predictive Methods).
  - ISATe is an analytical tool to examine the safety performance and predict crashes on freeways and interchanges.

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[7] Spreadsheets for Part C calculations

  - CMF Clearinghouse is the database that contains CMFs listed in the HSM. It supports implementation of HSM Part D (Crash Modification Factors).

- *SafetyAnalyst*

  SafetyAnalyst is a collection of analytical tools used for guiding the decision-making process to identify safety improvement needs and to develop a system-wide program of site-specific improvement projects. The software includes a diagnosis tool to diagnose the nature of crashes and guides the analyst through appropriate investigations to identify safety concerns of the project and their possible countermeasures. The countermeasure selection tool guides the analyst in the selection of countermeasures to crashes at specific areas on the project. Additionally, SafetyAnalyst network screening tool has procedures that explicitly distinguish intersection and non-intersection related crashes and also address the safety performance of individual interchange ramps. Other tools contained in the SafetyAnalyst are economic appraisal tool and counter measure evaluation tool.

- *IHSDM*

  Development of IHSDM is coordinated with the HSM and SafetyAnalyst. It includes six evaluation modules—crash prediction, design consistency, intersection review, policy review, traffic analysis, and Driver/vehicles.

- *ISATe*

  ISATe is a spreadsheet based tool. It provides a relationship between freeway design features and safety. The tool automates the safety prediction method utilizing the procedure and methodology documented in the NCHRP Project 17-45[8] . ISATe predictive model uses safety performance function (SPF), crash modification factors (CMFs), and a calibration factor to estimate average crash frequency by total crashes, crash type or severity level. The ISATe model has ability to combine existing crash data to obtain a more reliable prediction. The tool's predictive method for freeways is different from that of ramps. The analyst should review limitations of the two predictive methods before applying the tool to analyze the project.

- *CMF Clearinghouse*

  CMF Clearinghouse is a web-based database of CMFs along with supporting documentation to aid practitioners identify appropriate crash countermeasures for their safety projects. It is maintained by the FHWA. The CMF stored in the CMF Clearinghouse are assigned star ranking based on the quality with respect to study design, sample size, standard error, potential bias, and data source. CMFs can be used in transportation safety management, road safety audits or design exception process in conjunction with other aspects of the HSM.

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[8] Safety Prediction Methodology and Analysis Tool for Freeways and Interchanges. Final Report. NCHRP Project 17-45.

Guidance on using traffic safety analysis tools is provided in **Table 4.3**.

Table 4-3 Levels of Analysis and Safety Analysis Tool

Level of Analysis	Project Need	Performance MOE	Tool
Generalized Planning	Identify sites likely to benefit from a safety improvement	Crash Frequency	HSM Part B and D; CMF Clearinghouse, SafetyAnalyst
	Predicting future performance of an existing facility	Crash Frequency	HSM Part C, IHSDM
Conceptual Planning	Identifying locations with higher-than-expected crashes	Crash frequency and severity	SafetyAnalyst—Network Screen Tool
	Identifying safety issues and alternative solutions	Crash Frequency	HSM part B and D, SafetyAnalyst, CMF Clearinghouse
	Identifying ways to improve safety as part of a traffic impact study	Crash Frequency	HSM Part B and D, SafetyAnalyst, CMF Clearinghouse
	Assessing safety performance of different conceptual corridor designs related to changes in roadway geometry or operation	Crash Frequency	HSM Part C and D, IHSDM, CMF Clearinghouse
Preliminary Engineering and Design	Improving the performance of a roadway facility from a capacity or safety perspective	Crash Modification Factors (CMFs)	HSM Part D, CMF Clearinghouse
	Compare the effect on safety of different improvement alternatives	Crash frequency	HSM Part D, CMF Clearinghouse
	Predicting future performance of a proposed facility based on different design attributes	Crash frequency	HSM Part C, IHSDM
Operational	Estimating the change in crashes as the result of implementing countermeasures	Crash Modification Factors (CMFs)	HSM Part D , CMF Clearinghouse
	Identify countermeasures to reduce crash frequency and severity	Crash frequency and severity	HSM Part B, SafetyAnalyst—Counter measure evaluation
	Assess the effect of existing roadway element such as on-street parking, shoulder, etc.	Crash frequency	HSM Part B, SafetyAnalyst
	Monitoring safety of an existing facility	Crash frequency	HSM Part B, SafetyAnalyst

Chapter 5
Data Collection

This chapter provides guidance on the data requirements, data resources, and data collection procedure. Data collection and quality assurance procedures are also described in this chapter.

5.1 Field Observations

Field observations (or field inspections) are requisite to obtain accurate traffic analysis results. The field observations enable the analyst to become familiar with the general traffic operating characteristics and the surrounding environment in the analysis area. Desktop review of data through aerial photographs, video logs or online street view applications should not replace physical field observations.

5.2 Required Data

The reliability of traffic analysis results depends on the accuracy and quality of data used. As such, a thought-out traffic data collection plan is necessary before collecting data. Data requirements and assumptions depend on the analysis type and level of analysis. For instance, generalized planning analysis requires less data (in term of both quantity and quality) compared to operational analysis which are performed at a higher degree of detail and accuracy. To minimize project costs existing data should be used as much as possible.

Data for a traffic analysis can be grouped as traffic operations and control, traffic characteristics, facility characteristics, and crash data as follows:

- Traffic Operations and Control
  - Speed (free flow speed, running speed, average speed, turning speed)
  - Posted speed limit
  - Driver behavior characteristics (e.g. aggressiveness, age) and their composition
  - Parking characteristics (on-street parking presence and type, bus stops)
  - Signing (static, dynamic or variable) and pavement markings
  - School zone
  - Signal phasing and timing plans
  - Detectors types and their location
  - Intersection control type
  - Arrival type
  - Right turn and left turn treatments
  - Railroad crossing location
  - Lane restriction for vehicles or time of day
  - Toll facility
  - Ramp metering
  - Other specialized equipment

- Traffic Characteristics
    - Demand (Annual Average Daily Traffic (AADT), hourly traffic volumes, K, D, T, spatial and temporal variation, turning movement counts (TMCs), origin-destination (O-D) matrices)
    - 95th percentile queue lengths
    - Capacity and/or saturation flow rate
    - Pedestrian counts
    - Bicycle counts
    - Transit stops (type, frequency/schedule, dwell time, trip length, bus blockage)
    - Fleet characteristics (trucks, passenger cars) and composition
    - Vehicle Occupancy
    - Major traffic generators
- Facility Characteristics
    - Roadway classification (functional class, rural/urban designation, access class, area type)
    - Cross section elements (number, width and purpose of lanes, shoulder type and width, median type and width, pavement type and rating condition, cross slope, sidewalk, bicycle lane)
    - Geometry (horizontal and vertical alignment, storage lengths, intersection/interchange configurations, auxiliary lanes)
    - Pedestrian and bicycle accommodation
    - Transit (location, position, proportions with shelters and benches)
    - Roadside (clear zone width, lateral clearance, driveway counts)
    - Access control
    - Access density
    - Signal density
    - Street lights
    - Sight distance
    - Aerial images
- Safety Data
    - Reported crash data—crash location, severity, crash type, and crash involvement
    - Facility data—physical characteristics of the crash site
    - Traffic Volume—AADT is the principal traffic data required. Other traffic data may include Average Daily Traffic (ADT) volume, vehicle-miles traveled (VMT), intersection total entering volume (TEV), pedestrian counts, and TMCs. If surrogate safety assessment is desired additional data such as speeds, traffic conflicts, number of lane changes can be collected.

Not all data listed above are input parameters of the traffic analysis tools. Some of the data are collected or analytically computed to evaluate the existing traffic problem or support justification for improvements utilizing other quantitative or qualitative approaches. For instance street light, clear zone, driveway density, pavement markings, sight distance, school zone, etc. are used to qualitatively analyze the safety of traffic operation on the roadway and are not input to the traffic analysis tools. Data needs for various traffic analysis tools are summarized in **Table 5.1.** Data needs for HSM depends on the performance measure being evaluated, see **Table 5.2**.

Table 5-1 Typical Input Data for Different Analysis Types

Input Data Category	**Traffic Analysis Tool**							
	GSVT	**LOSPLAN**	**HCM/ HCS**	**SIDRA**	**Synchro/ SimTraffic**	**CORSIM**	**VISSIM**	**HSM[1]**
Traffic Operations and Control Characteristics								
Speed			x	x	x	x	x	
Speed Limit	x	x	x	x	x	x	x	
Driver Behavior						x	x	
Parking			x	x	x		x	
Signs				x		x	x	
Signals		x	x	x	x	x	x	
Detectors			x		x	x	x	
Intersection control type	x	x	x	x	x	x	x	x
Right/left turn treatment	x		x	x	x	x	x	x
Railroad Crossing					x		x	x
Lane Restriction						x	x	
Toll Facility						x	x	
Ramp Metering						x	x	
Traffic Characteristics								
Demand	x	x	x	x	x	x	x	x
Queue				x	x	x	x	
Capacity/ Saturation Flow					x	x	x	
Pedestrian Counts			x	x	x		x	x
Bicycle counts			x	x			x	x
Bus & Transit			x		x		x	
Fleet Characteristics			x	x	x	x	x	
Occupancy						x	x	
Major traffic generators						x	x	
Roadway Characteristics								
Road Classification	x	x	x	x	x	x	x	x
Cross Section	x	x	x	x	x	x	x	x
Geometry	x	x	x	x	x	x	x	x
Roadside			x				x	x
Access Control	x	x	x			x	x	x
Access Density			x			x	x	
Parking				x	x		x	
Aerial images			x		x	x	x	

An "x" indicates a data category is used as an input to the analysis tool. A blank cell indicates the corresponding data is not needed

[1] Data needs for HSM are shown in **Table 5.2**.

In addition to input data, microsimulation tools would require calibration and validation data to be collected or analytically determined. This data include capacity, saturation flow rate, speed, travel time, bottleneck detail, delay and queues.

Table 5-2 Summary of Data Needs for Commonly Used Safety Performance Measures

Performance Measure	Safety Data			
	Crash	Facility	Traffic Volume	Calibration
Crash Frequency	x	x		
Crash Rate	x	x	x	
Crash Severity	x	x		
Level of Service of Safety (LOSS)	x	x	x	x

An "x" indicates data is used as an input

5.3 Input Parameters Default Values

It is recommended to field-measure input parameters. However, there are circumstances which permit use of default values for input parameters. For instance, default values are mostly used in planning level analyses in which case data is not readily available or cannot be field-measured because future geometric and operational characteristics of the proposed facilities are unknown. Additionally, default values may be used when past experience and research have shown such input parameters have negligible effect on the outcome of the results.

Contrary to planning level analysis, design and operational analyses are more detailed and thus require use of accurate field-measured data. In some instances, design and operational analyses utilize locally adapted default values when field data are yet to be collected. Appropriate default values for various applications of analytical analysis are presented in the 2013 Quality/Level of Service Handbook[9]. HCM default values may be used when typical local values are not available. Guidance on default values for microsimulation applications is presented in **Chapter 7**.

5.4 Data Collection Plan

After the traffic analysis methodology is known, a data collection plan should be prepared and agreed upon with the reviewing entity. The data collection plan is prepared to document data needs for the traffic analysis and the procedures for collecting the data. Also included in the data collection plan are data reduction procedures and quality assurance protocols that the analyst will follow to ensure both correctness and completeness of the data collected.

5.4.1 Data collection Checklist

Prior to developing the data collection plan, the analyst should understand what to collect, when to collect, how long to collect, where to collect, and how to manage the data. Additional questions that the analyst should answer include:

- What is the level of analysis?
- Can the use of published default values fulfill the objectives of analysis?

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[9] 2013 Quality/Level of Service Handbook. Florida Department of Transportation (FDOT), 2013

- What type of traffic data is available?
- How old is the existing data? What format?
- What is the traffic analysis procedure (tool and approach)?
- What performance measures will be evaluated?
- What degree of accuracy (confidence level) of the results is required?
- What are the project alternatives to be analyzed? Will the alternatives require additional data?
- Is the existing data sufficient enough to support the project objectives?
- Does the data (to be collected) adequately support the objectives?
- Are there any data collection assumptions?

5.4.2 Data Collection Resources

The data collection plan should be developed dependent on the project specific needs and existing data collection guidelines. These guidelines include:

- FDOT's Manual on Uniform Traffic Studies (MUTS)
- Highway Capacity Manual 2010, TRB, 2010, 1200 pp., ISBN 0309160773.
- Manual of Transportation Engineering Studies, H. Douglas Robertson, Joseph E. Hummer, and Donna C. Nelson, Institute of Transportation Engineers, Washington, DC, 1994, ISBN 0130975699
- Introduction to Traffic Engineering: A Manual for Data Collection and Analysis, T.R. Currin, 2013, ISBN-13: 978-1111878619

5.4.3 Estimation of Sample Size

The sample sizes of different data to be collected are derived from the desired levels of accuracy related to the objective of the study. The minimum sample size, n is estimated as:

$$n = (sk/e)^2$$

Where s is the sample standard deviation, k = the constant corresponding to the desired confidence level, and e is an allowable error or desired accuracy.

Since sample standard deviation is unknown before data is collected, the analyst should make an engineering guess based on past experience or previous data collected on similar locations.

A 95% confidence level is typical; however, the analyst may choose higher or lower levels of confidence depending on the purpose of the project. Use of different confidence levels requires project manager approval. It is important to note that higher levels of confidence would require a large sample size. If a large sample size (greater than 30) is desired, a standard z-score is used otherwise Student's t-score is used. Z-scores and t-scores tables are published in most statistics books.

A 5 – 10% error is desired. Allowable or acceptable error can also be expressed as a desired half-width of the confidence interval.

5.4.4 Data Collection Plan Format

At minimum, the format of data collection plan consists of the following elements:

- Objectives of the analysis.
- Data required to meet objectives and performance measures used for evaluation.
- Desired level of accuracy of the data dependent on the level of analysis.
- Collection method and data sources.
- Data storage.
- Schedule and resources requirements.
- Budget.

5.5 Existing Data Sources

Existing data should be used as much as possible to streamline the project and minimize the cost of the project. As such, existing data resources should be explored before new data is planned to be collected from the field. The following is the list of data resources that the analyst should explore:

- Florida Traffic Online (FTO)[10] which is a web-based mapping application that provides current and historical traffic count data. This data is also published in the Florida Transportation Information (FTI) DVD.
- FDOT TRANSTAT Roadway Characteristics Inventory (RCI) which is a database of roadway descriptive characteristics within Florida.
- FDOT TRANSTAT IView which provides access to FDOT's evolving store of ArcSDE-based raster data layers.
- Straight-Line Diagrams (SLD) which are graphical linear representation of selected RCI data reported for individual roadways.
- Florida Geographic Data Library (FGDL)[11] which is an online portal for distributing spatial data throughout the state of Florida.

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[10] http://www2.dot.state.fl.us/FloridaTrafficOnline/viewer.html

[11] http://fgdl.org

- Florida Aerial Photography Archive Collection (APAC) which is the Florida's largest collection or inventory of aerial photography.
- Traffic counts from local agency databases.
- Regional Integrated Transportation Information System (RITIS)[12] which is an automated real time and archiving system for sharing among the various transportation data and performance measures.
- State and local governments' crash databases.

Even when existing data is deemed sufficient to meet the analysis objective, field observations should be conducted to verify and confirm key traffic and roadway data (such as roadway geometric, traffic control, driver behavior) that would impact traffic operating characteristics in the analysis location. The findings from site observations should be documented and included in the existing conditions report or analysis report, as appropriate.

It is normally difficult to measure the true traffic demand when oversaturated traffic conditions exist because automatic data recorders do not account for demand caused by queuing. Under these conditions, the demand should be estimated, based on the FDOT's 200th Highest Hour Traffic Count Reports using data for unconstrained sites with similar roadway and geometric characteristics. The 200th Highest Hour reports are published in the Florida Traffic Online (FTO). Alternatively, counting arrival volume upstream of the bottleneck would help to capture the true demand.

5.6 Data Collection Schedule

Once the data collection technique is determined and analysis approach has been determined, the data collection schedule should be developed and integrated into the scope of the project. The data collection schedule may show the resources (manpower and equipment), and time required for completing data collection effort. To ensure the quality of data collected and the process as the whole, the data collection personnel should have sufficient experience to collect data. When a new collection technique or technology is proposed, a pilot data collection may be conducted before the actual data collection starts so as to understand the accuracy of the data collected by the new technology.

A field inspection is compulsory in any traffic analysis to confirm existing characteristics

When TMCs and daily traffic counts are to be collected, they should be scheduled to occur simultaneously so that the turning counts can be used to validate the daily counts. It is important to note that the standard traffic counts collected should be 48-72 hour bi-directional volume counts for all approaches of an intersection.

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[12] https://www.ritis.org/

When microsimulation approach is proposed, the data collection schedule should include additional field reviews during model calibration process to re-review traffic operating characteristics and compare with model outputs. Alternatively, the analyst may videotape the analysis area as vehicle behavior data is needed to visually verify the simulation models.

5.7 Data Reduction

Data reduction is the process of organizing collected data in a form that can be used in the analysis. Data reduction is used to descriptively examine data by summarizing in simplest form. Data reduction process is also used as a statistical quality control check for the integrity of the data. In which case statistics such as minimum, maximum, average and variance are used to check the integrity of the data. Any data adjustments or process of removing bad data (data *smoothing*) should follow the concept of truth-in-data principle[13] and have to be documented. Truth-in-data principle provides a means of addressing if and how missing or questionable data are modified as part of data acceptance and use.

> Data *smoothing* if performed should consider the concept of truth-in-data principle

In the data reduction process, lane schematics of the network are prepared to detail roadway geometrics, traffic volumes, and traffic control. When simulation approaches are proposed, the lane schematics are used to create link-node diagrams to aid the analyst in building the network model.

Guidelines and methodology for estimating intersection turning movement volumes and techniques for balancing the volumes are presented in the FDOT Project Traffic Forecasting Handbook.

5.8 Calibration and Validation Data

Usually, calibration and validation data is required only when a microsimulation approach is used. In this case, the scope of the data collection has to include calibration (and validation) data. The importance of the accuracy of traffic counts and other field measured data for model calibration and validation emphasizes the need for careful planning and diligence of a data collection plan. It is strongly recommended that calibration and validation data be collected simultaneously with demand data to maintain consistency with the simulation demand inputs. This would help to compare field-measurements and simulation output and eventually streamline the calibration process.

> Calibration data must be collected simultaneously with demand data

The following data may be collected to calibrate and validate the simulation model with real world conditions.

- Travel speeds
- Travel times and delay
- Queue lengths

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[13] FDOT Project Traffic Forecasting Handbook; ASTM E2759 - 10 Standard Practice for Highway Traffic Monitoring Truth-in-Data

- Saturation flow rate or capacity
- O-D data
- Weaving and lane changing observations

5.9 Quality Assurance

Data collection plans must emphasize on the quality of data since use of good data can lead to good analysis results and poor data yields bad results. Regardless of the tool used, the outputs from the traffic analysis will be no better than the accuracy of the data used in the analysis. One general rule of obtaining good data is to incorporate and follow quality control protocols throughout the data collection process. Thus, checking data collected for completeness, accuracy and reasonableness is strongly recommended. It is prudent to verify the reliability of the data collected by examining their trends and descriptive statistics. These statistics such as mean and standard deviation are useful in assessing the accuracy and precision of the measurements. Trend analysis would help to determine variation of data in time and space domain.

> The accuracy of the traffic analysis results is no better than the accuracy of the data used in the analysis

Moreover, all data collected should be properly handled by documenting data attributes such as source, collection time and condition, and any other information that might have affected the data collection process. To streamline the process, the analyst should use adequate data management strategies which is understandable by the data collection personnel.

A good practice is to use a second analyst who was not involved in collecting data to check the reasonableness of the data. Verification should include checking that weather, incidents or construction did not influence the data collected. Checking variation of the data (in both space and time), data discrepancy or missing data to determine any abnormalities or outliers (based on historical data, local knowledge or experience) and determining their probable causes is necessary to understand the accuracy of the data collected.

Additionally, maximum traffic count should be compared with the capacity of the facility and travel time data should be compared with the operating speeds at the time of data collection. A difference of more than 10% should necessitate a second look at the calculations and field measurements to determine the cause of the discrepancy.

When an error found in the data collected is caused by equipment malfunction or human error, the data should be recollected.

Quality assurance of the data collection also includes checking and verifying hourly traffic volumes are balanced within the analysis boundary limit. Traffic counts will have to be checked by starting at the beginning or perimeter of the system and adding or subtracting entering and exiting traffic, respectively. When volume imbalances are detected, the cause of such discrepancies should be determined, reconciled and documented in the data collection summary or narrative. A 10%

difference between upstream and downstream counts for location with no known traffic sources or sinks (such as driveways or parking garage) is considered acceptable[14].

When microsimulation approaches are proposed the analyst has to collect the data that is as precise as possible. Small errors in input data used in the microsimulation could lead to amplification errors which create large errors in the simulation results that cannot be calibrated. Such errors have a tremendous negative effect on the performance of the simulation model. As such, the quality assurance reviewer should verify that data used for model calibration and validation is not only correct but also was collected or measured at the same time and location as the data that was used to code the model.

Small error in input data could have tremendous impact on the simulation model performance

5.10 Data Collection Summary

A data collection summary should be provided to document the various data needs, collection methods, collection strategies, data storage, descriptive summaries, and quality assurance procedure. The summary should contain a narrative of the existing conditions as supported by the field observations. This summary is typically included in the existing conditions report or final traffic analysis report. When traffic microsimulation tools are used, the summary should include calibration data. Most of the individual vehicle data details are attached as appendices and omitted in the summary to increase clarity. Data collection managers and traffic analysis reviewers commonly use data summaries for quality control therefore the data collection summary has to be presented in a manner that is easy to comprehend.

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[14] FHWA Traffic Analysis Toolbox, Volume III

Chapter 6
Traffic Analysis using Analytical Tools

This chapter provides additional guidance on analytical tools that are used to perform traffic analysis. Users of this handbook are advised to consult each specific tool's User Guides and Manuals for details of the analytical procedures.

6.1 HCM and HCS

When the context of the project does not justify the use of microscopic traffic simulations, analytical (deterministic) tools should be used. Guidance on how to conduct analytical analysis is provided in the HCM and its accompanied software HCS. Despite its strength to analyze quality of service on transportation facilities from sketch-level planning to high-level operational evaluations, HCM procedures have limitations of analyzing oversaturated conditions and time-varying demand. Methodology limitations for each system element analysis are further identified and discussed throughout Volumes 2 and 3 of the HCM.

The HCM methodologies contain default values which represent nationally accepted values. Since typical conditions within the state of Florida may be different from national values, the analyst may be required to change some of the default parameters to Florida based values. When HCM default values or assumptions are changed, justification for such should be documented.

Irrespective of the tool used in preliminary engineering, design or operational analyses, input parameters that represent basic segment, intersection geometry, and demand flow rates should always be measured in the field or drawn from the best available evidence. The analyst should refrain from using "rules of thumb estimates" to obtain the values of these parameters because such methods usually produce incorrect estimates of the performance measures.

Special considerations should be given to the following parameters:

- *Peak Hour Factor (PHF)*
  HCM methodologies use demand flow rates for the 15 minutes peak period. If flow rates have been measured from the field the flow rates for the worst 15 minutes should be used in operational analyses. PHF is used to calculate the equivalent hourly flow rate.

  When the 15-minute forecast demands are not available, conceptual planning and preliminary engineering levels of analyses may use a PHF of 1.0. However, it is advantageous to use lower PHF values consistent with field observations at locations that may experience capacity problems.

  Approval entity must concur with the PHF values prior to their use in the analysis

  In absence of field measurements of the PHF, design analyses may use a default PHF of 0.95 on freeway facilities and urban arterials. A PHF value of 0.92 may be used on other facilities; however, data shows that PHF increases as demand volume increases. Lower PHF signifies greater variability of flow while higher PHF signifies less flow variation within the analysis hour. Rural areas tend to have slightly lower PHF values than urban areas. Thus, PHF higher than 0.95 may be used on urban areas if justified by traffic conditions. It is recommended that the analyst sought concurrence with the reviewing and approving entity (of the analysis) results prior to using default PHF values in the analysis.

PHF is not needed in multiple analysis periods where 15-minute traffic demand measurements are directly used. This approach tends to accounts for residual queues from one 15-minute period to another.

- *Standard K Factors*
  Regardless of the level of analysis, FDOT Standard K factors should be used. These factors are categorized based on area type, facility type and facility peaking characteristics. However, standard K factors are not directly applicable for the design analyses for the Turnpike facilities, other toll roads, and managed lanes[15].

- *Free Flow Speed (FFS)*
  Free flow speed is field-measured under low volume conditions, when drivers are not constrained by other vehicles, roadway geometry or traffic control. In absence of field data, FFS can be estimated at five (5) mph above the posted speed limit.

- *Saturation Flow Rates and Capacities*
  The maximum generally acceptable volumes published in the Quality/Level of Service Handbook may be used to override the HCM saturation flow rates as HCM values were developed based on national research while Quality/ Level of Service Handbook values are Florida specific. Coordination with the reviewing entity or lead agency is required before overriding these values.

- *Signalized Intersection Parameters*
  It is recommended to obtain input values for intersection signals parameters (such as signal control type, sequence of operation, and controller settings) from the agencies that maintain the signals. However, planning analyses may use the 2010 HCM quick estimation methodology published in Chapter 31 (Volume 4) to estimate a reasonable signal timing plan. For arterial street analysis, each intersection is individually analyzed before their inputs are imported into the module that analyzes streets.

- *Level of Service*
  LOS is an input for high-level planning analyses to determine number of lanes for a new road facility.

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[15] FDOT Project Traffic Forecasting Handbook

6.2 Generalized Service Volumes Tables (GSVT) and LOSPLAN

GSVT and LOSPLAN are intended for generalized and conceptual planning purposes only. Generalized planning is most appropriate when a quick review of capacity of a facility is needed to identify initial problem and needs analyses. Conceptual planning analyses are performed to support decisions related to developing design concept and scope, preliminary evaluation of alternatives, assessing development impacts, and determining project needs. Conceptual planning is more detailed than generalized planning, however does not involve extensive or detailed operational analysis.

GSVT are intended to provide an estimate of the LOS of an existing facility or provide quick estimation of the number of lanes of a proposed facility. This tool should not be used for evaluating or developing detailed improvement plans or operational analysis.

LOSPLAN differs from HCS in terms of extensive use of Florida specific default values and simplifying assumptions to the HCM operational methodologies. Users of this handbook should review the 2013 Quality/Level of Service Handbook for more guidance on planning level assumptions used for vehicle turning movements, queue spillback, capacity, bus operation, and other transportation characteristics. Major features of the three software programs contained in the LOSPLAN are discussed in the 2013 Quality/Level of Service Handbook. LOSPLAN should not be used to perform a full operational or design analysis of transportation facilities.

6.3 SIDRA INTERSECTION

SIDRA INTERSECTION's Standard Right and HCM 2010 models can be used to analyze various roundabout geometries such as raindrop design, strip islands (between lanes), wide splitter island, slip/bypass lane, and roundabouts with more than 2 lanes.

Special considerations should be given to the following parameters:

- *HCM LOS and Geometric Delay*
  Geometric delay is the delay caused by vehicles slowing down when entering, negotiating and exiting the roundabout. This delay is very important when comparing operations of different intersection alternatives. HCM roundabout LOS does not consider geometric delay, rather it calculates delay solely based on unsignalized intersection control delay.

- *Practical Degree of Saturation (DOS)*
  Practical degree of saturation (DOS) is the maximum volume to capacity (v/c) ratio or degree of saturation that corresponds to an acceptable level of performance. It is one of the two MOEs of a roundabout analysis. The second MOE is the LOS based on delay. A DOS of 0.85 is desired for roundabouts without metered signals. For DOS above 0.85, the analyst is encouraged to perform sensitivity analysis to determine the influence of volume on roundabout delay and queues.

- *Environmental Factor*
  Since research conducted in the United States (e.g. NCHRP Report 572[16] and NCHRP Report 672[17]) found lower capacity values at United States roundabouts compared with European and Australian ones, a default Environmental Factor of 1.2 is suggested.

- *Number of Circulatory Lanes*
  The number of lanes in the circulatory roadway should provide lane continuity through the roundabout. The number of lanes is a function of the sum of the entering and conflict volumes. Maximum number of circulatory lanes should be two (2).

- *Pedestrians*
  In absence of existing count data taken within a 60-minute interval, default pedestrians count per hour of 400 and 50 should be used for projects located in the central business district (CBD) and other areas, respectively.

- *Extra Bunching*
  This parameter is used to model the effect of platoon arrivals from the upstream signals on the capacity of roundabouts. Platooned arrivals are not important at roundabouts that are spaced at least a half-mile from a signalized intersection. Values for Extra Bunching are provided in the SIDRA INTERSECTION User's Manual as summarized in **Table 6.1**.

Table 6-1 Extra Bunching Values

Distance from Upstream Signal (ft)	Extra Bunching (%)
<350	25
350 – 700	20
700 – 1300	15
1300 – 200	10
200 – 2600	5
>2600	0

6.4 Synchro and SimTraffic

Synchro is used to analyze traffic on urban streets where adjacent signalized intersections influence each other and signal optimization or simulation may be required. Synchro is also used for operational analysis projects which include signal re-timing, corridor operational assessments, and capacity analysis of individual intersections (signalized, unsignalized, or roundabout). The recent version of Synchro (version 8) has a capability of performing traffic

> Reporting Synchro outputs in an HCM format is strongly recommended.

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[16] http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_572.pdf
[17] http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_672.pdf

analysis and producing reports based on both 2000 and 2010 HCM methodologies. It is strongly recommended that the analyst reports the analysis results from Synchro using HCM format except when reporting signal optimization results where Synchro output can be used.

Since optimization of intersection signal timings is performed to attain one or more objectives. The objectives must be quantifiable and tied with the intersection or street network MOEs.

Synchro does not have capability to analyze freeways, multilane highways, and two-lane rural roads. For freeway analyses that include evaluation of crossing arterials and local roads, Synchro is used to develop optimized signal timing plans which are then used as input to the freeway analysis tools such as HCS, CORSIM or VISSIM.

The analyst should be aware that Synchro does not accurately model oversaturated traffic conditions. Under such conditions, SimTraffic or other microsimulation tools can be used. Like Synchro, SimTraffic does not have capability to simulate freeway corridors including ramp junctions, weaving areas and traffic management strategies such as managed lanes and ramp metering.

A SimTraffic model is created by importing a Synchro model. Therefore, any Synchro coding error or warning should be reviewed and corrected before initiating SimTraffic.

Multiple simulation runs are performed with different random number seeds. SimTraffic automatically combines performance MOEs from multiple runs.

6.4.1 Inputs for Synchro/ SimTraffic

Basic inputs for Synchro are identified in **Table 5.1** in **Chapter 5**. To obtain reasonable results, the analyst should use existing (or field-measured) data as much as possible. The following specific input guidelines should be followed when preparing Synchro traffic models:

- *Nodes*
  Numbering of nodes in logical order along the main street is recommended to enhance the review of the results.

- *Traffic Demand*
  Hourly volumes should be used. Volumes and heavy vehicle percentages should be calculated based on the existing turning movement counts data. In absence of counts data, guidelines provided in the HCM-based Tools should be used.

- *Lane Utilization Factor*
  This parameter only affects Synchro's saturation flow rate, it is not used by SimTraffic. Default lane utilization factors should be overridden with field measurements when more vehicles use one lane group than the other. Additionally, as demand approaches capacity, lane utilization factors that are closer to 1.0 may be used to override default values.

- *PHF*
  The Synchro default PHF is 0.92. PHF guidelines are provided in **Section 6.1**.

- *Signal Timing*
  Signal timing plans including offsets, cycle lengths, interconnection, and phasing plan should be obtained from the district traffic operations offices or local agencies maintaining the signals. For future analyses that require signal retiming, timing data should be calculated based on the Manual on Uniform Traffic Control Devices (MUTCD)[18] requirements and the guidelines published in the FDOT Traffic Engineering Manual (TEM)[19].

- *Bends and short links*
  When coding the street network, excessive bends and short links should be avoided as they impair performance of the SimTraffic model or CORSIM model when built from Synchro. It's recommended to use curved links as much as possible instead of bend nodes.

- *Intersection and street geometry*
  These parameters include number of lanes, turn lanes, storage lengths, and grade. Data for existing analysis should be obtained from field measurements or as-built (record) drawings. Future analyses should be based on proposed design plans. In absence of field measurements or design plans, the analyst should consult HCM 2010, FDOT Plans Preparation Manual (PPM)[20], FDOT Design Standards[21], Florida Intersection Design Guide[22], or FDOT TEM for selection of standards and other project parameters that are specific for a project and would require deviations from the standards. The analyst is required to document justification for any deviations from the standards that will help development of design exception/variation process.

- *Link Speeds*
  Link speeds coded in the Synchro network should match the posted speed limit or actual operating speed of the roadway.

6.4.2 Calibration of Synchro and SimTraffic

The following guidelines are provided for Synchro model:

- Lost time adjustment factor should be adjusted to replicate field observed queue lengths.

- In order to calculate reasonable queuing in the model, all link terminals should extend at least 1000 feet from the last node.

- 95th percentile queue lengths that are tagged with "#" or "m" should be examined for the extent of queuing problems.

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[18] http://mutcd.fhwa.dot.gov/
[19] http://www.dot.state.fl.us/trafficoperations/operations/Studies/TEM/TEM.shtm
[20] http://www.dot.state.fl.us/rddesign/ppmmanual/ppm.shtm
[21] http://www.dot.state.fl.us/rddesign/designstandards/standards.shtm
[22] http://www.dot.state.fl.us/rddesign/FIDG-Manual/FIDG.shtm

SimTraffic simulation model requires calibration to simulate the existing traffic operating conditions. Before adjusting SimTraffic calibration parameters, it is advised that the analyst verify the Synchro input parameters such as lane assignments, demand, the PHF are coded correctly.

At minimum, simulation MOEs should include vehicles exited, 95th percentile queues, and travel times/ speeds. The analyst should verify the number of vehicles exiting the intersection is within 5% of the input volumes. Calibration target for queues, speeds and travel time should follow the guidance outlined in **Chapter 7**.

SimTraffic calibration parameters are:

- Headway factor
- Speeds within the intersections
- Driver reaction time.
- Lane usage

Headway factor adjusts headways on a per movement basis. It is used to calibrate the saturation flow rates. When calibrating saturation flow rates, the link turning speeds should be coded as realistically as possible.

SimTraffic model can be calibrated to realistically simulate existing conditions

Simulating turning speed is adjusted by driver speed factor.

Driver reaction time can be field calibrated by observing the level of aggressiveness of the drivers as they cross the intersection—a typical urban core area driver is more aggressive than a rural area driver.

Lane usage or lane choice in SimTraffic is controlled by Positioning/Mandatory Distance parameters. Prior to changing these parameter, it is advised the analyst should review the simulation for any unbalanced lane utilizations or unbalanced queue and compare with the existing conditions to determine the cause of the problem.

Additional calibration guidance that is provided by Trafficware, developers of Synchro and SimTraffic, is summarized in **Table 6.2**. **Table 6.2** contains common traffic flow issues that are related to calibration and suggested order of preference to assist users with the selection of the most appropriate parameters to adjust. 1, 2, 3 is the order of adjustment preference.

Table 6-2 Guidance for Calibrating SimTraffic Model[23]

Traffic Flow Issues in the Model	SimTraffic Calibration Parameters								
	Link-Based Parameters (Synchro Simulation Settings)				Global Parameters - Model (SimTraffic Drivers and Internal Settings)				
	Lane Alignment	Mand. & Pos. Dis.	Turning Speed	Headway Factor	Speed Factor (%) Alignment	Headway @ 1, 20, 50, & 8-mph	Gap Accpt.	Mand. & Pos. Dist Adjust (%)	PHF Adjust & Anti PHF Adjust
Vehicles too slow when making a left or right turn			1						
Queuing seems too short/long (assuming no upstream bottle-necks)	1						2		3
Travel time seems too low/high					1				
Lanes not utilized properly - unbalanced queues		1						2	
Volume simulated too low			1	2		3			

Mand. & Pos. Dist. = Mandatory and Positioning Distance
Gap Accpt. = Gap Acceptance

6.5 Safety Analysis Tools

Traditionally, safety analysts have identified hazardous locations and other safety concerns on an analysis area based on past crash history. The identification has largely relied on crash data reviews from historical crash records for a study period. In this approach, a comparison of crash statistics from the analysis area with statistics from other similar locations or statewide averages is conducted to assess the magnitude of the existing safety problem.

Since crashes are random events, study period for safety analyses is often three to five years to reduce the effect of random errors that may result over a short period.

Descriptive crash statistics such as crash frequency (total crash) and crash rate are used to summarize crash pattern by location, crash type, severity level, or operating characteristics. Graphical tools, cluster analysis and Chi-square analysis have been used to determine inferences from crash patterns. Crashes are also categorized by type and severity level.

When analyzing crash history from a crash database, the analyst should fully understand how the crashes were recorded. This is essential to determine the true reference location of the crash with respect to the area being analyzed. To better understand how the crash occurred, the analyst may request and review actual crash reports.

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[23] Trafficware, Calibration Guide, Synchro Snippets, Volume 4, July 2013

Crash analysis is reactive as it waits for a crash to occur before corrective measures are applied

Safety analysis based on crash history is deemed to be reactive as it waits for the crashes to occur before any corrective measures are applied. As such, there has been a paradigm shift toward proactive approaches to traffic safety whereby safety is analyzed as early as in the planning phase of the project development. The proactive approaches use both qualitative and quantitative evaluations dependent on data availability.

6.5.1 Qualitative Procedures

Qualitative safety evaluation is performed to identify any safety concerns and their corresponding corrective measures during planning and preliminary engineering phases where enough data is not readily available or details of the projects are very broad. In this evaluation, the analyst should review variation in the facility elements with respect to the three crash contributing factors—human, vehicle, and environment/context. Qualitative evaluation methods may include surrogate safety assessments and Road Safety Audits (RSA).

RSA reduces costs by proactively identifying safety issues and correcting them before the roadway is built

RSA entails a qualitative assessment of the performance of an existing or proposed corridor or intersection by an independent, multi-disciplinary audit team of experts to identify safety issues and their countermeasures. Experience from elsewhere has shown that RSA is both effective and cost beneficial as a proactive safety improvement tool. One of the benefits of RSA is to reduce costs by proactively identifying safety issues and correcting them before the roadway is built.

Surrogate safety assessments involve examining proxy measures of crashes. These measures are precursors of roadway crash events. The proxy measures include, but not are limited to traffic conflicts, speed variation, lane changing, longer queue, and roadway curvature. The surrogate safety assessments are useful when crash data is not available because the roadway is yet to be built or the roadway has unique features. They can be performed through field observations or reviews of the outputs of the traffic operational analysis tools. Safety and traffic engineering expertise is required to assess surrogate safety measures. Surrogate safety assessments can be performed independently or included in the RSA. The limitation of surrogate safety assessments is that its outcome does not predict actual crashes but rather the likelihood of the crash occurrence.

Regardless of the method of qualitative assessment, the analyst should understand that majority of the crashes are caused by driver error. Therefore in any proposed improvements, human factors issues and driver behavior should be reviewed for any fatal flaws in information deficiencies, driver's expectancy or driver's workload that would lead to degradation of safety levels.

6.5.2 Quantitative Procedures

Quantitative safety analysis should be used whenever possible as it yields performance measures that are quantifiable and would lead into impartial decisions.

Quantitative safety evaluation uses the roadway safety management process, predictive methods or CMFs that are documented in the HSM. The HSM methods use statistical models that are superior to traditional approaches because they account for the effect of the regression to the mean and selection bias in evaluation of the countermeasures. Reliability of the HSM is improved when site specific historical crash data is incorporated in the model estimation. Since HSM safety SPFs were developed utilizing national research, calibration of the SPF to reflect the local conditions is essential. Calibration factors for roadways with fewer crashes than the roadways used in the development of SPFs will have values less than 1.0. Additionally, the analyst can replace the default values such as collision type distribution with locally derived values to improve crash prediction.

Assumptions that were used to estimate safety performance measures should be documented

As with any traffic analysis, professional judgment is required when the analyst applies HSM procedures and methodologies, particularly CMFs, to the analysis area. This is essential because certain CMFs used in the analysis of existing conditions and proposed improvements may not be compatible. As such, it is prudent to document all assumptions that were used when estimating safety performance measures of any project.

6.6 Quality Control

It is prudent to check the results obtained from deterministic and other analytical tools. The reasonableness of the results should be checked by an independent reviewer who has sufficient experience in performing traffic analyses. Such checks are performed to confirm the results reasonably represents the performance of the system and meet the objectives of the analysis. The independent reviewer should specifically:

- Verify number of lanes, lane usage, lane alignment, turn lane restriction, traffic demand, traffic control data are correct.
- Verify values of default parameters are reasonable.
- Results are reasonable estimates of the analyzed conditions.

Chapter 7
Microsimulation Analysis

Microsimulation analysis involves application of computer models to stochastically replicate traffic flow on the transportation facility. Microsimulation traffic models use input information (e.g. traffic volume, facility type, vehicle-driver characteristics) to move traffic using simple acceleration, gap acceptance, and lane change rules on a split second (time step) basis. Microsimulation models cannot optimize traffic signals but rather have strong ability to examine complex congested traffic conditions in urban areas. Typical outputs of the microsimulation model are given per individual vehicle in form of text reports and visual animations.

The analyst must refer to microsimulation software user guides and training manuals for modeling fundamentals

This chapter provides guidance to the traffic microsimulation analysis by highlighting key steps to be followed when performing microsimulation analysis. Emphasis is given to the base model inputs, quality control checks and calibration process. The guidelines contained in this chapter are intended for CORSIM and VISSIM models. This guidance is not applicable to multimodal alternative analysis studies. Guidance for SimTraffic simulation is provided along with Synchro guidance in **Chapter 6** because SimTraffic takes direct input from Synchro network. The modeling process given in this chapter references the information contained in the following publications:

- Traffic Analysis Toolbox Volumes III[24] and IV[25] prepared by FHWA
- Advanced CORSIM Training Manual prepared by Minnesota Department of Transportation[26]
- Protocol for VISSIM Simulation prepared by Oregon Department of Transportation[27]
- Microscopic Simulation Model Calibration and Validation Handbook prepared by Virginia Transportation Research Council[28]

7.1 Microsimulation Modeling Steps

Generally the following steps are followed in the development of traffic microsimulation models:

1. Establishment of project purpose and need, analysis limits and modeling approach
2. Data collection
3. Base model development
4. Model verification or error checking
5. Model calibration and validation
6. Alternatives analysis

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[24] http://ops.fhwa.dot.gov/trafficanalysistools/tat_vol4/index.htm
[25] http://ops.fhwa.dot.gov/trafficanalysistools/tat_vol3/index.htm
[26] http://www.dot.state.mn.us/trafficeng/modeling/training.html
[27] http://www.oregon.gov/ODOT/TD/TP/APM/AddC.pdf
[28] http://www.virginiadot.org/vtrc/main/online_reports/pdf/07-cr6.pdf

7. Model documentation and presentation of results

Steps 1 and 2 are covered in chapters 2 through 5. Steps 3, 4 and 5 are covered in this chapter. Steps 6 and 7 are covered in chapters 8 and 9, respectively.

7.2 Base Model Development

A base-year model (base model) is a simulation model of the existing (or current) conditions which serves as a footprint from which other project modeling alternatives are built. Development of an accurate and verifiable base model is essential to simulate the existing traffic characteristics.

Before starting to code the base model the analyst may review previous microsimulation projects within the region. The review would help the analyst to understand modelling issues and calibration parameters, and the performance of the model against post deployment estimation, if any.

To increase modeling efficiency, the base model for one analysis period should be fully developed, calibrated and functional before being copied to create other analysis period scenarios. Calibration parameters in the base model are carried forward in all subsequent models. Base model development guidelines for CORSIM and VISSIM are provided in this section.

> The model for one analysis period should be fully developed, calibrated and functional before creating another analysis period model

7.2.1 CORSIM Modeling Guidelines

A step-by-step procedure to develop a CORSIM model is presented in the Traffic Analysis Toolbox Volume IV. Key issues and specific input requirements are only highlighted in the following subsections.

Coding

When coding a CORSIM model, the analyst should adhere to the following general guides:

- Use base map (orthorectified aerial image and CADD drawing) to create link-node diagram. A simulation model built from a base map with the real world coordinate system would be easily transferable from one phase of the project to another or easily merged to another project. Thus, developing a link-node diagram using real-world coordinates is recommended. Lane schematics should also be prepared using CADD, Microsoft Excel or any other graphic design program. Examples of a link-node diagram and lane schematics are shown in **Figure 7.1** and **Figure 7.2**, respectively.
- Use different sets of numbers of nodes to represent different areas of the network. For example, use 1000s for a freeway and 100s for the arterial segments. The node numbering scheme depicted in **Table 7-1**, which is adapted from the FHWA Traffic Analysis Toolbox Volume III, is recommended. A standardized node numbering scheme can assure the quality of the model by reducing modeling mistakes. Additionally, use of the standardized numbering system would not only simplify the model review process but also minimize efforts that would be required to reuse the model with a different design or operational condition

- The node numbering begins upstream of the facility and increases sequentially to the end of the facility. The node numbering should include gaps between nodes to accommodate future or revised access points.

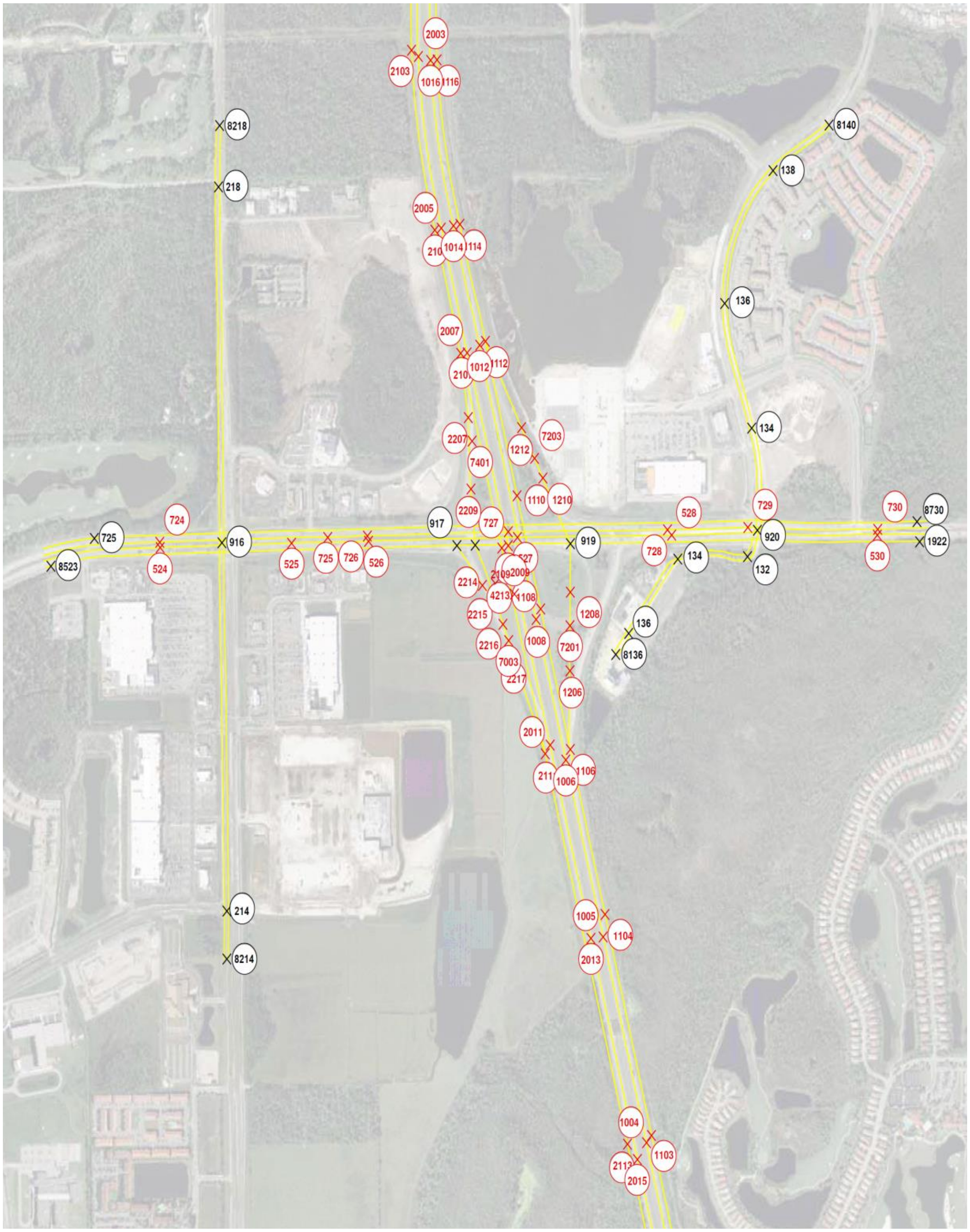

Figure 7-1 Link-Node Diagram

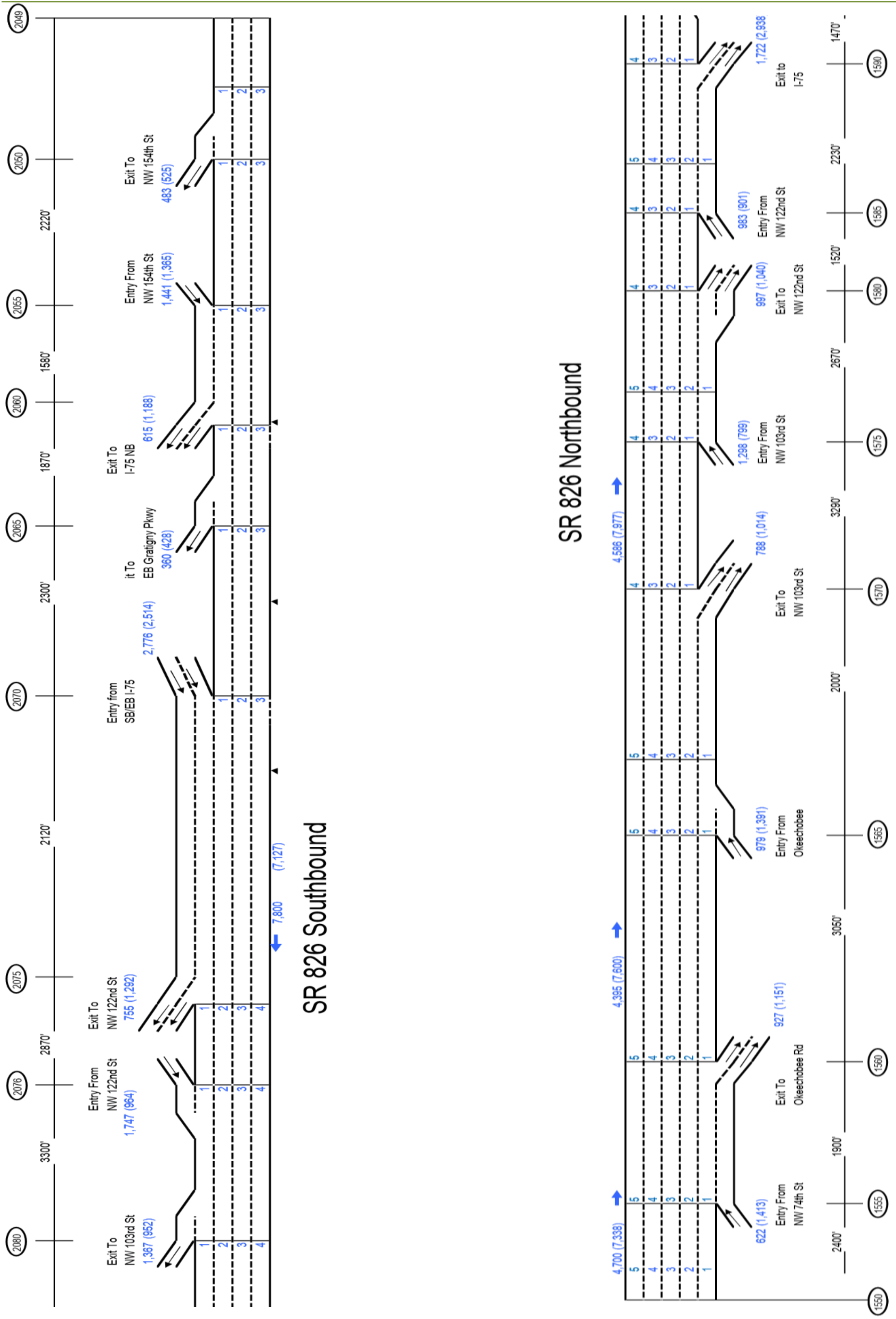

Figure 7-2 Lane Schematics

Table 7-1 Node Numbering Scheme[29]

Range		Description
From	To	
1	999	Surface Street
1000	1199	Northbound Freeway Mainline
1200	1299	Northbound Freeway Ramps
2000	2199	Southbound Freeway Mainline
2200	2199	Southbound Freeway Ramps
3000	3199	Eastbound Freeway Mainline
3200	3299	Eastbound Freeway Ramps
4000	4199	Westbound Freeway Mainline
4200	4299	Westbound Freeway Ramps
5000	5999	East-West Arterials
6000	6999	North-South Arterials
7000	7999	Interface Nodes
8000	8999	Network Entry Nodes

- Node values in the range between 1 and 999 should be assigned on surface streets. The lowest range of node numbers is recommended for surface streets as the Synchro software is often used to create a preliminary surface street network for CORSIM. Nodes created by Synchro start at number one (1).

- Split the links and place nodes consistent with the HCM definition of Analysis Segments for a Ramp Configuration as documented in the HCM Freeway Facilities Chapter. For instance, in order to correlate the CORSIM model to the LOS criteria for ramp junctions, a node should be placed 1,500 feet away from the ramp junction.

- Code curves on freeway and ramp alignments only when the radius of the curve is less than 2,500 feet.

- Space nodes at an average of 2,000 feet or less throughout the freeway network to facilitate the review of MOEs. Multiple nodes should be considered on long stretch of basic segments. The 1,500 feet rule on ramp influence areas should be applied as much as possible consistent with the HCM definition of the merge and diverge density.

- Code a node at a ramp meter location in ramp-metered operations.

- Code 15-minute volume that are derived from a profile of the balanced hourly traffic throughout the study period. The onset, presence, and dissipation of congestion are incorporated by varying the input volumes over multiple time periods.

- Code sink/source nodes at significant traffic generators to account for volume imbalances.

- Review and correct any errors when Synchro network is transferred into CORSIM.

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[29] FHWA Traffic Analysis Toolbox Volume IV

- Document all assumptions made during the model development process to aid the reviewer and potential future modeler to understand the analyst's intent.
- Perform cursory reviews of the network at multiple steps in the development of the base model to catch and correct any errors as early as possible in the coding process.
- Place nodes feeding the approaches to the intersection far enough away so that storage lanes can be accommodated. It is recommended to place entry exit nodes at the center of adjacent intersections.
- Place interface nodes closer to the freeway mainline at exit ramps and closer to the arterial street at entrance ramps.

Coding O-D data

Often O-D tables created by CORSIM are inaccurate. The inaccuracies are most prevalent when the model includes both surface streets and freeways. Therefore it is highly recommended that the analyst develop and code full O-D tables before testing the model. This approach would contribute to significant time savings. When O-D tables are used, the analyst should develop a spreadsheet to estimate (and balance) entry volumes and exit percentages based on O-D data.

An O-D table can be developed by utilizing select link analysis output from the travel demand model. Alternatively, O-D table can be created by assigning weaving movements before estimating the remaining O-D percentages. Using this approach, the analyst must use balanced entry and exit volumes.

Coding vehicle data

CORSIM has four different vehicle fleets (Passenger Car, Truck, Bus and Carpool) and defaults to nine vehicle types as shown in **Table 7-2**. Equivalent FHWA Classification Scheme F classes are also shown in **Table 7-2**.

Table 7-2 Default CORSIM Vehicle Fleet Specifications

Vehicle Fleet	Vehicle Type	Type Description	Default % NET/FRE	Length (ft)	Occupancy	FHWA Scheme "F" Class
Passenger Car	FRESIM 1- NETSIM 5	Low-performance car	25/25	14	1.3	1 - 3
	FRESIM 2 – NETSIM 1	High-performance passenger car	75/75	16	1.3	
Truck	FRESIM 3 –NETSIM 6	Single unit truck	100/31	35	1.2	5 -7
	FRESIM 4 - NETSIM	Semi-trailer with medium load	0/36	53	1.2	8- 10
	FRESIM 5 – NETSIM 7	Semi-trailer with medium load	0/24	53	1.2	
	FRESIM 6 – NETSIM 8	Double-bottom trailer	0/9	64	1.2	11- 12
Bus	FRESIM 7 – NETSIM 4	Conventional	100/100	40	25.0	4
Carpool	FRESIM 8 – NETSIM 9	Low-performance Carpool	0/25	14	2.5	1-3
	FRESIM 9 – NETSIM 3	High-performance Carpool	100/75	16	2.5	

Scheme F classification counts are obtained from the Florida's continuous traffic monitoring sites. By default 25% of passenger cars have a length of 14 feet, and 75% of passenger cars have a length of 16 feet. When there is no possibility of queue spillover or queue spillback, vehicle length would have no significant effect on the simulation results. It may be necessary to evaluate vehicle composition/length of cars within the study area, when no other adjustments to modeling parameters provide accurate results. These adjustments should have supporting justifications.

7.2.2 CORSIM Model Input Parameters

Table 7-3 provides specific guidance to CORSIM input data. The default values or range of values were created based on the experiences of developing CORSIM models throughout the state of Florida. The table should be used by both analysts and reviewers. Additional default values are listed in **Table 7.8**. When different values are coded, justification for these values has to be provided.

Table 7-3 Guidance to CORSIM Model Input Parameters

Input	Guidance
Vehicle entry headway	■ Erlang distribution with parameter "a" set to 1 for networks with FRESIM dominance ■ Normal distribution for networks with arterial dominance
Time periods	■ Use approved temporal limit of analysis; One time period is 900 seconds ■ Time interval duration is typically 60 seconds
Node IDs	■ Conform to node numbering scheme
Freeway geometry	■ Enter lane numbers, lane types, ramp positions, lane add/drops per approved spatial limit of analysis ■ Enter correct link lengths per lane schematics ■ Enter correct warning sign location for anticipatory lane change, exit ramps
Arterial geometry	■ Enter number of lanes, storage lanes, lane drop/add locations ■ Enter correct link lengths per lane schematics ■ Network length should match approved spatial limit of analysis
Grade	■ Code grades ≥ 4% if longer than 2600 ft
Freeway radius	■ Code curves on mainline and ramps only when their radii are less than 2,500 feet
Free flow speed (FFS)	■ Use field-measured FFS
Off-ramp reaction points	■ Code an actual measured point if known, default is 2,500 feet
Traffic demand	■ Enter entry volume (vehicles per hour) explicitly for each time period if proportion of turning vehicles is relatively stable over the analysis period ■ Enter turn percentages for the first time period only ■ Enter percentage of trucks and carpool for each time period
O-D data	■ Enter O-D data for each time period when required ■ Pay attention to the O-D within weaving areas
Minimum separation for generation of vehicles	■ 1.6 seconds
Lane distribution	■ Enter percentages based on field data (FRESIM only)
Freeway ramp exit volumes	■ Enter for the time period for first period only
Intersection control types	■ Code pre-timed versus actuated as per approved methodology ■ In consultation with traffic operations and signal system engineers, exercise caution in changing the parameters
Traffic control	■ Code all freeway and arterial control parameters correctly and as per confirmed methodology
Traffic management	■ Code all types of operations and management data that exist on the system

*Additional input default values are listed in Table **7-8**

7.2.3 VISSIM Modeling Guidelines

For a step-by-step procedure used to develop VISSIM models, the analyst should refer to the VISSIM User Manual. Key issues and specific input requirements are only highlighted in the following subsections.

Coding

When coding a VISSIM model, the analyst should adhere to the following general guidelines:

- Prepare lane schematics for the network. Split links based on HCM Freeway Facilities definition of Analysis Segments for a Ramp Configuration.
- Prepare lane geometry and network configuration with balanced demand volumes.
- Create a scaled base model from an orthorectified aerial image, computer aided drafting design (CADD) drawing, or other scaled background images.
- Minimize the number of connectors as much as possible by avoiding unnecessary segmentation along the corridor sections with similar geometry.
- Minimize or eliminate links and connectors overlap since overlaps tend to affect traffic flow in the network.
- Differentiate display types for overlaps between freeway elements and arterial streets.
- Code the merge/diverge section as a single link with the number of lanes equal to the mainline plus auxiliary lanes.
- Code driveway links between major intersections to reflect significant volume gains or losses between the intersections (e.g., a volume sink/source).
- Code intersection turn bays as separate links. Code turning movements and weaving movements to occur across connectors.
- Identify areas where planned improvements (in the proposed model) are likely to change the initial coding to accommodate future splitting of links and adding of connectors.
- Separate Merge/Weaving Parameter Set from Freeway (free lane selection). However, the number of additional link types should be minimized to the extent possible.
- Code data collection points, travel time sections, and queue counters or use node evaluation to collect delay and queue length. Increase the default Upstream Start of delay Segment parameter to capture queue delay.
- Define all critical intersections as nodes for evaluation purposes.
- Increase the default maximum queue length parameter to capture longest queue possible.
- Code external links (where vehicles enter the network) such that all vehicles (demand volume) can be loaded into the model within the analysis time period.

- Code special use lanes as part of multilane link using lane closures.

Additional VISSIM simulation model development guidelines are provided in **Table 7-4** to streamline coding and model review process.

Table 7-4 Guidance to VISSIM Model Development

Item	Guidance
Simulation parameters	- Set simulation period to be equal to the approved temporal limit of analysis plus a warm-up time. - The warm up time should be based on the longest travel time for a vehicle to fully traverse the network. - Simulation resolution has a significant impact on the capacity. Simulation resolution of 10 time steps/simulation second is recommended. For a large network 5 time steps/simulation second is also acceptable. In very large planning studies a time step of up to 1 second can be used.
Desired speed	- Use free flow speed distribution from field measurements or previous studies at similar locations.
Route decision and O-D data	- Use O-D tables from adopted (and validated) regional model. When traffic assignment is used over a model, it should be calibrated and validated. - Freeway lane change distance on freeways should be located on per lane basis. Code location of routing decision points to match sign location or field observations and user demographics to allow for accurate weaving and/or merging and lane utilization. - For closely spaced intersections, Combine Routes tool should be used to combine static routes. - Vehicle routes should be coded in 15-minute demand increments. Hourly increments may be acceptable when volumes are consistent throughout the hour (PHF =1). - Dynamic traffic assignment is preferred on large networks or when actual route behavior is of interest to solve the problem. - Routing decision must be reviewed to verify correct route paths have been defined accurately in the network.
Traffic demand	- Input balanced demand (15-minute) volumes including traffic composition for all links entering the network. - Default vehicles in the NorthAmerican Default.inp should be used instead of VISSIM standard default.
Traffic control and management	- Conflict areas are preferred over priority rules to control permissive movements within signalized intersections and all movements within unsignalized intersections. - Ring Barrier Controller (RBC) should be used whenever possible and the vehicle actuated programming (VAP) module can be used to model unique and complex traffic controls that RBC cant model. - Code all types of operations and management data that exist on the system. - Code signal heads, stop bars and detectors at proper locations. - In consultation with traffic operations and signal system engineers, exercise caution in changing the parameters
Assumptions	- Document all assumptions made during network coding to streamline the review process and help future modeler to understand the analyst's intent.

*Additional input default parameters are listed in **Table 7-9**

Coding O-D data

For complex networks, coding of O-D data using dynamic assignment is preferred over static route assignment because it predicts travel behavior more realistically. Dynamic assignment has a potential to capture temporal interactions of the transportation demand and supply, congestion build-up and dissipation, and the effect of traffic controls such as ramp metering, traffic signals, and ITS technologies. Dynamic assignment allows VISSIM to assign traffic to the network using O-D tables (time and vehicle class-dependent) and travel cost function. O-D matrices can be obtained from travel demand models. Each O-D table is related to a user-supplied traffic composition and to a 15-minute period of the simulation.

> A verified simulation model does not necessarily meet the performance goal of the analysis

When Dynamic assignment method is used it is recommended to check convergence of the model using Travel Time on Paths criteria. The two other options should be left unchecked. Convergence will be assumed to be satisfactorily met (and hence stable model) when 95% of travel time on all paths change by less than 20% for at least four consecutive iterations for each peak time interval.

7.3 Model Verification/Error Checking

Before proceeding to calibration, the base model has to be examined for completeness and accuracy. The objective of the model verification step is to confirm the model building process is complete and the model contains no errors in its implementation. When an error-free model is prepared and accurately measured data is entered, the calibration process would be more efficient. Therefore, the model verification process seeks to answer the following basic questions:

- Is the model implemented correctly?
- Are the input parameters correctly represented by the model?

To answer these questions, the model is verified by reviewing software error messages (including warnings), input data and model animation. A good practice is to use a peer reviewer (who has sufficient expertise in the modeling approach) to review the coded base model. The peer reviewer should only review the model after the analyst has vetted the model for completeness and accuracy in a quality assurance/quality control (QA/QC) process which follows the same model verification guidelines presented in this section. The peer reviewer may individually visit the site during each period for which the base model is being developed.

> Use a peer reviewer to verify the accuracy of the coded base model

When both analyst and peer reviewer complete the verification process and the peer reviewer is satisfied with the model structure, parameters and its reasonableness in emulating existing network, the base model is considered working. It is important to note that the verified simulation model file will be used for calibration process.

7.3.1 Base Model Verification Checklist

Checklists for verifying the accuracy of the base model coded using CORSIM and VISSIM are provided as **Table 7.5** and **Table 7.6**, respectively.

The following strategies can be used to increase the effectiveness of the verification process:

- Use the latest version and “patch” or “service pack” of the software to ensure latest known bugs are corrected by software developers. Additionally, a review of the software and user group websites would help to understand workarounds for some known software problems.
- If a software error (computational limitation) is suspected, code simple test problems (such as a single link or intersection) or sub-network where the solution can be computed manually and compare the manually computed solutions to the model output. It is essential to fix errors in the order they are listed.
- Use color codes to identify links by the specific attribute being checked (for example: links might be color coded by free-flow speed range, facility type, lanes, etc.). Out of range attributes or breaks in continuity can be identified quickly if given a particular color.
- Review intersection attributes.
- Load 50% or less of the existing demand and observe vehicle behavior as the vehicles move through the network. Look for congestion that shows up at unrealistically low demand levels. Such congestion is often due to coding errors.
- Load the network with 100% demand and review MOEs such as speeds, processed volumes. Any substantial difference from the field measurements could indicate a modeling error.
- Follow or trace a single vehicle through the network (possibly at very low demand levels) and look for unexpected braking and/or lane changes. Repeat for other O-D pairs.
- Look for network gridlock and consistent traffic conflicts (vehicle-vehicle, vehicle-pedestrian/bike) which may indicate coding errors.
- When the model animation shows unusual traffic behavior, the behavior should be verified in the field.

Table 7-5 CORSIM Model Verification (Error Checking) Process Checklist

Project Name: ____

State Road Number: _____________ **Co./Sec./Sub.** ____________

Error Type	Description	Check
Software	▪ Verify no runtime error existing in the network	☐
	▪ Verify runtime warning messages do not affect network operation	☐
Model run parameters	▪ Verify number of time periods against temporal boundary limit	☐
	▪ Verify fill time is large enough to load network with vehicles	☐
	▪ Check the output data to verify equilibrium has been reached	☐
Network	▪ Verify spatial boundary limit against link-node diagram	☐
	▪ Check basic network connectivity. Are all connections present?	☐
	▪ Verify if the link-node diagram has been created, and a base map was created in real world coordinates	☐
	▪ Verify lane schematics and check link geometry (lengths, number of lanes, free-flow speed, facility type, etc.)	☐
	▪ Check for prohibited turns, lane closures and lane restrictions at intersections and on links	☐
Demand	▪ Verify coded volumes and against counts	☐
	▪ Check vehicle mix proportions	☐
	▪ Check identified sources and sinks for traffic. Verify sink volumes against traffic counts	☐
	▪ Check lane distributions	☐
	▪ Check turn percentages	☐
	▪ Verify O-D on the network when coded	☐
Control	▪ Check intersection control types and data	☐
	▪ Check ramp meter control types and data	☐
Traffic operations and management data	▪ Verify bus operations—routes, dwell time	☐
	▪ Check parking operations	☐
	▪ Verify pedestrian operations and delays	☐
Driver behavior and vehicle characteristics	▪ Check and revise, as necessary, the default vehicle types properties and performance specifications	☐
	▪ Check and revise, as necessary, the driver behavior specifications	☐
Animation	▪ Review network animation with the model run at extremely low demand levels-check for unrealistic operational characteristics	☐
	▪ Review network animation with 50% demand levels	☐

For comments, use additional paper

Table 7-6 VISSIM Model Verification (Error Checking) Process Checklist

Project Name: ______________________________

State Road Number: ____________ **Co./Sec./Sub.** ____________

Error Type	Description	Check
Software	Verify no runtime or syntax error occurs in the Protocol Window	☐
	Review the error file (.err) for any errors or runtime warnings that affect simulation results	☐
	Review RBC errors or warnings	☐
Model run parameters	Review temporal boundary limit to confirm it matches the approved methodology	☐
	Verify initialization period is at least equal to twice the time to travel the entire network	☐
Network	Verify spatial boundary limit against approved methodology	☐
	Check basic network connectivity.	☐
	Verify the background image has been properly scaled	☐
	Verify link geometry matches lane schematics	☐
	Check link types for appropriate behavior parameters	☐
	Check for prohibited turns, lane closures and lane restrictions at intersections and on links	☐
	Check and verify traffic characteristics on special use lanes against general use lanes	☐
Demand and routing	Verify coded volume and vehicle mix/traffic composition	☐
	Check HOV vehicle type and occupancy distribution as appropriate	☐
	Check routing decision including connector look back distances	☐
	Verify O-D matrices and their placement in the network	☐
Control	Check and verify intersection control type and data are properly coded. Verify vehicles are reacting properly to the controls	☐
	Check ramp meter control type and data	☐
	Check conflict area settings	☐
Traffic operations and management data	Verify bus operations—routes, dwell time	☐
	Check parking operations	☐
	Verify pedestrian operations and delays	☐
Driver and vehicle characteristics	Check if driver behavior adjustments are necessary in saturated conditions	
	Verify no lane changes occur in unrealistic locations and vehicles make necessary lane changes upstream in appropriate location	☐
	Verify average travel speed reasonably match field conditions	☐
Animation	Review network animation with the model run at low demand levels—check for unrealistic operational characteristics such as congestion and erratic vehicle behaviors	☐
	Review reasonableness of the model against data coding, route assignment, and lane utilization	☐
	Compare model animation to field characteristics	☐
	Verify all turn bays are fully utilized and they a not blocked by through vehicles	☐
	Verify there are no vehicles turning at inappropriate time or locations	☐

For comments, use additional paper

7.4 Model Calibration and Validation

Model calibration and validation is the most important, yet challenging step of developing a realistic microsimulation model.

- Calibration is an iterative process whereby the model parameters are adjusted until simulation MOEs reasonably match the field-measured MOEs. Calibration requires both software expertise and knowledge of existing traffic conditions.
- Model validation is the process of testing the performance of the calibrated model using an independent data set (not previously used in the calibration). Validation is an additional check to confirm that a model has been correctly calibrated and closely match the existing conditions.

Calibration parameters are model inputs that control human and vehicle characteristics

Calibration is performed for all base models prior to their applications to reduce prediction errors. When AM peak and PM peak models are prepared, both models have to be coded with the guidance provided in the Base Model Development Section of this Chapter. Calibrated parameters from the base model are to be carried forward without being changed in the future year (proposed) models. It is important that calibration and validation are done on model parameters that control human and vehicle characteristics which are difficult to collect from the field. Calibration parameters should be distinguished from model input parameters such as number of vehicles, number of lanes, vehicle mix, network terrain, etc., which are field collected. The accuracy of the model input parameters is checked during the model verification/error-checking stage as outlined in the previous Section.

Data collection points in the simulation network must match data collection locations on the field

Default values for the model calibration parameters are provided as a starting point to model real-world traffic conditions and do not necessarily represent the analysis area characteristics. The initial step of calibration is to compare graphically and visually the simulation performance data based on default parameters with the field data. The field data collection locations should match the data collection points in the simulation network to obtain comparable results. Only under very rare conditions will the model be able to replicate the existing conditions using default values. As such, calibration of these parameters is essential to replicate the reality to a high degree of confidence.

The analyst should refrain from using default or calibrated values from other software models because their computational algorithms are different.

7.4.1 Model Calibration Process

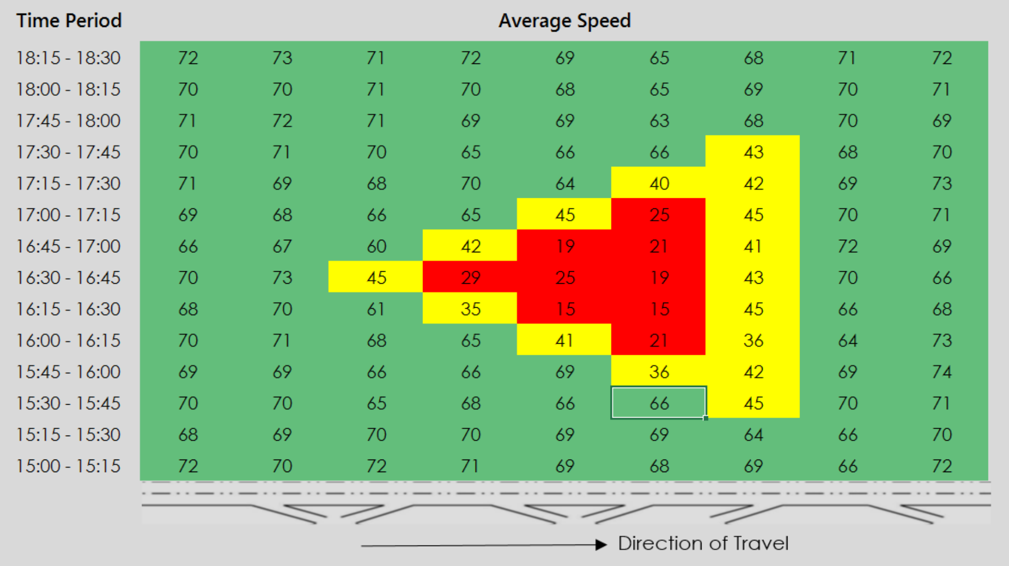
Simulation model calibration process involves iteratively changing default parameters, simulating the model and comparing calibration MOEs with field-measured MOEs. If the residual errors between simulated and field measured MOEs are within an acceptable margin of error, the model is calibrated; otherwise model parameters are modified until all MOEs residual errors are within the acceptable range. The modified values of the calibrated parameters should be reasonable and realistic. The calibration process involves the following:

- Defining the objectives of calibration.
- Determining a calibration strategy to achieve the objectives.
- Determining the minimum required number of simulation runs.
- Performing calibration and validation to obtain an acceptable field match.

The model calibration process should place a high emphasis on matching the MOEs at critical locations on the network such as bottlenecks and areas where improvements are proposed.

It is recommended to use histograms, X-Y plots, scatter diagrams and other chart-based analyses to iteratively check the validity of the calibration parameters (and their adjustments) to replicate existing traffic conditions. For example, the analyst can use speed-contour plots (heat diagrams) and hourly speed or flow profiles to assess the model in replicating the duration and distance of congestion. Speed-contour plots are effective for bottleneck analysis since they can show the formation and dissipation of the congestion in a time-space domain. An example of speed-contour plot is shown in **Figure 7.3**.

Chart-based techniques are recommended to graphically compare calibration MOEs



Time Period	Average Speed								
18:15 - 18:30	72	73	71	72	69	65	68	71	72
18:00 - 18:15	70	70	71	70	68	65	69	70	71
17:45 - 18:00	71	72	71	69	69	63	68	70	69
17:30 - 17:45	70	71	70	65	66	66	43	68	70
17:15 - 17:30	71	69	68	70	64	40	42	69	73
17:00 - 17:15	69	68	66	65	45	25	45	70	71
16:45 - 17:00	66	67	60	42	19	21	41	72	69
16:30 - 16:45	70	73	45	29	25	19	43	70	66
16:15 - 16:30	68	70	61	35	15	15	45	66	68
16:00 - 16:15	70	71	68	65	41	21	36	64	73
15:45 - 16:00	69	69	66	66	69	36	42	69	74
15:30 - 15:45	70	70	65	68	66	66	45	70	71
15:15 - 15:30	68	69	70	70	69	69	64	66	70
15:00 - 15:15	72	70	72	71	69	68	69	66	72

Figure 7-3 Speed-Contour Plot

In addition to evaluating calibration MOEs, a qualitative evaluation of the model has to be performed by visual inspection of the animation of the calibrated base model against field observations to determine the degree of reasonableness that the model replicates reality.

7.4.2 Calibration Objectives

The objective of the calibration process is to minimize the difference between simulation MOEs and the field-measured MOEs by iteratively adjusting calibration parameters. To properly calibrate a microsimulation model, calibration locations on the simulation network and their MOEs should be known when data collection plan is devised. This would enable collection of adequate and relevant data that is used to test the performance of the simulation model in replicating real world traffic operating conditions.

A minimum of two system performance MOEs in addition to capacity and traffic volumes should be selected for calibration. When modeling limited access facilities, at least one of the MOEs has to be associated with surface streets modeled within the analysis limits. The system performance MOEs includes travel time, speed, delay, and queue length.

Calibration MOEs should include capacity, traffic volumes and at least two other MOEs

7.4.3 Model Calibration Strategy

Since model calibration is an iterative process, the analyst should develop a practical strategy for achieving the objectives of calibration. A good practice is to divide the calibration parameters into two basic categories that have to be dealt with separately:

- *Parameters that the analyst is certain about and does not wish to adjust.*
  The values of these parameters are measured directly from the field and input in the model (e.g. vehicle length). Parameter values which can be taken from previous analyses and are applicable to the problem being analyzed also belong in this category. Also included in this category are parameters which do not have strong influence on the calibration MOEs.
- *Parameters that the analyst is less certain about and is willing to adjust.*
  Included in this category are parameters that have high to medium levels of sensitivity to the calibration MOEs.

Thus, it is worthwhile to focus more on calibrating parameters that are appropriate to the problem being solved and have strong influence on the calibration MOEs. Working on parameters that influence the calibration MOEs reduces the amount of time to adjust and calibrate the model. It is also important to divide adjustable parameters into those that directly affect capacity and those that impact route choice.

Calibration process should focus on adjusting parameters that have strong effect on model outputs

When manual calibration is proposed, a reasonable number of adjustable parameters (dependent on the network type and traffic conditions) should be kept to appropriately calibrate the model within the required degree of accuracy. However, more parameters give the analyst more degrees of freedom to better fit the calibrated model to the specific location.

Parameters to be adjusted should be divided into global and local parameters. Global parameters affect all elements of the simulated network while local parameters affect individual links or points in the network. Global parameters should be adjusted prior to local parameters.

The following strategy can be followed to improve the efficiency of the calibration effort:

1. *Capacity calibration*—model calibration parameters are adjusted to best match throughput of the typical road section (global) and at key bottleneck locations (local). If the model does

not show congestion as in the field, one approach could be to temporarily overload the network to force queue formation for at least 15 minutes. Any temporary increase of demand has to be removed before proceeding to route choice or system performance calibration. Overloading should not be used when lane selection is important as congestion may prevent some vehicles from reaching their desired lanes (such as turning bays) and hence skewing the simulation throughput.

Bottleneck calibration involves extracting a sub-network containing the bottleneck from the verified simulation network from which capacity calibration is performed. Prior to calibrating the bottleneck, the analyst should determine its causal and contributing factors which could include roadway geometrics, traffic control, or regulatory constraints.

2. *Route choice calibration*—route choice parameters are calibrated when the simulation model involves parallel streets. It involves adjusting route choice algorithm parameters such as drivers' familiarity with the area. The parameters that were previously calibrated in the capacity calibration stage are not subject to adjustment during route choice calibration.
3. *System performance calibration*—this involves fine tuning the model parameters to enhance the overall model performance with respect to speed, travel times and queues.

7.4.4 Number of Multiple Simulation Runs

Simulation models are run multiple times with different random number seeds to minimize the impact of the stochastic nature of the model on the results. Averages and variances of the results (MOEs) from multiple runs are reported. Ten (10) simulation runs with different random numbers are usually adequate. However, the number of simulation runs that is required to achieve a certain confidence level about the mean of the performance measure can be computed mathematically as:

$$n = \left(\frac{s * t_{\propto/2}}{\mu * \varepsilon}\right)^2$$

Where:

n is the required number of simulation runs

s is the standard deviation of the system performance measure (such as total traffic volume) based on previously conduced simulation runs.

$t_{\alpha/2}$ is the critical value of a two-sided Student's t-statistic at the confidence level of α and $n-1$ degrees of freedom. An α of 5% is typical.

μ is the mean of the system performance measure

ε is the tolerable error, specified as a fraction of μ. A 10% error is desired.

The CORSIM output processor can automatically calculate the required number of simulation runs necessary to achieve results that are within the tolerable error. For VISSIM, analyst needs to assume an initial number of runs and apply the method to calculate the required number of runs using the system MOEs, such as speeds, volumes, or travel times. It should be noted that this is an iterative process and due to the time constraints the methodology is limited to a maximum of 30 runs.

7.4.5 Assessing Calibration Parameters and MOEs

Proper calibration requires an assessment of the degree of closeness of the calibration MOEs to the field-measured MOEs. The assessment involves measuring the magnitude and variability of simulation errors in replicating existing traffic conditions. Since the process of adjusting calibration parameters is iterative, calibration tolerances or targets are set to curtail the process.

Calibration tolerances are set depending on the objectives of the traffic analysis as well as the types of the decisions that will be made from the analysis. Prior to proceeding with the calibration effort, the reviewing entity or lead agency of the project has to concur with the calibration tolerances. Such concurrence should occur during methodology development stage of the traffic analysis.

The following methods or tests can be used to determine whether the objective of calibration has been reached:

- Calibration tolerances or targets that are published in the Traffic Analysis Toolbox Volume III.
- Measures of goodness-of-fit to quantify the relationship between simulated and field data
- Hypothesis tests to determine whether the difference between simulated and observed data is statistically significant.

It is noteworthy that each test used in the calibration process can also be used in the validation of the simulation model only if a new data set is used. If a calibrated model fails the validation test, further calibration is required.

Classical Calibration Targets

The calibration targets presented in **Table 7.7** were developed by Wisconsin DOT for their freeway modeling program. These targets were developed based on the United Kingdom’s guidelines. While some agencies still use the classical calibration targets presented in **Table 7.7**, their use will soon be phased out as the methods for calibrating microsimulation evolve following the current research being conducted both nationally and internationally. The analyst is encouraged to coordinate with the reviewing entity on using these targets before proceeding with the calibration effort.

Table 7-7 Classical Model Calibration Targets

Calibration item	Calibration Target/Goal
Capacity	Simulated capacity to be within 10% of the field measurements.
Traffic Volume	Simulated and measured link volumes for more than 85% of links to be: ▪ Within 100 vph for volumes less than 700 vph ▪ Within 15% for volumes between 700 vph and 2700 vph ▪ Within 400 vph, for volumes greater than 2700 vph.
	Simulated and measured link volumes for more than 85% of links to have a GEH* statistic value of five (5) or lower.
	Sum of link volumes within calibration area to be within 5%.
	Sum of link volumes to have a GEH* statistic value of 5 or lower.
Travel Time (includes Transit)	Simulated travel time within ±1 minute for routes with observed travel times less than seven (7) minutes for all routes identified in the data collection plan.
	Simulated travel time within ±15% for routes with observed travel times greater than seven (7) minutes for all routes identified in the data collection plan.
Speed	Modeled average link speeds to be within the ±10 mph of field-measured speeds on at least 85% of all network links.
Intersection Delay	Simulated and field-measured link delay times to be within 15% for more than 85% of cases.
Queue Length	Difference between simulated and observed queue lengths to be within 20%.
Visualization	Check consistency with field conditions of the following: on- and off-ramp queuing; weaving maneuvers; patterns and extent of queue at intersection and congested links; lane utilization/choice; location of bottlenecks; etc.
	Verify no unrealistic U-turns or vehicle exiting and reentering the network.

*GEH is an empirical formula expressed as $\sqrt{\mathbf{2} * (\boldsymbol{M} - \boldsymbol{C})^2/(\boldsymbol{M} + \boldsymbol{C})}$ where M is the simulation model volume and C is the field counted volume.

Goodness-of-fit Measurements

Prior to analyzing the goodness-of-fit measurements, the analyst should graphically compare the distributions (in both space and time) of simulation outputs and observed data. When field observation and predicted (simulated) data closely match, the measures of goodness-of-fit should then be employed to quantify the amount of error between the two data sets. The following measures of goodness-of-fit are minimized during the calibration process:

- Root Mean Square Normalized Error (RMSNE)
- Correlation coefficient (CC)
- Mean absolute percentage error (MAPE)

The Root Mean Squared Normalized Error (RMSNE) or Normalized Root Mean Square Error (NRMSE) measures the percentage deviation of the simulation output from observed data. This statistic measures the percentage of the typical relative error and it can be used to determine the width of the confidence intervals for the predictions. Mathematically, it can be expressed as:

$$RMSNE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{y_{i,sim} - y_{i,obs}}{y_{i,obs}}\right)^2}$$

where n is the total number of traffic measurement observations, $y_{i,sim}$ and $y_{i,obs}$ are simulated and observed data points , respectively, at time-space domain, i. $y_{i,sim}$ is an average of the total number of simulated output. RMSNE is also called Root Mean Squared Percent Error (RMSPE). A RMSNE of less than 0.15 is considered acceptable for traffic model calibration. Lower measurements may lead to higher RMSNE values.

The Correlation Coefficient (CC) indicates the degree of linear association between simulated and observed data. The mean and variance of the simulated and observed data should be known. Mathematically, it is expressed as:

$$CC = \frac{1}{n-1}\sum_{i=1}^{n}\frac{(y_{i,sim}-\bar{y}_{sim})(y_{i,obs}-\bar{y}_{obs})}{s_{sim}s_{obs}}$$

Where n is the total number of traffic measurement observations, $\bar{y}_{sim}$ and $\bar{y}_{obs}$ are means of the simulation and observed measurements, respectively. s_{sim} and s_{obs} are the standard deviations of the simulated and observed measurements, respectively. This statistic is also referred to as Pearson Product-Moment Correlation Coefficient (PPMCC). A correlation coefficient of 1 shows a perfect and direct relationship while a correlation coefficient of -1 shows a perfect and inverse relationship. A coefficient of correlation of 0.85 is considered acceptable for model calibration.

The mean absolute percentage error (MAPE) measures the size of the error in percentage. It is estimated as the average of the unsigned errors for data that is strictly known to be positive. The advantage of this statistics is lack of effect of averaging positive and negative errors. Since this statistic is expressed in percentage terms, it is easier to comprehend without knowing what constitutes a big error in the measurements. Mathematically, MAPE is expressed as:

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{y_{i,sim}-y_{i,obs}}{y_{i,obs}}\right| x100$$

MAPE statistic should not be used when working with low-volume data because it is scale sensitive. Very low $y_{i,obs}$ values results into higher MAPE static.

The GEH statistic used in **Table 7.7** is not a true goodness-of-fit statistic despite having a mathematical form that is similar to a Chi-square statistic[30]. The GEH statistic is an empirical equation that has been used in traffic engineering and transportation planning to compare two datasets of traffic volumes.

An example depicting goodness-of-fit calculation is presented in **Figure 7.4.**

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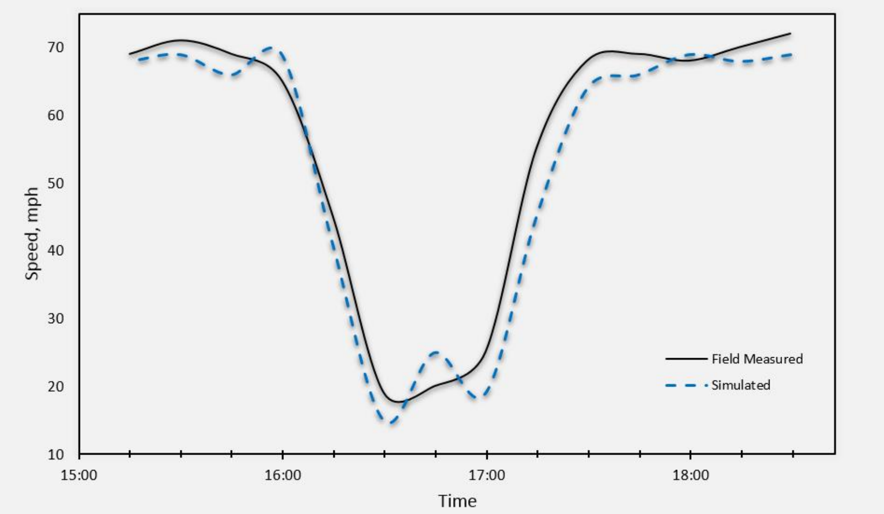
[30] Chi-square (χ^2) statistic is used to compare observed data with predicted data under the assumption of no association between them.

Comparison of field-measured speeds and averages of the calibrated model at the bottleneck location is shown graphically below. Root Mean Squared Normalized Error (RMSNE) was computed to be 0.092. Examination of the the speed profiles and the RMSNE confirms that the model reasonably replicates existing speeds.

Field-measured Vs. Simulated Speed Profiles



RMSNE Calculations

Time	Observed, y_{obs}	Simulated, y_{sim}	$\left(\frac{y_{i,sim}-y_{i,obs}}{y_{i,obs}}\right)^2$
18:30	72	69	0.00174
18:15	70	68	0.00082
18:00	68	69	0.00022
17:45	69	66	0.00189
17:30	68	64	0.00346
17:15	55	45	0.03306
17:00	25	19	0.05760
16:45	20	25	0.06250
16:30	19	15	0.04432
16:15	45	41	0.00790
16:00	65	69	0.00379
15:45	69	66	0.00189
15:30	71	69	0.00079
15:15	69	68	0.00021
	$\sum\left(\frac{y_{i,sim}-y_{i,obs}}{y_{i,obs}}\right)^2$		0.11957
	n		14
	RMSNE= $\sqrt{\frac{1}{n}\sum\left(\frac{y_{i,sim}-y_{i,obs}}{y_{i,obs}}\right)^2}$		0.09204

Figure 7-4 RMSNE Calculation Example

Hypothesis Testing

Statistical hypothesis tests, such as student *t*-test or *z*-test, can be used to compare simulation output and field-measured data to determine whether their difference is statistically significant. These tests involve comparing the two averages of the data and inferring the extent to which they differ. In hypothesis testing, the first step is to formulate the null hypothesis which can be defined as "there is no difference between the averages of the two distributions". Then data are analyzed to determine the probability associated with an alternative hypothesis which will provide sufficient evidence to reject the null hypothesis.

Hypothesis testing by using *t*-test or z-test should be used with caution since the method requires distributions of simulation and field-measured data to be mutually independent and identically distributed. Therefore, the distributions of the simulation and field-measured data should be checked for independency and identical assumptions before any inferences are drawn from the hypothesis tests.

Another hypothesis testing method uses experimental design techniques that employ analysis of variance (ANOVA) to examine the difference between two sets of measurements from the simulation and field observations. Experimental design is the process of planning a study to meet specified objectives. A full factorial design can be applied under this method. Factorial designs are used to improve the precision of the results of hypothesis testing. To enhance the statistical tests, a power analysis is recommended to determine the capability of the experimental design to detect an effect of sample size constraints with a given degree of confidence.

When ANOVA is used the analyst must make sure that the errors in the two sets of measurements are not only independent and identically distributed but also normally distributed. ANOVA is performed using any statistical program including Microsoft Excel Analysis ToolPak.

When analyzing the difference between the two distributions, the analyst should distinguish between statistical significance and practical significance/importance. For instance, the ANOVA for the difference of the average speeds on the two improvement alternatives were found to be statistically significant; however, the average speeds on the two alternatives were 51mph and 54 mph. Although the two alternatives' speeds are statistically significantly different, the amount of the difference (3 mph) could be too small to be practically important. As such, the analyst's judgment is required when interpreting the results of hypothesis tests.

7.4.6 CORSIM Model Calibration Process

A summary of guidance to CORSIM model calibration parameters for freeways and surface streets is presented in **Table 7.8**. The calibration process should concentrate on parameters that have substantial effects on the model's performance—these parameters are labeled with high to medium sensitivity levels in **Table 7.8**. The default values can be found in CORSIM User's Guide and Minnesota CORSIM Manual. Changes made to these parameters should be documented in the calibration report and become part of the simulation model documentation.

> Parameters to be adjusted should have substantial effects on the model's performance

Table 7-8 CORSIM Calibration Parameters

Calibration Parameter	Sensitivity Level[31]	Default Value	Remarks
FREESIM			
Lag acceleration and deceleration time	Medium	0.3 s	
Pitt car following constant	Medium	10 ft	
Time to complete a lane change	Medium	2.0 s	
Maximum non-emergency deceleration	Medium	8 ft/s^2	13 ft/s^2 (cars), 10 ft/s^2 (trucks)
Maximum emergency deceleration	Medium	15 ft/s^2	
Leader's maximum deceleration perceived by its follower	Medium	15 ft/s^2	
Car following sensitivity multiplier	High	100%	50% - 200% based on traffic volume
Warning sign locations	Medium	2500 feet (Exit) 1500 feet (Lane add/drop) 5280 feet (HOT/HOV lane)	Field-measured or add 1,000 ft for each lane greater than two lanes
Anticipatory lane changes speed	Medium	2/3 free flow speed	
Anticipatory lane changes distance	Medium	1500 ft	Field-measured
Mean Free flow speed	High	Field-measured	Field-measured
NETSIM			
Acceptable gap in oncoming traffic (left and right turns)	Medium	7.8 s for timid drivers to 2.7 s for aggressive drivers, with a mean value of 5.0 s	
Cross-street acceptable gap distribution (near and far side)	Medium	5.0 s for timid drivers to 2.0 s for aggressive drivers, with a mean value of 3.8 s	
Time to react to sudden deceleration of lead vehicle	High	1.0 s	
Minimum deceleration for a lane change	Medium	5 ft/s^2	
Spillback probabilities	Medium	100%, 81%,69% and 40% for 1st, 2nd, 3rd, and 4th vehicle, respectively	
Mean discharge headway	High	1.8 s	
Mean start-up delay	High	2.0 s	
Mean free-flow speed	High	Field-measured	Field-measured
Deceleration of lead vehicle	Medium	12 ft/s^2	
Deceleration of following vehicle	Medium	12 ft/s^2	
Max. allowable left turn speed	Medium	22 fps	
Max. allowable right turn speed	Medium	13 fps	

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[31] http://www.fhwa.dot.gov/publications/research/operations/its/04131/05.cfm

7.4.7 Notes Regarding CORSIM Calibration Process

- Oversaturated conditions require multi-period simulation to allow all input volumes to be served. In such modeling conditions, the beginning of the first time period and the final time period should be undersaturated.
- Global free-flow speed parameter (free-flow speed multiplier) should not be modified.
- Global car following sensitivity factor should not be modified.
- Mean start-up delay at the global scale (start-up delay multiplier) should not be modified.
- Mean discharge headway at the global scale (discharge headway multiplier) should not be modified.
- Warning sign locations (reaction points) are not locations of actual signs on the highway. Thus, reactions points should be coded in the base model based on actual field observations to the extent possible.
- Off-ramp (exit) warning signs should always be placed downstream of a lane drop.
- If undesirable free flow speeds are obtained, presence of curvature, superelevation and friction in the model should be checked to determine whether they affect speeds.
- If undesirable high speeds are obtained when volume is higher than a certain level contrary to the traditional traffic engineering theory, car-following sensitivity factors in FRESIM should be adjusted per segment.
- When the capacity and performance of permissive left turners is an important issue, it may be preferable to “zero out” or at least reduce the percentage of left-turn jumpers. By default, 38% of permissive left turners at the front of the queue will discharge before the opposing queue has begun movement—a phenomenon referred to as Left-turn “jumpers” in NETSIM.
- At intersections (or intersection approaches) where saturation flow rate is measured or estimated to be lower than normal, excluding reductions caused by permissive left-turn and right-turn effects, the mean discharge headway should be increased for a more accurate model. Mean discharge headway is closely correlated with, and inversely proportional to, the HCM saturation flow rate. Typical reasons for a lower-than-normal saturation flow rate include narrow lane widths, parking maneuvers, bus blockage, pedestrian/bike interference, heavy vehicles, and grade.
- If the simulated average phase durations (for actuated controllers) do not closely match field-measured average phase durations, the analyst should make corrections to the simulation input parameters to realize a more accurate model. If the simulated average phase durations do not fluctuate (i.e., behavior of a pre-timed controller) but the field-measured phase durations fluctuate significantly, the analyst should make corrections to the simulation input parameters.

7.4.8 VISSIM Model Calibration Process

Calibration of VISSIM models involves adjusting default driver behavior (lane changing and car-following) parameters. Default network parameters that may also be adjusted include priority rules/conflict areas, gap parameters, reduce speed areas, connector lane change distance, turning speed, routing decision point locations. Prior to adjusting these parameters the analyst should check and confirm field-measured data for vehicle types, traffic composition and speed have been correctly coded in the model. The use of field-measured data is vital to a successful calibration process.

A summary of guidance to VISSIM model calibration parameters for freeways and surface streets is presented in **Table 7.9**. The values of these calibration parameters should be considered as a starting point for the calibration process. The values were obtained from Oregon VISSIM Manual, VISSIM User Manual and guidance obtained from VISSIM developer. Adjustments made to these parameters should be documented in the simulation model calibration report and become part of the simulation model manual which is discussed in **Section 9.2.4**. Additionally, these parameters may be specific to a vehicle class or area (link) in the network or a combination of values per vehicle class and area within the same link in the network.

7.4.9 Notes Regarding VISSIM Calibration Process

- Weaving and merge and diverge areas' driver behavior parameters values are different from the basic freeway parameters. Thus, weaving, merge and diverge areas link behavior types could be separated from basic freeway (free lane selection) behavior type.
- Standstill distance (CC0), headway time (CC1), and following variation (CC2) have strong influences on model MOEs. CC0 and CC1 control most of the following behavior.

CCO, CC1, and CC2 have substantial effect on the model's performance

- Negative and positive 'following' thresholds (CC4 and CC5) are other means of calibrating break-down conditions.
- Standstill acceleration (CC8) is useful parameter for calibration of the recovery from breakdown conditions.
- Default values for maximum acceleration functions can be used since VISSIM driver's acceleration decisions are influenced by the car following algorithm.
- Connector Lane Change Distance for freeway connectors can be increased above the default (which is set to be appropriate for arterial operations).
- The default truck characteristics (such as lengths) used in VISSIM do not represent trucks found on Florida highways. Thus, use of truck dimensions representative of at least 2-axle single unit trucks (Class 5-7) and 5-axle tractor-semi trailers (Class 4, 8-13) may be needed to accurately calibrate capacity and queue lengths.
- Waiting time before diffusion value should only be adjusted if there is field data to warrant the additional time to wait before diffusing a vehicle. It should not be used as a primary calibration attribute as diffused vehicles are often a sign of coding errors.

- Saturation Flow Rate in VISSIM is affected by a combination of driving parameters. The additive part of desired safety distance and the multiplicative part of safety distance have major effect on the saturation flow rate for the Wiedemann 74 model. In the Wiedemann 99 model, CC1 has a major effects on the saturation flow rate. Other field-measured data such as desired speed and truck volume also affect the saturation flow rate significantly.

Table 7-9 VISSIM Model Calibration Parameters

Calibration Parameter	**Default Value**	**Suggested Range**	
		Basic Segment	**Weaving/Merge/ Diverge**
Freeway Car Following (Wiedemann 99)			
CCO Standstill distance	4.92 ft	>4.00 ft	>4.92 ft
CC1 Headway time	0.9 s	0.70 to 3.00 s	0.9 to 3.0s
CC2 'Following' variation	13.12 ft	6.56 to 22.97 ft	13.12 to 39.37ft
CC3 Threshold for entering 'following'	-8	use default	
CC4 Negative 'following' threshold	-0.35	use default	
CC5 Positive 'following' threshold	0.35	use default	
CC6 Speed Dependency of oscillation	11.44	use default	
CC7 Oscillation acceleration	0.82 ft/s^2	use default	
CC8 Standstill acceleration	11.48 ft/s^2	use default	
CC9 Acceleration at 50 mph	4.92 ft/s^2	use default	
Arterial Car Following (Wiedemann 74)			
Average standstill distance	6.56 ft	>3.28 ft	
Additive part of safety distance	2.00	1 to 3.5[i]	
Multiplicative part of safety distance	3.00	2.00 to 4.500[i]	
Lane Change			
Maximum deceleration	-13.12 ft/s^2 (Own) -9.84 ft/s^2 (Trail)	< -12 ft/s^2 < -8 ft/s^2	
-1 ft/s^2 per distance	200 ft (Freeway) 100 ft (Arterial)	>100 ft >50 ft	
Accepted deceleration	-3.28 ft/s^2 (Own) -1.64 ft/s^2 (Trail)	<-2.5 ft/s^2 <-1.5 ft/s^2	
Waiting time before diffusion	60 s	Use default	
Min. headway (front/rear)	1.64 ft	1.5 to 6 ft	
Safety distance reduction factor	0.6	0.1 to 0.9	
Max. dec. for cooperative braking	-9.84 ft/s^2	-32.2 to -3 ft/s^2	
Overtake reduced speed areas	Depends on field observations		
Advanced Merging	checked		
Emergency stop	16.4 ft	Depends on field observations	
Lane change	656.2 ft	>656.2 feet	
Reduction factor for changing lanes before signal	0.6	default	
Cooperative lane change	Unchecked	Checked especially for freeway merge/diverge areas	

[i]The relationship should be based on the User Manual i.e. Multiplicative = Additive+1

7.4.10 Manual Calibration

Currently, calibration of VISSIM and CORSIM traffic models is done manually by adjusting one parameter at a time. Manual parameter adjustments could cause one MOE to meet its calibration target and another previously calibrated MOE to deviate from its target. The remedy would be to fine-tune both parameters to achieve both targets. When repeated iterations of calibration and the reasonable relaxation of calibration targets do not result in a satisfactorily calibrated model, the analyst and the project team should reconsider the use of that particular software. Alternatively, if software limitations are deemed a problem, then the analyst will have to work around the limitations to produce the desired performance. Such work around should be properly documented in the calibration report.

CORSIM developers have invented a "self-calibration" tool to enable the analyst to choose calibration input parameters and output parameters that will measure the success of calibration process. This tool requires the analyst to have a prior traffic engineering expertise as the parameters will be chosen based on engineering judgment. Guidance presented in this handbook is still needed to effectively choose parameters and calibrate the model when self-calibration tool is used.

7.5 Correcting Effects of Unmet Demand in the Model

The following conditions should prevail for a model to reasonably replicate real world traffic operating characteristics:

- Simulated congestion should not extend beyond the boundary limits of the analysis
- Vehicles should not be blocked from entering (or being generated) the network in any simulation time step

Ideally, time periods for microsimulation models should be selected such that the first and last simulation periods are undersaturated. This is essential as it is worthwhile for the residual queues to accumulate during the "middle" time periods, and dissipate before the end of the final simulation time period. If residual queues do not dissipate before the end of the final time period, performance measurement reported at the end of simulation may not be accurate. The residual queues are also referred to as unmet demand. Presence of unmet demand in the model contributes to erroneous output.

Correction of demand violation is achieved by first extending the model's spatial and temporal limits to include the maximum back queue or congestion buildup and congestion dissipation periods. However, in some cases, it may be impossible to extend spatial limits of analysis due to nature of the project or physical limitations. Additionally, most simulation tools have capability of simulating network models for up to five (5) hours.

> Correction of unmet demand can be achieved by extending the model's spatial limits and temporal limits

When extension of boundary limits fails to account for all unmet demand, the model results should be adjusted to account for unreported congestion in the analysis outputs. Documentation should be provided to indicate that boundary limit expansion did not eliminate the unmet demand error. The following methods can be used to account for the effect of unmet demand in the performance of the network.

1. Adding blocked vehicles delay to the software reported delay for each simulation run. Blocked vehicle delay is obtained from multiplying the total number of blocked vehicles (reported by the software) for each time step by the length of each time step (hours).
2. Quantifying the amount of unreported residual delay (D') due to queues (Q) that are present at the end of the simulation run as: $D' = Q^2/2C$. Where C is the bottleneck capacity in vehicles per hour.

7.6 Future-Year Model Verification

After the base model is successfully calibrated, coding of the future-year models may begin. The future-year models are only checked for errors and reasonableness. The input parameter values of the calibrated model are carried forward to the future-year models without any adjustment or modification. However, future conditions of the proposed facility may dictate fine tuning of some of the calibration parameters. When modification of calibrated parameters is necessary, the reasons should be provided and documented.

Check of reasonableness includes verifying the future-year model volumes match travel demand model forecasts. Tests for reasonableness of future year models should be similar to calibration tests without numerical targets. Any significant volume differences should be reconciled by coordinating with the demand modelers before finalizing the analysis as the problem may be caused by the microsimulation model, demand forecasting model or both.

7.7 Calibration and Validation Report

Documenting how calibration was carried out is essential to streamline the review of the traffic model. As such, a good practice and recommended approach is to submit the base model (that has been calibrated) to the reviewing entity for concurrence prior to proceeding with alternative analyses. The base model should be supported with a model calibration and validation report to document the model development process. At minimum, the report should include a summary of the model verification process, assumptions and modeling issues, a detailed calibration process with all calibration parameters and calibration targets, goodness-of-fit measurements, site observations and how they have been accounted for in the model, and a history of model development.

Calibration report shall be submitted for review before proceeding with alternative analysis

Both calibrated and validated model results should be tabulated or graphed and compared with the field-measured data for each calibration periods. Any discrepancies between the model and local traffic conditions should be noted and discussed in the report. Review of the reasonableness of the calibrated model will rely on information presented in the report.

Due to stochastic nature of the microsimulation tools, higher probability of coding errors, and rationale for modeling judgments, this report should be well organized to elaborate all decisions and assumptions made in the process of developing and calibrating the model. As such, the calibration report should address the following information in detail:

Introduction

This section includes background of the project and methodology of traffic analysis; location; and type and version of the software that will be used.

Data Collection

This section contains a summary of the existing data that is used to generate microsimulation model. Descriptions of key calibration locations based on field observations are included in this section. Speed-contour plots or similar contour plots are prepared and presented to show existing congestion patterns along the corridor.

A summary of the calibration and validation data is provided in this section.

Important issues to be addressed through the calibration process are also described in conjunction with each calibration location. The issues will aid the understanding of the derivation of appropriate calibration measures and will be used as a guide when adjusting default parameters.

Base Model Development and Verification

This section consists of the following items:

- Coding of network geometry, traffic demands, and traffic control
- Model Verification/Error Checking—this includes both quantitative and qualitative evaluation of the model. The results of the simulated model with 50% and 100% demand loaded to determine there are no coding errors are summarized in this section. Any demand violation issues such as unrealized or blocked vehicles that cannot be processed by the model are discussed. Additionally, summary of the comparison of animation and real world traffic conditions is presented.
- Specific assumptions made to the model development.

Model Calibration and Validation

This section includes the following key items:

- Calibration MOE and key calibration locations.
- Calibration goal or acceptance tolerances.
- Calibration method and strategy.
- Default calibration parameter values that will be adjusted to meet calibration goals. Adjusted input parameter values can be categorized as global and local parameters. Additionally, links used for local parameters calibration can be grouped into categories with similar local characteristics. For instance, categorization by location includes freeway mainline segments, ramps merge/diverge and weaving areas,

intersection, or arterial segments while categorization by traffic conditions include congestion levels such as oversaturated and undersaturated conditions per v/c ratios.

Model Calibration Results

This section contains the following:

- Calculation of the minimum number of simulation runs.
- Detailed documentation for justifications or reasons for changing default input parameter values. Each parameter changed should be discussed in this section along with supportive statistics/MOEs or site characteristics that trigger the change.
- Results of the calibration model are presented in this section. Chart-based techniques are preferred to show performance MOEs of the calibrated model in both time and space domains. Be certain that the averaging of model outputs should match the format of the data collected in the field.
- Results of the bottleneck analysis should be presented using speed contour plots or similar plots.
- Validation results of the calibration model using an independent data set (data that was not used for calibration).

Summary or Conclusions

This section contains a summary of the calibration report.

7.8 Model Calibration Reviewer's Checklist

Table 7.10 presents the list that the reviewer can use to check the reasonableness of the base model in replicating the existing traffic characteristics. The reviewer should check all items that apply to the project otherwise indicate the item(s) is not applicable to the project.

Table 7-10 Model Calibration Reviewer's Checklist

Financial Project ID: ____________________ **Federal Aid Number:**____________________

Project Name: ____

State Road Number: ______________ **Co./Sec./Sub.** : _____________ Project MP: ____________

Item to Check	**Description**	**Check**
Model errors	Simulation model contains no errors	☐
	Simulation model was accurately verified	☐
MOEs	All calibration MOEs are listed	☐
	Calibration targets/goals have been outlined	☐
	Calibration and validation data is sufficient to meet the targets	☐
	Calibration areas are clearly identified	☐
Calibration process	Calibration process is documented with all relevant calibration data, assumptions, and include a history of base model development	☐
	Calibration effort cover both AM and PM peak periods	☐
	Default calibration parameters were changed and documented	☐
	Model animation matches expected driver behavior and conditions observed in the field	☐
	Model replicates real-world bottleneck(s) and lane utilization	☐
Calibration targets	Calibration results are based on at least 10 simulation runs with different random seeds	☐
	Model output volumes satisfy volume calibration requirements	☐
	Model link capacities satisfy capacity calibration requirements	☐
	Model link speeds meet speed calibration requirements	☐
	Model link travel time meet calibration requirements	☐
	Model intersection delay results meet calibration requirements	☐
	Model queuing replicates real-world conditions	☐
	Calibrated model is validated with an independent data set	☐

Comments:

Reviewer's Name:_______________________________________ **Date:**______________

Use additional papers for more comments

Chapter 8
Alternatives Analysis

Once the project objectives are known, the analyst starts to develop different potential improvement concepts. These concepts are the basis for developing preliminary project alternatives. It is noteworthy that professional judgment of the analyst is required when developing improvement concepts and checking whether the results of the traffic analysis present reasonable estimates of the existing and future performance of the analysis area. Coordination between planning, design, operation, construction personnel and other key decision-makers at this stage is vital to the project success. Guidelines to develop and evaluate the project alternatives are provided in this chapter.

> Coordination between planning, design, operation, construction offices and other key decision-makers is essential when developing alternatives

8.1 Alternatives Development

Alternatives should be generated based on the FDOT Project Development and Environment Manual (PD&E Manual)[32] procedures and guidelines. Generally, the analyst should start by developing improvement concepts with the least environmental impact and less expensive before proposing larger investment concepts that might have major impacts to the surroundings. The analyst can employ a two-stage process to evaluate the viability of the concepts. The first stage (Stage 1 analysis) involves developing and screening sketch-level improvement concepts using predetermined screening criteria. The second stage (Stage 2 analysis) involves identifying environmental limitations to the screened concepts and transforming the concepts to design alternatives.

The following should be considered when developing and analyzing project alternatives:

- A No-Build alternative is always a project alternative in additional to the improvement alternatives discussed in this section. The No-Build alternative represents a benchmark for evaluating all improvement alternatives. Any project that is planned to be funded and constructed within the design year of the analysis should be included in the analysis of No-Build alternative.

- Preliminary alternatives (improvement concepts) should be developed in cooperation with potential project stakeholders through a workshop, charrette or open house approach. Early coordination with other offices within FDOT that deal with planning, design, operations, environmental management, construction, and maintenance as well as other agencies owning impacted facilities is essential for a successful selection of viable improvement alternatives.

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[32] http://www.dot.state.fl.us/emo/pubs/pdeman/pdeman1.shtm

- Due to time and resource required for the traffic analysis efforts, especially microsimulation approaches, and uncertainty of developing improvements concepts in the early stages of the project, it is beneficial to assess general feasibility of the concepts (Stage 1 analysis) by using sketch-planning tools such as GSLV, LOSPLAN or HCS. This approach would use general performance measures such as v/c ratios to screen the concepts. Screening of concepts would generate viable improvement alternatives which may be carried forward for more detailed traffic analyses (Stage 2 analysis). When v/c ratio is used, the analyst should make sure demand volume is used. All improvement concepts that were rejected from further considerations should be documented and included in the alternatives analysis report.

> Any improvement concept screened out from detail evaluations should be documented in the alternatives analysis report.

- Any build alternative considered for analysis should address the purpose and need for the project. In addition to considering traditional infrastructure improvements, alternatives should consider incorporation of transportation system management and operation (TSM&O) strategies (e.g., ramp metering, traffic signal coordination, managed lanes and improved traveler information) as well as alternative transportation mode strategies such as improved transit service and multimodal accommodation.
- Signal optimization information for each alternative is obtained from signal optimization tools such as Synchro because of the limitation (or lack thereof) of microsimulation tools to optimize signal timing or ramp meter controls. Additionally, signal optimization analysis on urban areas should account for effectiveness of signal coordination in improving travel speeds and reducing delays along the impacted corridors. Application of signal optimization tools should be discussed in the analysis methodology and agreed upon by all stakeholders.
- All project alternatives should use the same boundary limits that were identified and approved in the project scoping. This is achieved by modeling networks for each alternatives from the calibrated base network. However, some alternatives may have impacts beyond the base network, in which case the analyst is required to include wider impacts in the analysis and document properly.
- Improvement alternatives should be further evaluated with respect to impacts to the natural and built environment and community before detailed traffic analysis is performed. The analyst should be aware that environmental criteria are part of the project's alternatives multi-criteria evaluation process. When environmental impacts are unavoidable, early coordination with environmental management is required so the impacts can be mitigated, or reduced to an acceptable level.
- Any impact to be caused by implementation of build alternatives should be adequately discussed. When mitigations are proposed, they should also be included in the analysis documentation.

- Two or three viable improvement alternatives should be considered for detailed traffic evaluations.
- Design standards and criteria published in the FDOT PPM, the American Association of State Highway and Transportation Officials (AASHTO) publication "A Policy on Geometric Design of Highway Streets" and FHWA policies on the National Highway System (NHS) should be followed when developing improvements alternatives. However, context-sensitive approaches that balance a broad range of project needs and environment are encouraged. When the design criteria cannot be met, the analyst should prepare background information sufficient to initiate a design exception or variation in the subsequent phases of the project development. Additionally, all improvement alternatives should be developed considering desired safety levels of the facility.
- Safety considerations should evaluate existing safety issues and concerns in the analysis area through application of safety diagnostic analyses. Diagnosis analyses are useful to make informed decisions about development of improvement concepts. Existing safety profiles (in terms of crash type, frequency and severity) should be examined and crash causation determined before selecting crash countermeasures in the project improvement alternatives. Crash predictive methods can be used to estimate changes in the number of crashes that is associated with changes in traffic patterns, roadway geometrics, or traffic volume and control across different improvement alternatives. Future safety conditions and crash countermeasures should be established on the analysis boundary limit.
- It is noteworthy that the safety analysis should analyze the proposed geometrics and address the results of crash analysis to demonstrate that the improvement alternatives will not introduce or worsen a safety concern. Some of the questions that the analyst should ask are:
  - Will the implementation of the project alternatives compromise safety of all facility users?
  - Is it possible to improve the safety of all road users even when no significant safety flaws are identified in the alternative development process?
  - What safety best practices can be incorporated into the improvement alternatives to further upgrade the safety level of the facility?
  - Is the proposed safety improvement part of the Florida Strategic Highway Safety Plan (SHSP)[33] goals?
- Any assumptions (regarding traffic behavior) made during development of the improvement alternatives should be logical and their reasoning should be adequately documented and included in the final traffic analysis report and technical memorandums. Documentation of the alternatives development process including the concepts screening process is vital to the success of the traffic analysis since it helps the review of the final analysis report and support informed decisions.

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[33] http://www.dot.state.fl.us/safety/SHSP2012/SHSP-2012.shtm

- To minimize errors in microsimulation analysis, the alternative analysis models should be built directly from the calibrated microsimulation file.
- The analyst should refrain from switching analysis tools in the middle of a comparison between alternatives since each tool uses different methodology to compute MOE. It is prudent to consistently use one set of tools to evaluate MOEs across all alternatives.

8.2 Travel Demand Forecasting

The traffic analysis for the project alternatives involves forecasting of the future demand for the base model, transferring demand forecast to the alternatives and evaluating performance of various improvement alternatives against the baseline future demand. The following guidelines are provided for future year demand forecasting:

- Future travel demand is estimated for the analysis years agreed in the analysis methodology. Establishment of the future level of demand to be used as a basis for evaluating project alternatives should be in accordance with the guidelines provided in the FDOT Project Traffic Forecasting Handbook.
- The analysis should make sure existing unmet demand at intersection and bottlenecks are incorporated in the future-year traffic demand projections. Any assumptions made to the demand volumes estimations should be documented.
- Future demand should be developed for the same analysis time periods that were used for base conditions. Any adjustments to the future year temporal distribution should be adequately documented.
- Demand forecasts from adopted regional models should be validated to be reasonable estimates of the existing traffic volumes in the subarea level. The validation should account for any demand variations brought about by economic slowdown, proposed changes to land use zoning, proposed transit services enhancements, or development plans that were not included in the adopted travel demand model. Such validation should be included in the analysis methodology memorandum and documented in the traffic analysis report or any interim traffic forecasting memorandum.

> Demand forecasts should be validated for assumptions regarding transportation infrastructure, land use and socioeconomic conditions

- If a new version of the MPO or FDOT model is adopted during the course of analysis, the analyst should consult the Project Manager and the reviewing entity about implications of changing their analysis. This is essential to avoid unnecessary re-do of the analysis.
- All future year turning movement volumes are to be balanced to closely match link forecasts.

- Since travel demand models are not precisely constrained to the system capacity, future year demand estimates should account for the effects of upstream bottlenecks (beyond the analysis area) that would meter the demand flow into the analysis area. When upstream bottlenecks meter the demand, the forecasted demand should be reduced by removing the excess demand. The proportion of excess demand (X) in excess of the available bottleneck capacity is computed as: $X = (D - C)/C$, where D and C are forecasted demand and bottleneck capacity, respectively. Reviewing entities must approve reductions of excess demand during methodology discussions.

Demand forecasts should account for the effect of any known upstream bottlenecks (beyond the analysis area) that meters the flow into the analysis area

- Prior to evaluating the alternatives, the effect of network modifications proposed as part of improvement alternatives on the analysis area on traffic pattern and demand should be established. For example, when additional capacity is proposed as part of an improvement along a very congested corridor, travel demand along the proposed corridor would be higher than expected due to the induced demand from neighboring parallel roadway corridors which experience higher degrees of saturation. As such, the forecast volumes should incorporate such impacts.

8.3 Evaluation of Alternatives

Evaluation of project alternative should proceed only after a general consensus (with the project stakeholders) on viable alternatives has been reached. This will avoid redoing the analysis if new alternatives are suggested later on. The evaluation of project alternatives is performed by assessing all selected MOEs for the project using proper analysis tools as approved in the traffic analysis methodology. MOEs are computed and compared for each project alternative for each analysis year. No-Build alternative MOEs are used as the baseline for comparison. This process results into recommendation of the best alternative that meets the project needs.

The analysis results for each alternative should be ranked based on the degree of impact to the analysis area as supported by the MOEs. The ranking methodology and evaluation matrix used should be concise and clearly documented. The alternative that provides the best overall performance to the analysis area is ranked the highest. It is important that the highest ranked alternative from traffic analysis point of view may not automatically become the overall best alternative (preferred alternative) for the project. Other design, constructability and environmental factors may affect the final selection of the preferred alternative.

The highest ranked alternative from traffic analysis standpoint does not automatically become the preferred project alternative

The following are additional guidance that the analyst should look when evaluating the alternatives using microsimulation analysis may require the following additional guidance:

- The simulation model of the project alternative should be created directly from a calibrated base model. The model parameters adjusted in the calibration process are typically carried forward without change during the alternatives analysis stage, assuming traffic characteristics in the base model do not change. However, future change in the facility type or proposed improvements with design exceptions may dictate modification of some of the calibration parameters. When such modification is necessary, documentation should be provided.

- Model verification/error checking is required to verify there are no coding errors in the model development process that could affect the accuracy of the model. The analyst should review the model input data for the alternative in question and may adjust physical design elements (such as lengths of acceleration/deceleration lanes and location of advance warning signs) in an attempt to improve operations.
- The number of runs and random seeds that were used to calibrate the base model should be used to simulate alternative models.

8.4 Performance Measures of Effectiveness (MOEs)

MOEs are project specific and are selected and agreed upon in the traffic analysis methodology. The selected MOEs are part of the alternatives evaluation criteria and should be included in the evaluation matrix which contain other measures (related to cost and environmental impact) used in the alternatives evaluation. When the purpose of need is refined in the course of analysis and demand additional MOEs, documentation for such change should be provided.

MOEs can be field-measured or computed by analytical and microsimulation tools. The analyst should consult the FDOT MUTS and HCM 2010 for procedures for measuring performance measures in the field.

A comprehensive list of the operational performance MOEs used in traffic analyses is discussed in the FHWA *Traffic Analysis Toolbox Volume VI*[34]. **Table 8.1** presents a list of typical candidate MOEs.

Table 8-1 Typical Candidate Measures of Effectiveness (MOEs)

Operational	Safety
Travel time	Crash rate
Speed	Total Crashes (Crash frequency)
Density	Severity level
Travel-time variance	Level of service of safety (LOSS)
Level of service (LOS)	Crash Modification Factor (CMF)
Volume-capacity (V/C) ratio	
Throughput	
Density	
Queue	

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[34] FHWA Traffic Analysis Tool Volume VI: Definition, Interpretation, and Calculation of Traffic Analysis Tools Measures of Effectiveness

8.4.2 Operational Performance Measures

Traffic operational MOEs can be directly computed/measured or derived from other measures. MOEs that are directly computed/measured are called basic measures while derived measures are computed from the basic measures and other inputs.

Operational measures should focus on the following areas depending on the purpose and need for the project:

- Mobility
- Reliability
- Accessibility
- Environmental quality

Mobility performance measures are related to the quantity (how many people and vehicles are using the facility) and rate of use of the facility. Typical measures that are used to quantify mobility are travel time, delay, speed, throughput computed or measured for the peak period.

Reliability performance measures are used to explain how much mobility varies from time to time or day to day on the facility. Typical reliability measures are travel time index and travel time variance which captures the relative predictability of the travel time. Analysts should review the proposed methodology for estimating reliability measures in the HCM that was prepared as part of Strategic Highway Research Projects 2 (SHRP 2) Project L08[35].

Accessibility measures are related to the user's ability to obtain desired goods, services, or activities through a transportation system. Although one of the ultimate goals of the project, accessibility is most difficult to measure from the traffic analysis stand point. Measurements of accessibility normally consider land use, mobility and mobility substitutes. Accessibility measures are very important on rural areas and they can be computed as access density within a segment of a corridor or percent population within a certain buffer area.

Environmental quality measures are related to NO_x emission and fuel consumption. It should be noted that the United States Environmental Protection Agency (EPA) may not accept environmental quality conformity analyses results that are produced by any tool except EPA approved tools. As such, environmental measures computed from traffic analysis tools may be used for informational purposes only.

8.4.3 Level of Service (LOS)

Commonly MOEs used to qualify the facility performance are HCM LOS and Volume/Capacity (v/c) ratio. Operations with LOS F or v/c greater than one are unacceptable. It is recommended to indicate which users (of the facility) are considered when reporting the LOS—e.g. LOS on this corridor is E for motorists.

LOS resulted from microsimulation analysis is not directly translatable into HCM LOS since microsimulation LOS is calculated from vehicles per hour per lane (vphpl) while HCM LOS is based

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[35] Incorporation of Travel Time Reliability into the HCM, SHRP 2 Project L08

on passenger cars per hour per lane (pcphpl). Additionally, HCM calculates LOS based on hourly during the peak 15-minute period within the analysis hour while simulation LOS calculations are based on the whole simulation period. Microsimulation analysis does not require PHF input. HCM and microsimulation tools also differ on the way they treat random arrivals in the traffic stream. HCM utilizes analytical procedure to account for random arrival effects while microsimulation tools uses statistical distributions to account for randomness in the traffic stream.

As such, LOS computed from microsimulation analysis should be reported as an "estimated LOS". Moreover, HCM precludes the use of the travel speed from microsimulation for LOS assessment of urban streets because microsimulation methods used to calculate delays and running speeds differ from HCM methodologies.

Performance measures obtained from the microsimulation of operations of freeway merge/ diverge and weaving areas should be reported consistent with the methodology described in the HCM. The analyst should avoid averaging densities across all merge/diverge lanes.

8.4.4 Safety Performance Measures

Commonly used safety performance measures include crashes, crash types and crash severity that are expressed as frequency, rates or ratios. Crash rates measure is more powerful than crash frequency because it normalizes the frequency of crashes with traffic exposure.

New performance measures that are introduced by HSM are Crash Modification Factor (CMF) and Level of service of safety (LOSS). LOSS is used to quantify the magnitude of the safety problem into four different classes. LOSS utilizes the SPF concept to reflect how the site is performing with respect to its expected crash frequency and degree of severity at a given AADT. The threshold value for LOSS is the expected average crash frequency plus or minus 1.5 standard deviations.

Moreover, the analyst can review the SHSP or other safety plan for additional safety performance measures and safety goals that can be incorporated in the analysis as the part of the statewide safety plan. In this case, coordination with the District Safety Engineer is essential.

8.5 Sensitivity Testing

All demand forecasts and future improvement concepts are subject to uncertainty. Future changes in land use, driving population, peaking characteristics, or implementation of the planned capacity projects in the vicinity of the analysis area may have dramatic effects on the perceived benefits of the analysis results. As such, evaluation of the alternatives may include assessing how their performances are affected by uncertainties in the assumptions of the input parameters. Additionally, the analyst may use sensitivity or "what if" analysis as an opportunity to determine the strengths and weaknesses of the alternatives in meeting broader project needs. The following sensitivity tests may be performed:

- *Demand Sensitivity* – Traffic demand can be varied to at least a 10% error margin to determine the acceptability of the alternative to the forecasted demand and to identify potential failure locations in the system. Determination of potential failure locations could be used to refine the design or to provide operations flexibilities in the future improvements.

- *Weaving Sensitivity* – The percentage of weaving traffic is typically estimated in projects related to freeway corridors. Altering the weaving traffic percentages by at least a 10% error margin can be used to identify the sensitivity of the alternative to the number of weaving maneuvers.
- *Design Sensitivity* –Modifications to the alternatives design elements may be performed and their effects on the system performance determined. Such modifications may include adding or modifying auxiliary lanes; modifying storage lane lengths; increasing the number of basic lanes; or modifying traffic controls. Additionally, when the alternative includes design exceptions and variations such as narrow shoulders or short vertical curves that are not present under existing conditions, then the sensitivity of the analysis results to those parameters can be considered.
- *Safety Sensitivity* – Modifications to the design elements and operation of the facility may be performed and their effect on safety of the project alternative analyzed.

8.6 Alternatives Analysis Report

A stand-alone report or section for a larger document will be developed at the conclusion of the evaluation of alternatives. The report contains No-Build and all project alternatives including alternatives that were considered but rejected from detailed analysis. The report also include all necessary information that will assist the reviewer in thoroughly reviewing the reasonableness of the results in replicating real world traffic operating conditions. Such information includes input data, verification process, critical area that would need attention (e.g. locations that would experience high flows), assumptions, alternatives development and analysis process including ranking criteria.

For microsimulation analysis, the report include discussion of model development process. The model development process include details about the changes made to the base model when creating project alternatives.

Chapter 9
Analysis Documentation

The traffic analysis report and its supporting documentations, such as technical memorandums and data submitted in the appendices, should be prepared by transportation practitioners who have experience in the respective areas. The purpose of this chapter is to provide guidelines on the requirements for analysis documentation and presentation of the results.

9.1 Presentation of Results

Understanding how the results will be used by decision makers is critical to producing a good and effective traffic analysis report. As such, the analyst should present the traffic analysis results in a manner that is concise and understandable to the intended audience. For instance, elected official and other representatives of the public would prefer to see performance measures that are easily understood by their constituents. In such cases, presentation and format of the report should also target a non-technical audience while allowing a technical reviewer to perform independent analysis and verify the results of the analysis presented in the document.

To enhance a presentation, traffic analysis results can be presented in the following three formats:

- Tabular format
- Graphical format
- Animation (microsimulation analysis only)

The results presented in the above formats should be adequately discussed to enable both technical and non-technical readers comprehend the content of the analysis.

9.1.1 Tabular Summaries

Tables are used to present summaries of the results of the analysis. Raw data from the analysis outputs and other details of the analysis should be attached in the appendices. The outputs from microsimulation analysis should be post-processed to report the average MOEs from multiple simulation runs. Tabular summaries should be prepared to present the results of the comparison of the MOEs for each alternative. Different patterns or colors should be used to discern failing conditions within the elements of the network when comparing the alternatives. Colors used to present key information in the tables should be carefully selected such that the document can maintain its readability when reproduced in black and white ink.

Tabular summaries should be categorized in two sets. The first set would contain tables summarizing analysis results of the entire network. These tables are essential to review the integrity of the analysis and provide information used for general comparative analysis. The second set would include the comparative summary tables that filter information from the first set to compare the MOEs of critical network elements in each alternative.

When HCM based analysis is used, it is recommended to display tabular values and calculated results as they are presented throughout in the HCM.

9.1.2 Graphical Presentation

Graphical presentation of the data and results should be carefully created to help understanding of the results. The analyst should simplify the presentation such that both technical and non-technical audiences can easily understand them. Overdoing the presentation by decorating the graphical summaries should be avoided.

Graphical displays are excellent visual tools and are very effective in identifying the effects of each alternative on traffic operations within the analysis area. The lane schematics and link-node diagrams that were developed in the analysis stage can easily be converted into a tool for displaying the results. An example of the presentation of the results on lane schematic diagrams is shown in **Figure 9.1**. Additionally, a time-series plot that compares MOEs from the simulation outputs can also be prepared to facilitate understanding of the spatial-temporal behavior of the alternatives and eventually aid in making decisions.

9.1.3 Animation

One of the advantages of microsimulation over analytical tools is its ability to describe or demonstrate the problem and potential solutions by animating the individual vehicles trajectories from the model. Animation can be very effective tool to present traffic analysis results to non-technical audience such as elected officials, policy makers and the general public. Like graphical summaries, animation is an excellent visual tool to identify and compare the effects of each improvement alternative on traffic operations.

It is possible to record animation from the analyzed system in the video format and present the video in various public information platforms such as public meetings and project websites. The animation prepared for public presentation or forum should support the goal of the project and audience characteristics. In which case the animation should be created from parts of simulation results that exhibit the findings of the analysis. If it is desired to show a comparative analysis of two alternatives, a side by side display of animations with same traffic loadings should be prepared. Screen shots of animation of critical locations can also be prepared and presented to the public as still images.

Animation is used in the traffic analysis report to complement the results presented in tabular or graphical displays only because of the following challenges:

- Time constraints to review animation in the whole time-space domain.
- Animation provides only a qualitative assessment of the overall performance of an alternative.
- Animation outputs are produced from a single simulation run while MOEs are reported from the averages of multiple runs.

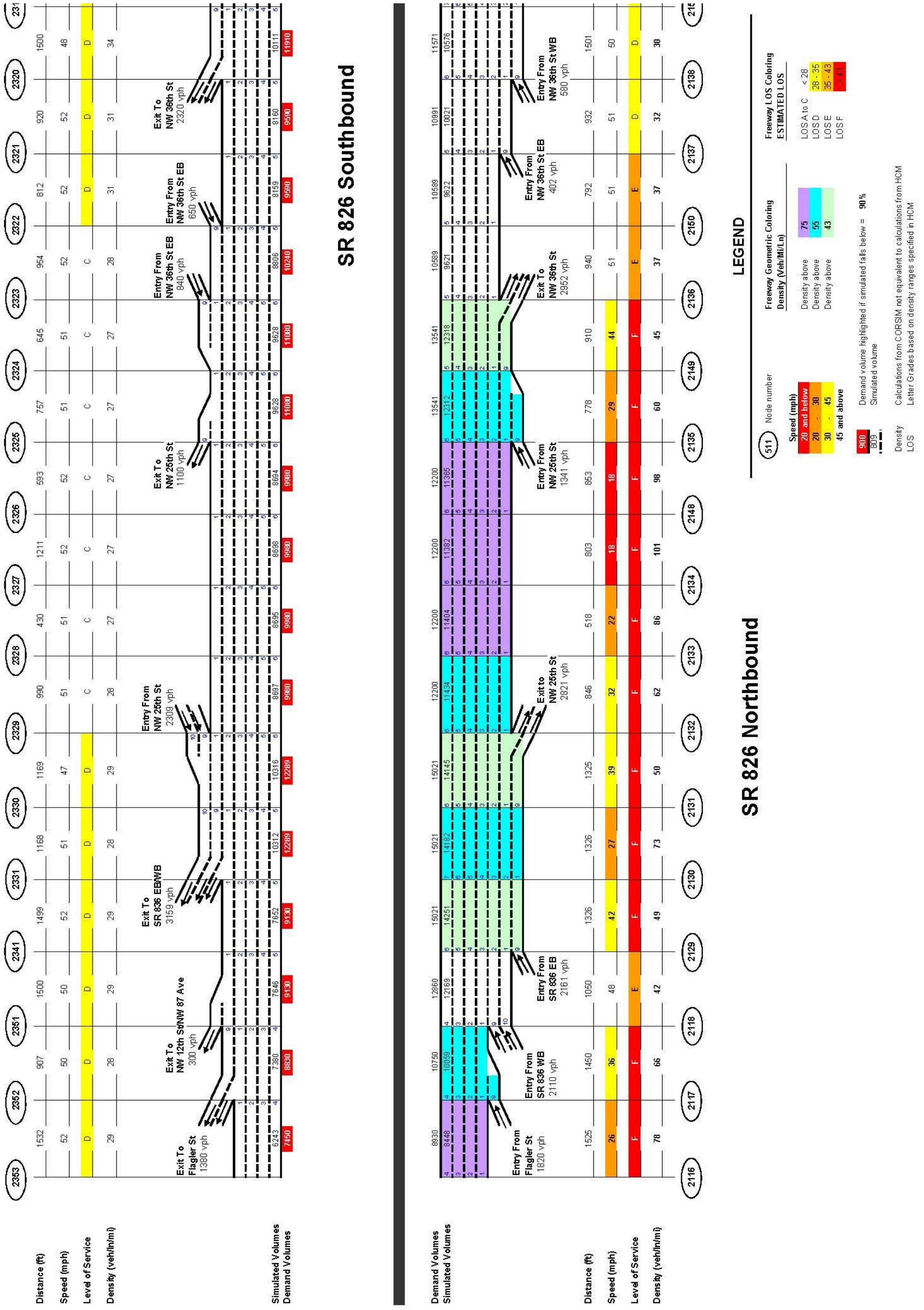

Figure 9-1 Graphical Method of Presenting the Results

In the report, the animation results are presented in the form of screen shots of the animation system with supporting description of the animation.

9.2 Analysis Documentation

Traffic analysis documentation includes two parts—Project Traffic Analysis Report and Technical Memorandums. The project traffic analysis report documents the analysis assumptions, analysis approach, data collection, analysis, and analysis results in detail. Furthermore, the report is developed in detail to document or support assumptions, findings, recommendations and decisions that were made from the analysis. The final report includes the summaries of all interim technical memorandums that were prepared and submitted in the form of technical memorandums or interim reports to address one or more stages of the analysis process. The technical memorandums can be attached in the traffic analysis report as appendices.

9.2.1 Traffic Analysis Report

The size of the report depends on the size and complexity of the project. Regardless of the complexity, the traffic analysis report should contain at least the items presented in **Figure 9.2**. The report should be divided into logical sections that can be easily followed and understood by the intended audience. All graphical and tabular displays presented in the report should be supported by text. The report is developed in a two-stage process. The first stage is the draft report to present the findings of the analysis and the second stage is the final report which incorporates any comments received from the review of the draft report.

9.2.2 Technical Memorandums

Technical memorandums (tech memos) are interim reports documenting technical issues relevant to the analysis process during the course of a project development. The memos give the reviewing agency an opportunity to review study results before the analysis is completed and the final report prepared. The number and contents of the tech memos depend on the type and complexity of the analysis and they should be included in the analysis methodology and agreed upon with the reviewing entity. The reviewing entity must review and concur with the content of the technical memorandums before the analyst prepares the final report.

Generally, the following tech memos may be submitted prior to development of the final traffic analysis report:

- ***Existing Conditions Report.*** This report provides an overview of the condition of the existing transportation network under study. The purpose of this report is to set a context for understanding of the existing conditions in the network and assessing the problem that is to be solved by the traffic study. Its contents are derived from field observations, data collection from various sources, and existing data analysis.

- ***Model Calibration Report***. This report provides documentation of the calibration and validation process and resulting changes made to the base model. The report should provide justification for any changes of the values of the default parameters and supportive statistics which compares field-measured and calibration MOEs. The format for this report is provided in **Chapter 7**.

1. **Title Page**
2. **Executive Summary**
3. **Table of Contents**
    A. List of Figures
    B. List of Tables
4. **Introduction**
    A. Description of the proposed project
    B. Analysis objective and project scope
    C. Project location map
5. **Analysis Methodology**
    A. Analysis methodology and assumptions
    B. Analysis (temporal and spatial) boundary limits
    C. Analysis tool(s)
6. **Data Requirements**
    A. Data requirements and data sources
    B. Data collection methodology
    C. Summary of data collection and field observations
7. **Baseline Analysis (Existing Conditions Analysis)**
    Analytical Approach
    A. Operational analysis of the existing conditions
    B. Safety analysis based on crash data and HSM procedure as appropriate
    C. Multimodal evaluation
    Simulation Approach
    A. Base model development
    B. Model verification/error checking
    C. Model calibration
    D. Model validation
8. **Alternatives Analysis**
    A. No-Build alternative
        i. Future year demand forecasts
        ii. No-Build analysis (operational and safety)
    B. Preliminary alternatives
        i. Development of project concepts
        ii. Screening of concepts
    C. Build alternatives
        i. Alternatives considered
        ii. Traffic volume forecasts, trip pattern/circulation routes & assumptions
        iii. Design considerations
        iv. Model development (simulation approach only)
        v. Operational analysis
        vi. Safety analysis
    D. Alternative evaluation matrix and description of success/failure of alternatives
9. **Conclusions and Recommendations**
10. **References**
11. **Appendices**

Figure 9-2 Typical Traffic Analysis Report Outline

- ***Project Traffic Forecasting Report***. This report presents the traffic forecasting process and documents procedures, assumptions, and results. Its contents include travel demand model description, input data, alternatives, and demand forecasts for each analyzed alternative. The report is important because future year demand forecasts are vital to the accuracy of the alternatives analysis. It is recommended that traffic forecasts results be agreed to by all parties before the analyst proceed with analyzing the alternatives.
- **Alternative Analysis Report**. This report summarizes the interim results of the alternatives analysis.

9.2.4 Model Manual

Model manual (or model development report) is prepared to support and document the analyses performed on complex systems using microsimulation tools. Simple analyses such as analysis of isolated locations do not require preparation of separate analysis development reports. An example of the analysis development report is the simulation model manual which documents input data, field observations, model verification, calibration, and outputs. Also included in the model manual are all electronic input files used in the analysis process. The purpose of the model manual is to:

- Provide sufficient materials to review and verify the accuracy of the model against real world conditions
- Enable an independent analysis to be conducted
- Maximize the return on the considerable resources expended in developing the model by making the model available to use on other phases of the projects
- Document lessons learned and best practices for the benefit of future applications.

Different model manuals can be prepared for the base model and for each alternative simulated. A typical model manual should include all the documentation pertaining to the model development, including the following:

- Description of existing site conditions including all field observations notes
- Traffic volume data (flow rates, traffic volumes, O-D data)
- Geometric data (link-node diagrams, lane schematics)
- Traffic control data
- Data sources
- Model parameters and inputs
- Model calibration and validation
- Model outputs and analysis results
- Model/analysis assumptions

The recommended outline of the model manual is shown in **Figure 9-3**.

1. **Overview**

   Contains a brief statement of the purpose of the study, study area map, existing conditions narrative with discussion of driver behavior, location of physical constraints, and a discussion of the study approach (tools used, method, rationale).

2. **Data Collection**

   Contains a summary of the data collection methods and sources of data; input data (link-node diagrams, lane schematics, arterial turning movement counts—raw and balances, freeway and ramp volumes, O-D tables, traffic control data, transit and multimodal data, field observation. If signal optimization software was used then its input and output files should be included in this section.

3. **Base Model**

   Contains model assumptions, all model input and output files and model verification documentation including all checklists used in the QA/QC process. Coding techniques for complex or unconventional geometrics or operations are included here.

4. **Error Checking**

   Contains error checking process, QA/QC process and results

5. **Base Model Calibration and Validation**

   Contains calibration and validation process narrative, which include calibration targets, measures of effectiveness and documentation supporting evidence of changing default parameters.

6. **Alternatives Analysis**

   Contains input and output data (electronic files), signal optimization files, and MOE summaries, QA/QC documents each future year model analyzed. This section may be divided into subsections covering input data and output data for each analyzed alternative.

Figure 9-3 Model Manual Outline

9.2.4 Review of Traffic Analysis

The review and approval of traffic analysis report is based on the methodology of the analysis and information contained in the submitted report and other interim technical documents which include model manuals. The submitted analysis documentation is subject to an independent review which can include recreating the analysis models. As such, the analyst must submit the model (or analysis) manuals for review prior to the submission of the draft project report. Concurrence on the analysis approach, assumptions, and outputs must be reached prior to report preparation. This approach will help to identify issues and their resolutions very early in the process and consequently avoid delays.

Appendix A – Technical References

These documents were referenced in preparation of this handbook. The analyst may review these documents for detailed information to gain better understanding of the traffic analyses and the tools used to perform such analyses.

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Park, B., and Won, J. *Microscopic Simulation Model Calibration and Validation Handbook*. Publication FHWA/VTRC 07-CR06, Virginia Transportation Research Council, Richmond, VA, 2006. Access Online January 10, 2014. www.virginiadot.org/vtrc/main/online_reports/pdf/07-cr5.pdf

Transport for London. Traffic Modelling Guidelines, TfL Traffic Manager and Network Performance Best Practice, Version 3.0, London, UK, 2010.

Zhang, L., and Holm, P. *Identifying and Assessing Key Weather-Related Parameters and Their Impacts onTraffic Operations Using Simulation*. Publication FHWA-HRT-4-131. FHWA, U.S. Department of Transportation, 2004

Appendix B – Tool Selection Worksheet

Table 14. Tool selection worksheet.

Tool Name: ____ **Version/Release:** __________________________

Vendor Name/Contact Information: ____

1	2	3	4	5
Criteria	Sub-Criteria Relevance	Tool Relevance*	Col 2 x Col 3	Comments
1 Geographic Scope (0 = not relevant, 5 = most relevant)				
Isolated Location				
Segment				
Corridor/Small Network				
Region				
Other: ________________________				
		Subtotal		
		Relevance Weights Above 0		
		WEIGHTED SUBTOTAL		
2 Facility Type (0 = not relevant, 5 = most relevant)				
Isolated Intersection				
Roundabout				
Arterial				
Highway				
Urban				
Rural				
Freeway				
Mainline				
Shoulder				
HOV Lane				
Barrier-separated				
Buffer-separated				
Shoulder HOV				
HOT Lane				
HOV Bypass Lane				
Ramp				
Auxiliary Lane				
Reversible Lane				
Truck Lane				
Bus Lane				
Toll Plaza				
Light Rail Line				
Other: ________________________				
		Subtotal		
		Relevance Weights Above 0		
		WEIGHTED SUBTOTAL		

Table 14. Tool selection worksheet (continued).

1	2	3	4	5
Criteria	Sub-Criteria Relevance	Tool Relevance*	Col 2 x Col 3	Comments
3 Travel Mode (0 = not relevant, 5 = most relevant)				
SOV				
HOV				
HOV 2+				
HOV 3+				
As percentage of total vehicles				
Bus				
Local				
Express				
Train				
Truck				
Motorcycle				
Bicycle				
Pedestrian				
Other: ____________________________				
		Subtotal		
		Relevance Weights Above 0		
		WEIGHTED SUBTOTAL		
4 Management Strategy/Application (0 = not relevant, 5 = most relevant)				
Freeway Management				
Adding general purpose lanes				
Adding HOV lanes				
Geometric improvements				
Interchange geometric improvements				
Electronic toll collection (ETC)				
Fixed-time ramp metering				
Adaptive/actuated ramp metering				
Centrally controlled metering				
Add HOV bypass				
Freeway connector metering				
Reconstruction management				
Arterial Intersections				
Adding lanes				
Pre-timed signal				
Actuated signal				
Traffic adaptive control signal				
Centrally controlled signal				

Table 14. Tool selection worksheet (continued).

1	2	3	4	5
Criteria	Sub-Criteria Relevance	Tool Relevance*	Col 2 x Col 3	Comments
4 Management Strategy/Application (0 = not relevant, 5 = most relevant) (continued)				
Work Zone/Special Events				
Road closures due to events				
Traffic diversion due to events				
Work zone management				
Work zone safety monitoring				
Maintenance/construction vehicle AVL				
Maintenance/construction vehicle maintenance				
Advanced Public Transportation Systems				
Fleet maintenance				
Automatic scheduling for transit				
Automatic vehicle location (AVL)				
Transit security systems				
Electronic transit fare payment				
Advanced Traveler Information Systems				
Pre-trip ATIS				
Telephone-based traveler information				
Web-based traveler information				
Kiosks				
Handheld traveler information				
En-route ATIS				
Highway Advisory Radio (HAR)				
Dynamic Message Sign (DMS)				
Transit DMS				
In-vehicle/handheld traveler information				
Rail Grade Crossing Monitor				
Commercial Vehicle Operations				
Fleet administration				
Electronic screening				
Weigh-in-motion				
Electronic clearance				
Safety information exchange				
On-board safety monitoring				
Electronic roadside safety inspection				
HazMat incident response/management				

Table 14. Tool selection worksheet (continued).

1	2	3	4	5
Criteria	Sub-Criteria Relevance	Tool Relevance*	Col 2 x Col 3	Comments
4 Management Strategy/Application (0 = not relevant, 5 = most relevant) (continued)				
Advanced Vehicle Control & Safety System				
Ramp rollover warning				
Downhill speed warning				
Longitudinal collision avoidance				
Lateral collision avoidance				
Intersection collision avoidance				
Vision enhancement for crashes				
Safety readiness				
Automated highway system				
Traffic Surveillance				
CCTV/radar/microwave				
Loop detectors				
Probe vehicles				
Travel Demand Management (TDM)				
Dynamic ridesharing				
Congestion pricing				
Flex-time				
Park and ride facilities				
Preferential parking				
Trip reduction programs				
Traffic Calming				
Roundabout				
Raised intersection				
Speed humps				
Speed control				
Parking Management				
On-street				
Off-street/parking garages				
Bicycle Program				
Bike lane/path routing				
Bike racks/lockers				

Table 14. Tool selection worksheet (continued).

1	2	3	4	5
Criteria	**Sub-Criteria Relevance**	**Tool Relevance***	**Col 2 x Col 3**	**Comments**
4 Management Strategy/Application (0 = not relevant, 5 = most relevant) (continued)				
Weather Management				
Data collection				
Information processing/distribution				
Automated treatment				
Winter maintenance				
Resource allocation management				
Other: ______________________				
		Subtotal		
		Relevance Weights Above 0		
		WEIGHTED SUBTOTAL		
5 Traveler Response (0 = not relevant, 5 = most relevant)				
Route Diversion				
Pre-Trip Route Diversion				
En-Route Route Diversion				
All-or-nothing				
Capacity restraint				
Stochastic/probabilistic				
Incremental				
Equilibrium				
Dynamic				
Transit system-based				
Route-based				
Timetable-based				
Multipath				
Other: ______________________				
Departure Time Choice				
Mode Shift				
Logit				
Nested logit				
Other: ______________________				

Table 14. Tool selection worksheet (continued).

1	2	3	4	5
Criteria	**Sub-Criteria Relevance**	**Tool Relevance***	**Col 2 x Col 3**	**Comments**
5 Traveler Response (0 = not relevant, 5 = most relevant) (continued)				
Destination Choice				
Gravity model				
FRATAR model				
Trip chaining				
Parking cost-based				
Other: ____________________				
Induced/Foregone Demand				
Other: ____________________				
		Subtotal		
		Relevance Weights Above 0		
		WEIGHTED SUBTOTAL		
6 Performance Measures (0 = not relevant, 5 = most relevant)				
LOS				*Circle all that apply:* Aggregated by link/node/vehicle type/facility type/regionwide/other: _____
Speed				link/node/vehicle type/facility type/regionwide/other: _____
Space-mean speed				link/node/vehicle type/facility type/regionwide/other: _____
Time-mean speed				link/node/vehicle type/facility type/regionwide/other: _____
Travel Time				link/node/vehicle type/facility type/regionwide/other: _____
Volume				link/node/vehicle type/facility type/regionwide/other: _____
Detector volume				link/node/vehicle type/facility type/regionwide/other: _____
Link average volume				link/node/vehicle type/facility type/regionwide/other: _____
Travel Distance				link/node/vehicle type/facility type/regionwide/other: _____
Ridership				link/node/vehicle type/facility type/regionwide/other: _____
Transit frequency				
Transit reliability				
Average Vehicle Occupancy (AVO)				link/node/vehicle type/facility type/regionwide/other: _____
V/C Ratio				link/node/vehicle type/facility type/regionwide/other: _____
Density				link/node/vehicle type/facility type/regionwide/other: _____
VMT/PMT				link/node/vehicle type/facility type/regionwide/other: _____
VHT/PHT				link/node/vehicle type/facility type/regionwide/other: _____
Delay				link/node/vehicle type/facility type/regionwide/other: _____
Stopped delay				link/node/vehicle type/facility type/regionwide/other: _____
Intersection delay				link/node/vehicle type/facility type/regionwide/other: _____
Total delay				link/node/vehicle type/facility type/regionwide/other: _____
Queue Length				link/node/vehicle type/facility type/regionwide/other: _____
Number of Stops				link/node/vehicle type/facility type/regionwide/other: _____

Table 14. Tool selection worksheet (continued).

1	2	3	4	5
Criteria	Sub-Criteria Relevance	Tool Relevance*	Col 2 x Col 3	Comments
6 Performance Measures (0 = not relevant, 5 = most relevant) (continued)				
Crashes/ Accidents				link/node/vehicle type/facility type/regionwide/other: _____
Accidents by severity				link/node/vehicle type/facility type/regionwide/other: _____
Incident Duration				link/node/vehicle type/facility type/regionwide/other: _____
Travel Time Reliability				link/node/vehicle type/facility type/regionwide/other: _____
Emissions				link/node/vehicle type/facility type/regionwide/other: _____
Fuel Consumption				link/node/vehicle type/facility type/regionwide/other: _____
Noise				link/node/vehicle type/facility type/regionwide/other: _____
Vehicle Operating Costs				
Agency operating costs				
Mode Split				link/node/vehicle type/facility type/regionwide/other: _____
Monetized Benefits				link/node/vehicle type/facility type/regionwide/other: _____
Net Benefit				link/node/vehicle type/facility type/regionwide/other: _____
Implementation Cost				link/node/vehicle type/facility type/regionwide/other: _____
Benefit/Cost				link/node/vehicle type/facility type/regionwide/other: _____
Other: ___________________________				link/node/vehicle type/facility type/regionwide/other: _____
		Subtotal		
		Relevance Weights Above 0		
		WEIGHTED SUBTOTAL		
7 Tool/Cost Effectiveness (0 = not relevant, 5 = most relevant)				
Tool capital cost				Price:
Level of effort/training				Training classes available:
Easy to use				
Windows-based				
Drag-and-drop capabilities				
Popular/well-trusted				Years in the U.S. market:
Hardware requirements				Recommended minimum hardware:
Data requirements				
Volume				
Geometry				
Road conditions				
Signal or meter phase/timing				
Node requirements				
Link requirements				
O-D tables				

Table 14. Tool selection worksheet (continued).

1	2	3	4	5
Criteria	Sub-Criteria Relevance	Tool Relevance*	Col 2 x Col 3	Comments
7 Tool/Cost Effectiveness (0 = not relevant, 5 = most relevant) (continued)				
Turn movements/fractions				
Traffic composition				
Occupancy				
Control devices				
Spacing				
Computer run time				Average run time:
Post-processing requirements				
Metric option available				
U.S. standards option available				
Documentation				
User's Manual				Where to download:
Newsgroup available				Newsgroup address:
Chat rooms available				Chat room address:
E-mail lists available				How to join list:
User support				Tech support contact:
Free/affordable annual cost of support				Price:
Toll-free support available				Toll-free number:
24-hour support available				24-hour support number:
Rapid response				Turnaround time:
Key parameters can be user-defined				
Default values are provided				
Integration with other software				Compatible software:
Geocoding to GIS available				
Data exchange				
Animation/presentation features				
Dynamic				
Passive				
Network size limitations				Size limitations (nodes, links, vehicles):
Compatible with most operating systems				Ideal OS:

Table 14. Tool selection worksheet (continued).

1	2	3	4	5
Criteria	Sub-Criteria Relevance	Tool Relevance*	Col 2 x Col 3	Comments
7 Tool/Cost Effectiveness (0 = not relevant, 5 = most relevant) (continued)				
Other model capabilities/conditions				
Oversaturated conditions				
Weaving				
Effects of Incidents (objects, breakdowns, crashes)				
Weather effects (rain, ice, wind, snow)				
Queue spill back				
Effects of pedestrians				
Effects of bicycles/motorbikes				
Effects of parked vehicles				
Effects of commercial vehicles				
Acceleration/deceleration effects				
Models U.S. (right-hand side) roadways				
Other: ______________________				
Subtotal				
Relevance Weights Above 0				
WEIGHTED SUBTOTAL				

6	7	8	9
Criteria **(0 = not relevant, 5 = most relevant)**	Criteria Weight	Weighted Subtotals	Col 7 x Col 8
1 Geographic Scope			
2 Facility Type			
3 Travel Mode			
4 Management Strategy/Applications			
5 Traveler Response			
6 Performance Measures			
7 Tool/Cost Effectiveness			
TOTAL SCORE			

* Use the following values for Tool Relevance: 0 = not featured, 5 = strongly featured by the tool.

FLORIDA DEPARTMENT OF TRANSPORTATION

TRAFFIC ANALYSIS HANDBOOK

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