CORSIM Modeling Guidelines

September 2012

Nevada Department of Transportation
1263 S. Stewart Street
Carson City, Nevada 89712
775-888-7000
www.nevadadot.com

Brian E. Sandoval
Governor

Rudy Malfabon, P.E.
Director

This page intentionally left blank.

CORSIM MODELING GUIDELINES

September 2012

This page intentionally left blank.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ATTACHMENTS

GLOSSARY[1]

CORSIM: CORridor SIMulation. A microscopic traffic simulation tool supported by the TSIS environment.

FRESIM: FREeway SIMulation. The part of the CORSIM simulation that models freeway operations.

Microsimulation: Modeling of individual vehicle movements on a second or sub-second basis for the purpose of assessing the traffic performance of highway and street systems.

MOE: Measure of Effectiveness. An output measurement from a simulation tool used as a measure of the performance of the traffic flow on a network.

Model: A specific combination of modeling software and analyst-developed input parameters for a specific application. A single model may be applied to the same study area for several time periods and several existing and future improvement alternatives.

NETSIM: NETwork SIMulation. The part of the CORSIM simulation that models surface-street operations.

Time step: The smallest unit of time at which CORSIM moves vehicles (updates vehicle positions).

TRAFED: A graphical user interface-based editor that allows you to easily create and edit traffic networks and simulation input for the CORSIM model.

TRAFVU: TRAF Visualization Utility. A user-friendly graphics postprocessor that displays traffic networks, animates simulated traffic flow operations, animates and displays simulation output measures of effectiveness, and displays user-specified input parameters for simulated network objects.

TRF: A file that contains the input data used to define a CORSIM network and to drive the CORSIM simulation for a single simulation case.

TSIS: Traffic Software Integrated System. The integrated development environment that hosts the CORSIM simulation and its support tools.

[1] Definitions are from FHWA's *Traffic Analysis Toolbox Volume IV* (1).

This page intentionally left blank.

1.0 INTRODUCTION AND OVERVIEW

1.1 PURPOSE OF THE CORSIM MODELING GUIDELINES

The Nevada Department of Transportation (NDOT) developed the CORSIM Modeling Guidelines (Guidelines) to provide consistency in the procedures for accepting and approving technical methodologies for CORSIM analysis. The purpose of the Guidelines is to document NDOT's minimum requirements, and to provide appropriate checklists and guidance to illustrate the CORSIM modeling process. NDOT's goal is to detail the procedures and techniques used to create accurate, reproducible, reliable, and defendable CORSIM models that will result in consistent analysis across all transportation projects under NDOT jurisdiction in the State of Nevada (Nevada).

The target audience of the Guidelines is both model users/consultants(modeler) and decision makers/reviewers. The Guidelines allow both users and decision makers to follow a consistent process, which ultimately benefits both parties.

These Guidelines are not a CORSIM training manual. Rather, the intent is to explain how to apply CORSIM to transportation projects within Nevada in an appropriate and consistent manner that conforms to NDOT's expectations. It provides overall guidance. However, when the process, descriptions, and methods are already documented, the Guidelines refer to those publications.

Guidance is provided on:

- How to define and scope a CORSIM study;
- How, when, and what data to collect;
- How to consistently build a CORSIM model;
- How to check and fix errors;
- How to calibrate and validate a CORSIM model; and
- How to select appropriate Measure of Effectiveness (MOE) and document the results.

The Guidelines are based on previously published information (e.g., reports, manuals, and research papers), results from completed CORSIM projects, and NDOT's experience on working with and reviewing CORSIM models.

The Guidelines do not provide guidance on whether CORSIM is the appropriate tool for a project. Other available guidance and engineering judgment is to be used to determine the right tool to use for a given project and circumstance.[2] The Guidelines assume that CORSIM is the right tool for the subject project and it provides guidance on how to conduct a CORSIM study. In other words, the Guidelines are to be consulted when CORSIM is already selected as the appropriate traffic analysis tool for a project.

[2] Volumes 1 and 2 from FHWA's Traffic Analysis Tools provide guidance on selecting the appropriate tool for traffic analyses.

1.2 CORSIM OVERVIEW

CORSIM is the simulation model/system of the Traffic Software Integrated System (TSIS) developed and sponsored by Federal Highway Administration (FHWA). TSIS is an integrated development environment that hosts CORSIM and its support tools. CORSIM is a microsimulation model that models individual vehicle movements based on car-following and lane-changing theories on a second-by-second basis (time-step simulation) for the purpose of assessing traffic performance on a roadway network. CORSIM is a stochastic model that incorporates random processes to model complex driver, vehicle, and traffic system behaviors and interactions.

CORSIM is the predominant microsimulation used in Nevada, and the preferred microsimulation software used by NDOT. Based on prior approval by NDOT, other microsimulation models may be used if the purpose and scope of a project justifies their use. The methodologies described in the Guidelines generally apply to all microsimulation models.

1.3 RECOMMENDED REFERENCES

The primary sources used in preparation of the Guidelines were the following:

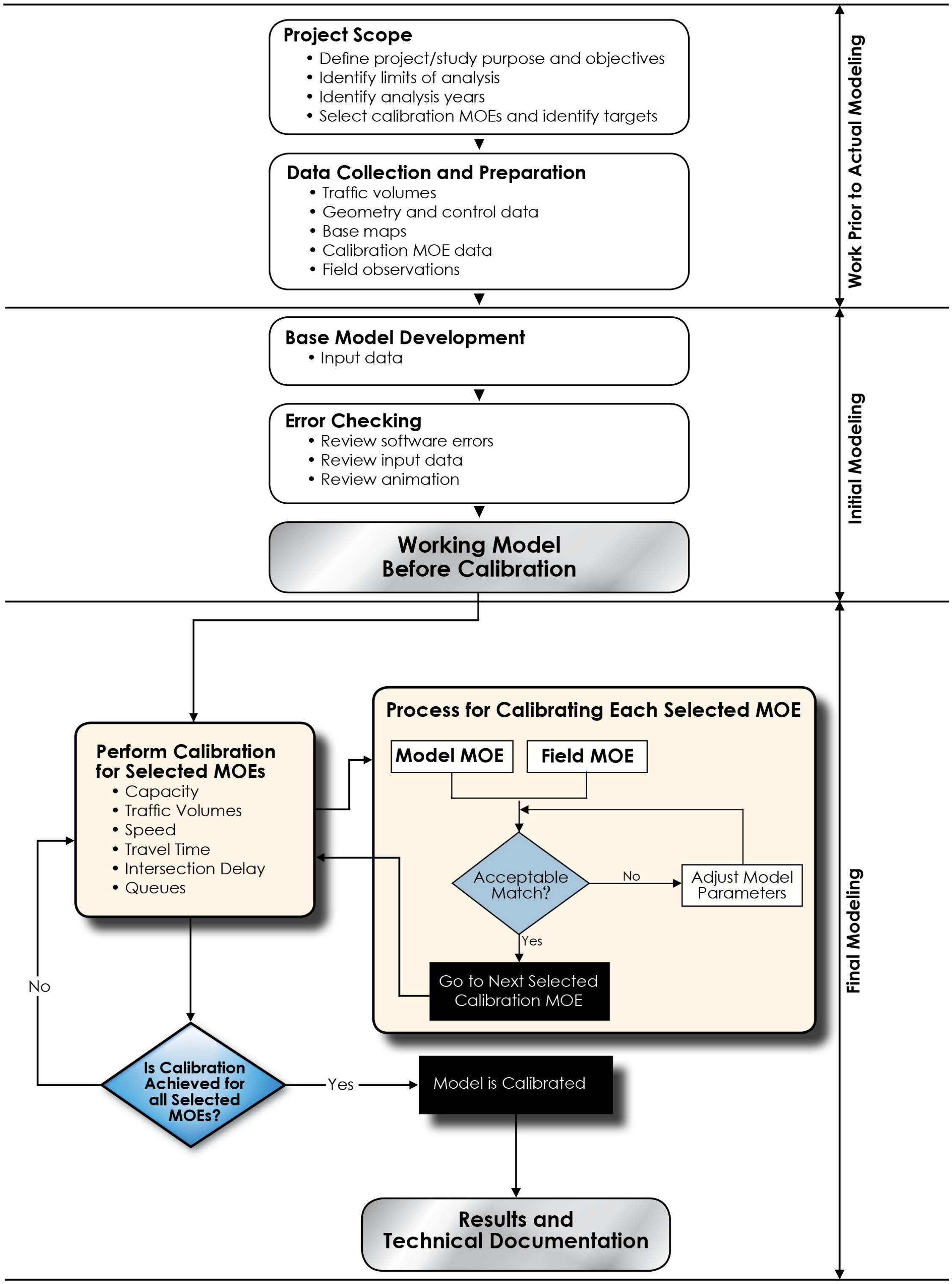
- *Traffic Analysis Toolbox Volume IV: Guidelines for Applying CORSIM Microsimulation Modeling Software* (1); and
- *Advanced CORSIM Training Manual* (2).

Most of the content included in the Guidelines is adapted or referenced from these two sources. Users are encouraged to refer to these sources for detailed explanation of subjects covered herein. These two sources are included in the list of references. In addition, a bibliography list that includes other CORSIM resources used in preparation of this Guidelines is provided. Readers are encouraged to review all of these resources for additional information.

1.4 CORSIM MODELING PROCESS

The CORSIM modeling process is generally illustrated in Figure 1. This flowchart is an adaptation of the process developed by FHWA (1) and the Minnesota Department of Transportation (MnDOT) (2). It provides direction on several stages of the modeling process and is helpful when preparing a scope of work for any CORSIM project. Chapters 3 through 8 of the Guidelines describe each stage illustrated in this flowchart.

Figure 1: CORSIM Modeling Process Flowchart



Adapted from the *Traffic Analysis Toolbox Volume IV* (1).

2.0 NDOT GENERAL MODELING REQUIREMENTS

2.1 METHODOLOGY MEMORANDUM

A Methodology Memorandum is required to be submitted to NDOT for approval prior to performing a CORSIM study. The purpose of the Methodology Memorandum is to clearly document the study's scope, approach, technical guidelines, tools, assumptions, and any other key items that need to be reviewed and agreed upon with NDOT. The goal is to mutually agree on the scope of the subject study and provide for early coordination. A checklist of items to include in the Methodology Memorandum is provided in Table 1. This checklist is required to be submitted to NDOT along with the Methodology Memorandum. A modeling methodology meeting is to be requested if the modeler believes that certain assumptions and/or the methodology needs clarification or refinement. The final traffic report and CORSIM models are to conform to the approved Methodology Memorandum.

2.2 MINIMUM CRITERIA FOR NDOT AND FHWA ACCEPTANCE OF CORSIM MODELS

Table 2 is a checklist of the minimum criteria to be met for CORSIM models to be accepted for review by NDOT. This checklist is required to be submitted to NDOT along with the final deliverables. Note that submittal of this checklist does not imply approval of the models.

Table 1: Methodology Memorandum Content Checklist

Item	Description	Check
Project Description and Background	Brief information about the project (purpose, general study area, etc.)	
Technical Guidance and Standards	Technical guidance and standards to be followed along with their version (HCM, MUTCD, NDOT Access Management Standards, etc.)	
Traffic Analysis Tools	Software to be used along with their version (CORSIM, HCS, TRAFFIX, etc.)	
Study Limits	Geographic limits of the analysis. This is to be consistent with the NDOT CORSIM Modeling Guidelines. List all study intersections to be included.	
Analysis Years	Design, opening and interim years.	
Analysis Scenarios	Existing, No-Action, Build - describe build alternatives to the extent possible.	
Analysis Periods	Modeling periods and multiple time periods description . The use of multiple time periods should conform to NDOT CORSIM Modeling Guidelines.	
Existing Conditions	Description of existing conditions and/or how existing analysis will be performed.	
Data Sources	List of sources of data and relevant information.	
Traffic Operations Analysis Calculations/Assumptions	Signal timing/phasing, i.e., whether to use optimized timing or actual timing data, peak hour factors, etc.	
Truck Percentages	Truck percentage to use for existing and future scenarios and their calculation/estimation.	
Storage Length Calculation Method	How the turn bay lengths will be calculated.	
Level of Service Threshold	LOS standard for each facility type. For intersections, document the details of the criteria (by movement, by approach, by overall intersection) and explain source or basis of the selected LOS standard.	
Traffic Forecasts	General methodology for projecting traffic forecasts. Note that a separate Traffic Forecast Memorandum is needed for NDOT Traffic Information Division approval of the projected volumes per NDOT Traffic Forecasting Guidelines. Note if the Traffic Information Division approved the traffic forecasts.	
CORSIM Coding and Analysis Assumptions	Documentation of support tools (if to be used) for intersection timing/optimization (such as Synchro, TRANSYT-7F, TEAPAC etc), pre-timed versus actuated control for signals, free-flow speeds (measured versus estimated/assumed). Coding items, such as O-Ds, conditional turning movements, handling weave/merge/diverge, and node numbering convention are to conform to the NDOT CORSIM Modeling Guidelines. HOV lanes, express lanes/managed lanes, and ramp meters are to be addressed.	
Calibration Approach	Calibration approach is to follow the methodologies described in the NDOT CORSIM Modeling Guidelines.	
Calibration MOEs, Locations, Targets	Calibration MOEs, locations to be calibrated and targets for acceptable match.	
Selected MOEs for Evaluation	List of MOEs for evaluation and alternatives analysis along with the selected threshold for successful operations. Clearly state if intersection/arterial MOEs will be reported from CORSIM output or from the signal timing tool used.	
Additional item(s)	Any unique item(s) that is appropriate to be discussed/approved by NDOT.	
Comments:		

Table 2: Minimum Criteria for Review of CORSIM Models Checklist

Criteria	**Met?**
Latest version of CORSIM is used (as of project start date).	
Models run without errors on a balanced traffic network that has reached equilibrium.	
Balanced traffic volumes from approved traffic forecasts are used.	
References are documented.	
Approved Methodology Memorandum is followed.	
Analysis years are as per approved Methodology Memorandum.	
Model geographical limits are as per approved Methodology Memorandum.	
Analysis time periods are as per approved Methodology Memorandum.	
Truck percentages are as per approved Methodology Memorandum.	
Node numbering conforms to NDOT CORSIM Modeling Guidelines.	
Origin-Destination (O-D) tables are developed and entered for all freeway entrances and exits.	
Conditional turning movement volumes are entered at each appropriate location.	
Grades of 4 percent or more are coded if longer than 1,000 ft.	
Freeway radii less than 2,500 feet are entered for mainline links, flyover ramps, and loop ramps.	
Model is calibrated consistent with the requirements of NDOT CORSIM Modeling Guidelines.	
Calibration is completed for the MOEs listed and approved in the Methodology Memorandum.	
All calibration targets listed in the approved Methodology Memorandum are met.	
All changes to calibration parameters are documented.	
Results are based on calculated number of runs (minimum 10 runs).	
For alternative comparison, same set of random seeds are used.	
Results are based on several MOEs, not just the service measure and the resulting LOS.	
MOEs for merge/diverge/weaving areas are reported based on "by-lane" data following HCM methodology.	
Start and end points for all alternatives are the same.	
Each assumption, calibration or non-calibration related, is documented throughout the modeling process.	
Comments:	

3.0 CORSIM PROJECT DEFINITION AND SCOPING

3.1 STUDY PURPOSE AND OBJECTIVES

Study purpose and objectives are to be clearly identified before starting the actual CORSIM modeling. Who, what, where, when, and why a study is being conducted must be clearly defined. The study's purpose and objectives must provide enough detail for independent reviewers to understand a project's context.

When scoping a project, sufficient time and resources to develop and calibrate the model must be allocated. *Guidance on the Level of Effort Required to Conduct Traffic Analysis Using Microsimulation* (5) provides guidance on the level of effort required for different project sizes.

3.2 ANALYSIS YEARS

In most operational studies, the analysis is for existing conditions or for short-term improvements (within five years). For roadway/design projects, NDOT's design year criterion is "20 years beyond opening." Other types of studies may have different project-specific operational analysis horizon years. Depending on the type of project, an opening year and/or interim year analysis may or may not be needed. These analyses years are to be decided during the project definition and scoping, and are to be described with justification in the Methodology Memorandum for NDOT approval.

3.3 LIMITS OF ANALYSIS

The geographic and temporal limits of the analysis are to capture all of the expected congestion to ensure a reliable analysis and to provide a valid and consistent basis for comparing alternatives.

3.3.1 Geographical Limits

The geographical limits of the CORSIM model are required to be beyond the physical limits of the project to account for the impact of the project on adjacent roadways as well as the impact of the adjacent roadways on the project.

The geographical limits of a freeway project must take into account significant sources of traffic upstream and bottleneck conditions downstream. In urban areas, the geographic limits must include <u>at least</u> one interchange on either side of the project. The limits may need to be extended beyond adjacent interchanges, especially in areas where interchanges are closely spaced. Furthermore, if there is a significant interchange beyond the adjacent interchange (such as a "system-to-system interchange" or a "service interchange" that may influence or be influenced by the project), it is required to be included in the CORSIM modeling network. Note that the determination of the geographic limits of a project is a key component of the Methodology Memorandum and requires NDOT's review and approval.

Ramp terminal intersections are required to be part of the CORSIM model. Signalized intersections immediately adjacent to the ramp terminal intersections (if within 0.5 mile) are also required to be included. Additional closely-spaced intersections may also be required depending on the specific project circumstance.

The geographical limits of an arterial project must take into account upstream metering and the downstream queuing of traffic because of traffic signals. For arterial projects, the model network is required to extend at least one signalized intersection beyond the intersections within the boundaries of the improvement up to a 0.5 mile distance.

3.3.2 Temporal Limits (Multiple Time Periods)

The modeling period is required to be more than one hour to capture the build up to peak congested conditions, the peak congestion period, and the dissipation of peak congested conditions.[3] Multiple time periods are entered to account for traffic fluctuations within the modeling period. Duration of each time period can be 30 minutes, although 15-minute time periods are preferred. Traffic fluctuation data on freeways in Southern Nevada may be obtained from the sensor data published in Regional Transportation of Southern Nevada's (RTC) "Interactive Dashboard," which is located on their website (www.rtcsouthernnevada.com). A similar system will be available for Reno/Sparks urban area in the near future. Furthermore, for all areas in Nevada, NDOT Traffic Information Division expects to collect permanent and portable count station data in 15-minute increments, which will be available upon request. Traffic fluctuations could be obtained from these NDOT count station data.

The following provides specific guidance that is required to be applied depending on the area and analysis horizon.

<u>For short-term (existing and up to five years) analysis for all urban and urbanized areas except for Las Vegas Area:</u> The modeling period is to be a minimum of **two hours** comprising of four 30-minute time periods, although eight 15-minute time periods are preferred. The first 30-minute time period reflects the build up to the peak conditions; the second and third 30-minute time periods reflect the actual peak period; and the last 30-minute time period reflects the dissipation of peak conditions. The volumes for each time period are to be based on actual existing count data or proportions of existing count data for future analysis.

<u>For short-term (existing and up to five years) analysis for the urban Las Vegas area:</u> In general, the Las Vegas urban area experiences peak periods longer than one hour (usually two hours of congestion or two-hour peak congestion). To account for the build up and dissipation of this two-hour peak congestion, the modeling period for Las Vegas projects is to be **three hours**, comprising of six 30-minute time periods, although twelve 15-minute time periods are preferred. The first 30-minute time period reflects the build up to the peak conditions; the second, third, fourth, and fifth 30-minute time periods reflect the actual peak period; and the last 30-minute time period reflects the dissipation of peak

[3] Modeling Period is the entire simulation period that includes build up to congestion/peak, the peak period, and the dissipation of congestion/peak. Time periods are the individual time slices (usually 15 or 30 minutes) within the modeling period. Peak period reflects the actual peak conditions.

conditions. The volumes for each time period are to be based on actual existing count data for existing conditions analysis. For future analysis, the calculated proportions of existing count data are to be used.[4] Areas within urbanized Clark County, but not necessarily in the urban core of Las Vegas, may experience peak congestion periods that do not extend beyond two hours. For those cases, a two-hour modeling period with four 30-minute time periods (or eight 15-minute time periods) may be proposed with supporting data. On the other hand, there may be cases where the congested peak period is greater than two hours, requiring more than three hours to be modeled. In all cases the congested time periods are to be captured. The time of day volume and/or density plots are also to be provided in order to justify the selected modeling period.

For long-term (more than five years) future analysis for all areas: The modeling period is to be a minimum of **two hours** with four time periods. The first 30-minute time period reflects the build up to the peak conditions; the second and third 30-minute time periods reflect the actual peak period; and the last 30-minute time period reflects the dissipation of peak conditions. Forecasted volumes for each 30-minute time period are to be based on the calculated proportions from existing volumes.[4] If an existing count is not available, such as the case where the analyzed roadway does not currently exist, the modeler is to calculate the volumes based on available count data in the vicinity of the project.

For areas where only hourly data are available, such as from NDOT's seven-day, hourly count data (i.e., no 15-minute or 30-minute counts are available), the modeling period is to still be more than one hour to account for build up to peak conditions and dissipation of peak conditions. To accomplish this, the method presented below may be followed. This method is only applicable to limited cases where actual 15-minute or 30-minute interval count data are not available and cannot be collected. Use of this technique or an alternative analysis method must be pre-approved by NDOT prior to application. The modeling period is to be a minimum of **two hours** consisting of three time periods as follows:

- First time period = 30 minutes to reflect build up of peak conditions. Calculations are based on the one hour volume prior to peak hour (i.e., apply proportion of previous hour's volume to peak hour volume).
- Second time period = 60 minutes to reflect the peak period. Actual available peak hour volumes are to be used.
- Third time period = 30 minutes to reflect the dissipation of peak conditions. Calculations are based on the one hour volume following the peak hour (i.e., apply proportion of next hour's volume to peak hour volume).

In summary; in addition to the peak period, build up to and dissipation of peak conditions, and fluctuations within the modeling period shall always be accounted in the models.

[4] To analyze peak periods for future conditions, essentially existing traffic patterns are being applied to the future in order to account for traffic fluctuations and analyze build-up, duration and dissipation of congestion.

Therefore, use of multiple time periods that add up to a modeling period of more than one hour is required. The two exceptions to this statement are as follows:

For small areas where there is only a short period of congestion (less than one hour) or no congestion, a single-peak hour analysis may be considered and proposed. This may be approved when adequately justified and at the sole discretion of NDOT and FHWA.

For oversaturated conditions where the peak congested period has little traffic fluctuations, it may not be required to divide the congested period to shorter time periods. In such a case, dividing the peak volume equally (i.e., no fluctuations) into smaller time periods is not likely to be different from analyzing the peak volume as a single time period. The use of time periods longer than 30 minutes because of oversaturated conditions may be approved when adequately justified and at the sole discretion of NDOT and FHWA. It is noted that this will be a rare situation. Additionally, note that the modeling period shall still be more than one hour.

4.0 DATA COLLECTION AND PREPARATION

4.1 IMPORTANCE OF GOOD DATA

Use of accurate data is critical to ensure reliable results from CORSIM models. If field measured data are entered to the extent possible, the calibration process will be much easier and more accurate. In addition to the basic data such as traffic volumes, geometry and control, all other data (e.g., free-flow speeds, merge/diverge lengths, curves and grades, location of yield signs, storage lengths, traffic volume source/sinks etc.) must be accurate matching actual field conditions.

4.2 MODEL INPUT DATA

4.2.1 Base Mapping

An accurately scaled background image is suggested for coding the network. NDOT maintains aerial images for various locations throughout Nevada. NDOT Imagery Services (775-888-7161) can be contacted to request any available aerial image. In requesting this, consultants must mention that they are working on an NDOT project. Consultants working on other projects may also request available aerial images, subject to a fee.

4.2.2 Geometry and Control Data

Existing geometry data can be collected using online maps (e.g., Google, Bing); however the accuracy of this data must be confirmed through field visit and/or as-built plans. Future geometry data must be based on design plans.

Data for curves and grades may be obtained from design plans.

Control data include stop and yield signs and traffic signal controller data for intersections and ramp meters. For signals, actual signal timing and phasing information are required for evaluation of existing conditions. If the focus is freeway operations, intersections can be coded with pre-timed or actuated control, especially for future scenarios.

4.2.3 Traffic Volume Data

Traffic volumes must be balanced prior to input into the CORSIM models.

Traffic volume counts must be conducted in 15-minute increments. Vehicle classification data must be obtained to calculate/estimate truck percentages. NDOT publishes its *Annual Vehicle Classification Distribution Report* (available at NDOT's website), which documents vehicle classifications by roadway segments for the majority of the state maintained highway system in Nevada. Data from this report may be used if field measured truck volume counts are unavailable or when estimating future truck volumes. The use of truck data is to be approved by the NDOT Traffic Information Division.

If congestion is present at a count location or upstream of it, it must be ensured that all of the demand is captured in the counts. To accomplish this, the count period must start before the onset of congestion and end after the dissipation of congestion.

Counts are ideally collected simultaneously at all count locations within the study corridor or area. If this is not possible because of the number of counts required, counts are to be collected during similar times and patterns. Even with simultaneously collected data, there will be traffic counts that do not balance. The counts must be reviewed to determine probable causes of discrepancies. Depending on the cause of the discrepancies, a method can be selected to reconcile the counts. For counting errors, it may be decided to re-count certain locations. Differences in counts caused by mid-block access locations are to be accounted for by using source/sink data. However, if there are major sources and sinks with continuous in and out activity, then these locations must be modeled as side streets with entry nodes and not with source/sink locations.

4.3 CALIBRATION MOE DATA

Calibration MOE data are collected to compare field conditions to the results of CORSIM, i.e., to perform calibration. Calibration data consist of measuring capacity/saturation flow, traffic volumes, and system performance, namely in terms of travel times, speeds, delays, and queues. Field inspection/visits to observe actual field conditions are also an important part of calibration data.

Capacity and saturation flow data: Capacity can be measured in the field on any street segment by counting the number of vehicles passing a point immediately downstream of a queue of vehicles (queue discharge rate), which is easier to measure than maximum flow rate before breakdown. The queue is to ideally last for one hour, but queues lasting for shorter periods (15 minutes) would allow for a reasonable estimate of capacity. The modeler is to refer to *Traffic Analysis Toolbox Volume IV* (1) and *Traffic Analysis Toolbox Volume III* (3) for details on how to measure capacity in the field. Saturation flow rate at intersections are measured following the Highway Capacity Manual (HCM) methodology (see the "Field Measurement Technique" section in *HCM 2010* (4)).

Traffic volume data: Traffic volume data are collected as described in Section 4.2.3.

Travel time data: Travel time runs along the study corridor are to be performed using the floating car technique (refer to appropriate traffic engineering sources on how to perform travel time runs using floating car technique).

Speed data: Speed data can be obtained either from travel time runs or from field sensor data. If the latter is used, then "detectors" must be set up in CORSIM at the locations of field sensors, and speeds from the field sensors are compared to the speeds from the CORSIM "detectors."

The minimum number of travel time runs required is seven per direction during the **peak period**. As an example, the peak period duration is one hour for a project that requires two-hour simulation (two-hour modeling period); therefore a minimum of seven travel time runs must be performed during this one hour peak period. Additional number of runs will be required during the peak period if the conducted number of travel time runs do not meet the 95 percent confidence level as calculated using the following equation:

$$n = \frac{(t_\alpha)^2 (\sigma)^2}{(E)^2}$$

n is the minimum number of travel time runs required;

$\boldsymbol{t_\alpha}$ is the t-statistic from Student's t distribution for confidence level α and n-1 degrees of freedom for a two-tailed test (confidence level is 95%);

σ is the standard deviation of the speeds;

E is the acceptable error – use 5% of the mean speed. If 5% of the mean speed is less than 2 mph, use 2 mph.

NDOT staff is available to discuss situations where the required minimum number of travel time runs during the peak period exceeds 15 (as calculated from the above equation).

Intersection delay data: Measures of intersection delay can be obtained from surveys of stopped delay on the approaches to an intersection (see *HCM 2010* (4) for the procedure). Measured stopped delay can be converted to control delay following the HCM methodology.

Queue data: Queue data can be collected by counting the number of queued vehicles on a given lane at intersection approaches and freeway ramps. The observations should be done to determine the maximum queue during the entire modeling period. Maximum queue from the field should be compared to maximum queue output from CORSIM. CORSIM's average queue output shall not be used, as CORSIM computes average queue during the entire simulation period accumulated every second, hence includes zero values in its calculation.

A minimum of three "maximum queue" observations shall be performed, which requires queue observations from minimum of three different days. The average of the three observations from the field will be compared with the CORSIM output.

For a particular movement, observing queues on the lane with the longest queue is sufficient. For example, if the queue calibration is to be performed for a left turn movement with dual left turns, calibrating the lane with the longer queue is sufficient; hence maximum queue data should be collected for that lane.

Field inspection: A thorough understanding of field conditions, such as where the congestion is occurring (bottlenecks) and how drivers react to weave/merge/lane drop situations, are invaluable for the calibration process. Visual inspection can identify behavior that is otherwise not apparent in the collected data. Field inspection is also helpful in identifying potential errors in data collection. Field observations must be performed during the times that correspond to the modeling period (usually typical weekday peak periods). Taking photos and videos during field inspection would be helpful. The following is a suggested list of operational observations for the calibration process:

- Identify bottleneck locations and hotspots, clearly documenting what the operating conditions are. Confirm that the situation is not due to non-typical conditions such as bad weather or incidents.
- For exit and entrance ramps with long queues, note the distance the queue backs up and whether it is impacting the freeway or arterial system.
- For closely spaced interchanges, watch to see if cars entering the mainline exit at the adjacent off-ramp.
- Identify end limits of congestion, noting that adjustments may need to be made to model boundaries if the congestion extends beyond the model limits.
- Note any cycle failures at signalized intersections.
- Observe unusual or unique driver behavior and document the influencing factors, such as sight distance limitations, substandard shoulders, and obstructed views.
- Note driver reaction to warning and guide signs, scenery, billboards, etc.
- Observe where drivers begin to line up for an exit.
- Observe driver weave and merging behaviors or patterns.
- Observe yield behaviors at entrance ramps.
- Observe lane change behaviors because of downstream ramps.
- Observe behavior at yield signs at intersections. For example, is the actual operation more free flow for a right turn controlled with a yield sign when turning vehicles have their own receiving lane? If yes, then a yield sign may not need to be coded to simulate this situation.
- Note turn lane queues that spillback into through lanes.
- Note lane usage and reasons for any observed lane utilization pattern.

Field inspection and summary documentation are required to be performed as part of the data collection process. If any assumptions are made regarding data, each is to be clearly documented along with proper justification.

5.0 BASE MODEL DEVELOPMENT

Base models must be verifiable, reproducible, and accurate, as defined herein.

- **Verifiable:** Documentation is adequate so that an independent reviewer can confirm model inputs.
- **Reproducible:** With documentation, an independent modeler is able to recreate the same model from the source data.
- **Accurate:** The model must reflect real-world conditions.

Consistency in developing base models results in easier quality control, reduced mistakes and review time, and increased credibility. A systematic process is required to develop base models. *Traffic Analysis Toolbox Volume IV* (1) and *Advanced CORSIM Training Manual* (2) offer step-by-step guidelines concerning base model development. Rather, the intent of this section is to provide guidance on specific data input requirements and to highlight key items/issues.

5.1 NODE NUMBERING CONVENTION

Using a standard node numbering convention for coding models is required. The purpose of using a standard scheme is to create consistency, which allows for efficient review. When assigning node numbers, the node value at the beginning of the roadway is to be a low number and increased sequentially as one moves down the roadway. The modeler is to allow "gaps" in the numbering to allow for the insertion of additional nodes later in the process. However, the modeler must be careful to not allow too many gaps to avoid the possibility of available numbers running out before the end of the modeled road. Table 3 lists the required node numbering convention, which is adapted from the *Advanced CORSIM Training Manual* (2). When assigning node values at ramps, it is suggested to "pair" the numbers, although this process is not mandatory if it becomes overly complicated. For instance, if there is a ramp junction node of 110, the first node on the ramp link would be 210. For arterial nodes, the modeler would first assign the lowest 900 series node numbers to the study intersections. For example, if there are 20 study intersections in the network, the modeler would code those 901 through 920. The modeler is to use the remaining 900 series node numbers for other arterial nodes. When there are no additional 900 series node numbers, the modeler may use node numbers 1 through 99.

5.2 LINK-NODE DIAGRAM AND LANE SCHEMATICS

It is essential to create a link-node diagram prior to the actual coding in TRAFED. A link-node diagram is the model blueprint for creating the network in CORSIM. The location of nodes and links connecting each are manually presented on the aerial background (if used) or on a CAD drawing prior to coding in TRAFED. This process makes coding more efficient because all nodes are already identified and numbered. A lane schematic complements the link-node diagram and facilitates model creation and review (see *Traffic Analysis Toolbox Volume IV* (1) and *Advanced CORSIM Training Manual* (2) for more information and examples on creating link-node diagrams and lane schematics).

Link-node diagram and lane schematic are required to be submitted for NDOT review.

Table 3: Node Numbering Criteria

Node Series	Range		Description
	From	To	
100s	100	199	Northbound Freeway Mainline
200s	200	299	Northbound Freeway Ramps
300s	300	399	Southbound Freeway Mainline
400s	400	499	Southbound Freeway Ramps
500s	500	599	Eastbound Freeway Mainline
600s	600	699	Eastbound Freeway Ramps
700s	700	799	Westbound Freeway Mainline
800s	800	899	Westbound Freeway Ramps
900s	900	999	Arterials
0s	1	99	Arterials*
* Use 1 to 99 for arterials when 900 series node numbers are not adequate.			

Adapted from the *Advanced CORSIM Training Manual* (2).

5.3 CODING LINK DATA

When coding link data, adherence to the following guidelines is required.

- Code radius for the following:
  - Freeway mainline curves with radii less than 2,500 feet;
  - Freeway loop ramps; and
  - Freeway flyover ramps such as system-to-system ramps. (Coding sections with radii less than 2,500 feet is adequate.)
- Code grades greater or equal to 4 percent if sustained for longer than 1,000 ft.
- Code reaction points based on actual field conditions to the extent possible.
- Code free-flow speeds accurately, as MOEs are very sensitive to free-flow speed. Ideally, free-flow speed is to be measured in the field. If field data are not available, enter five mile per hour (mph) over the posted speed limit as the surrogate assumed free-flow speed.
- Code managed lanes (e.g., high-occupancy vehicle (HOV) lanes, express lanes) and ramp meters.

5.4 CODING TRAFFIC VOLUME DATA

Traffic volume data are entered for each time period. Entry volumes are to be entered in terms of hourly flow (i.e., vehicles per hour for each time period). NDOT requires turning volumes to be entered in terms of vehicles instead of percentages. As discussed in Section 3.3.2, traffic volumes for multiple time periods over the course of the modeling period are required to be entered. It must be ensured that the traffic volumes balance for all time periods.

Key subjects to note regarding input of traffic volume data are as follows:

- Requirement of coding origin-destination (O-D) data for the entire FRESIM network; and
- Requirement for input of conditional turning movement data for critical locations in the NETSIM network.

5.4.1 Coding Origin-Destination Data

O-D data, which is the estimate of the number of vehicles from the mainline freeway and entrance ramps destined to the exit ramps and mainline freeway (2), are entered in CORSIM to model weaving conditions along freeways. CORSIM works without O-D data; however, if O-D data are not coded, CORSIM internally creates an O-D table by converting freeway entry volumes and turning percentages at ramp exits. It is also possible to code partial O-D data. When partial O-D data are entered, CORSIM utilizes this input to override the internally created O-D pairs. However, experience shows that coding partial O-Ds results in an incorrect number of vehicles exiting at several exit locations, leading to volumes being processed incorrectly for several locations throughout the network. This is because CORSIM often does not adjust the remaining O-D pairs correctly when partial O-Ds are used. At times, CORSIM does not create an accurate internal O-D table to begin with (i.e., even without any partial O-D input). Regarding these issues, developers have responded in noting that "whenever NETSIM and FRESIM are used together, the process that balances the FRESIM O-D table will be disrupted, possibly causing incorrect exit percentages. The user may need to observe results and adjust inputs to compensate for this."

Because of these issues, coding full O-Ds is an NDOT requirement. Experience shows that developing and coding full O-D tables results in time savings. When incorrect volumes exit at the off-ramps because of the wrong reasons (because CORSIM is not assigning vehicles properly), adjusting/manipulating exit percentages to match the correct exit volumes requires several iterations. This is often more time consuming than initial entry of full O-Ds. An O-D table can be developed by first assigning observed or anticipated weave patterns (such as for adjacent ramps or cloverleaf interchange), and then estimating the remaining O-D percentages, while assuring that the volumes sent from an entry location to all possible destinations add up to 100 percent of the total entry volume and assuring that volumes at exit locations from all possible origins add up to projected demand volume for that exit location. Another approach may be to utilize select link analysis from the travel demand model used to forecast the volumes. Essentially, models are to replicate field weave conditions between adjacent ramps.

O-D tables for AM and PM models will be different; however, within the same modeling period (AM or PM), using the same O-D percentages for all time periods is acceptable. The modeler has the choice and ability to modify O-Ds for each time period, if that is deemed correct and/or necessary. NDOT will accept the same O-Ds for all time periods within each modeling period.

Advanced CORSIM Training Manual (2) provides sample origin-destination tables. *Guidance on the Level of Effort Required to Conduct Traffic Analysis Using Microsimulation* (5) provides additional information/guidance regarding O-D table development.

5.4.2 Coding Conditional Turning Movements

Conditional turning movement data for a NETSIM model must be coded for diamond interchanges. Additionally, it is to be used for any other situation where coding conditional turning movements are required to correctly model actual field reality. An example of such a situation is modeling the weaving of vehicles from a free-flow right turn that are destined to turn left at a closely-spaced downstream intersection.

5.5 CODING TRAFFIC CONTROL DATA

If the focus is freeway operations, intersections can be coded with pre-timed or actuated control. Especially for future scenarios, using pre-timed control may be acceptable. It is understood and acceptable that Synchro is often used to create the NETSIM portion of the network and transferred into CORSIM. However, the Synchro to CORSIM transfer of actuated signal control is often not accurate and requires serious corrections in CORSIM. Similarly, other pre-processors may also be used to create the NETSIM portion of the network and transferred into CORSIM. In every case, CORSIM must be reviewed and corrected to ensure that the model has been transferred correctly.

Freeway ramp meter control data are required to be coded for existing and planned ramp meters.

5.6 TRAFFIC OPERATIONS AND MANAGEMENT DATA

Traffic Analysis Toolbox Volume IV (1) models traffic operations and management data, such as incidents, events, and bus operations. Note that CORSIM version 6.3, which is due to be released in 2012, will have the capability to model high-occupancy toll (HOT) lanes, advanced toll plazas, and adaptive cruise control.

5.7 SUMMARY OF MODEL INPUT

Table 4 presents basic information to code when developing CORSIM models. Critical items such as grade and curve thresholds are identified. Essentially, this is a checklist that will aid the modeler when developing models. The table shows the location of each input (in CORSIM version 6.2) along with guidance on key items.

Table 4: Summary of Model Input

Input	TRAFED location	Specific Guidance
Vehicle entry headway	Network properties/ Vehicle entry headway	Select Normal for networks with arterial dominance and Erlang with parameter "a" set to 1 for networks with FRESIM dominance.
Time period specification	Network properties/ Time period	Fill in these as per the approved time period information for the project. Time interval duration is typically 60 seconds.
Node IDs	Nodes	Conform to node numbering convention in NDOT CORSIM Modeling Guidelines.
Freeway geometry	Freeway links, nodes	Enter lane numbers, lane types, ramp positions, lane add/drops.
Arterial and intersection geometry	Arterial links, nodes	Enter number of lanes, storage lanes, and lengths
Grade	Links general tab	Enter grades ≥ 4 percent if longer than 1,000 ft.
Freeway radius	Freeway links general tab	Enter for mainline links, flyover ramps, and loop ramps with curves < 2,500 feet
Free flow speed (ffs)	Freeway and arterial links general tab	Enter ffs as per approved Methodology Memorandum
Off-ramp reaction points	Freeway node properties	Default is 2,500 feet. Enter a different value if actual condition is known.
Intersection turn movements	Intersection properties	Enter turn movements for the first time period. Remaining time periods can be left blank (same percentages from first time period will be copied over) if so desired.
Conditional turn movements	Intersection properties	Enter at appropriate locations. Entering for the first time period is sufficient, as this will be copied over to following time periods.
Entry link volumes	Entry properties	Enter for each time period.
Truck percentage	Entry properties	Enter for each time period.
Freeway ramp exit volumes	Freeway node properties at exit gores	Entering for the first time period is sufficient, as as this will be copied over to following time periods.
Intersection control types	Intersection properties control tab	For signals, code pre-timed versus actuated as per approved methodology.
Signal timing	Intersection properties control tab	Code as per confirmed methodology (actual timing vs. optimized from signal optimization tool). For actuated, confirm all parameters are coded accurately (coordinated vs. free, minimum, maximum greens, offsets, detectors, pedestrians, etc.).
Origin-destination (O-D) data	Origin Destination (FRESIM)	Enter for each time period. The information from first time period does not get copied to subsequent periods.
Calibration parameters	-	This is project specific. Make sure all established calibration parameters are entered for final models.
Note: This table is a minimum data input checklist. Additional specific/unique data should be entered as appropriate (source/sink data, traffic operations and management data etc.).		

6.0 ERROR CHECKING

NDOT requires that error checking is conducted for all CORSIM models. Error checking involves reviews of the coded network and coded demands. Error checking must be complete prior to calibration. The calibration process relies on an error-free model, where errors are eliminated in demand and network coding before beginning calibration. Basic stages of error checking are as follows:

- **Review Software Errors:** The modeler is to confirm the latest version and patch of the software being used and is to be aware of known "bugs" and workarounds. The latest version and patch information is located on the McTrans website (mctrans.ce.ufl.edu).
- **Review Input Data:** A modeler that is familiar with the project but not involved in the model coding is to check for data coding errors. Input data can be checked from TRAFED, TRAFVU, TRF files, or CORSIM by reviewing error and warning messages. Table 5 is a checklist for verifying the accuracy of the coded input data. This checklist is required to be submitted to NDOT.
- **Review Animation:** Animation must be observed to determine if vehicle behavior is realistic. Watching the simulation in TRAFVU is helpful in identifying errors.

Traffic Analysis Toolbox Volume IV (1) provides a detailed description of the error checking process.

Table 5: Coded Input Data Checklist

Item	Check
Check time periods and durations to ensure all time periods are specified correctly.	
Verify fill time is long enough for network to become fully loaded.	
Check vehicle entry headway type to ensure correct type is selected.	
Check basic network connectivity. (Are all connections present?)	
Check node numbers against node numbering convention.	
Check link geometry (lengths, number of lanes, free-flow speed, facility type, curves, grades. etc.).	
Check truck percentages at each entry node.	
Check entered volumes against volume data (entry volumes and turning movements).	
Check identified sources and sinks for traffic.	
Check origin-destination (O-D) input against developed origin-destination (O-D) matrices.	
Check conditional turning movements.	
Check intersection controls (control type, control data).	
Check data pertaining to ramp meters, HOV lanes, and other special lanes/requirements.	
Check data pertaining to traffic operations and management (incidents, parking, bus operations).	

7.0 CALIBRATION PROCESS

7.1 CALIBRATION OVERVIEW

FHWA defines calibration as the process where the modeler selects the model parameters that cause the model to best reproduce field-measured local traffic operating conditions. CORSIM comes with a set of user-adjustable parameters (calibration parameters) for the purpose of calibrating the model to local conditions. Calibration parameters are related to both driver and vehicle performance, as well as how the driver-vehicle unit reacts to traffic control devices and surrounding traffic conditions. The objective of calibration is to find the set of parameter values for the model that best reproduces local traffic conditions. **Regardless of the size or complexity of the network, NDOT requires calibration to be performed for microsimulation models. Models that are not calibrated are not acceptable to NDOT and FHWA.**

Calibration of models is performed for existing conditions. Calibration information from the existing conditions model is carried forward to the future conditions model. Calibration parameters shall not be changed in the future models. Calibration is performed for all models. For example, if the analysis is being performed for both AM and PM conditions, both AM and PM models are to be calibrated.

Keys to successful calibration include entering measured field data to the extent possible, understanding the field conditions thoroughly (such as where the congestion is occurring), and achieving an error-free base model. If actual field data are initially entered, the need for adjusting additional parameters is oftentimes minimal.

Adequate resources and time are to be allocated for calibration. Documenting every change to calibration parameters is a key NDOT requirement. This is particularly important to FHWA in being the final approval agency for federally-funded projects, environmental studies, change of access studies, etc. NDOT and FHWA strive to ensure that a change in the calibration parameters is justifiable and defensible. Therefore, it is crucial to clearly document the calibration process. What adjustments were made, where in the model the adjustments were made, and why the adjustments were made are critical elements to be documented.

The following information from the *Traffic Analysis Toolbox Volume IV* (1) is to be noted for clarification purposes. “Model validation” is to check the model predicted traffic performance against field data that is not used in the calibration process. It is the software developer’s job to perform “validation” of the model to ensure it produces data consistent with a wide-range of real-world applications. It is assumed that the software developer has already completed this validation of the software and its underlying algorithms in a number of research and practical applications. Therefore, the modeler’s responsibility is to adjust parameters or perform calibration so that the models correctly predict local traffic conditions. There is no need to perform “validation.”

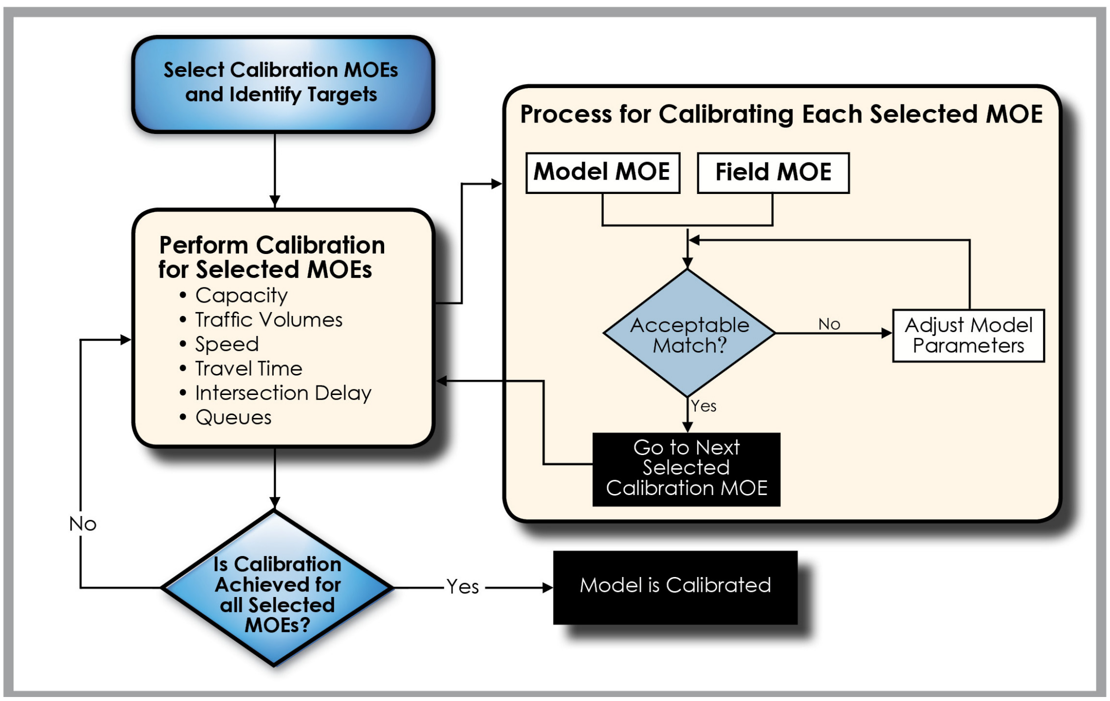
7.2 Recommended Calibration Process

The overall calibration process is changing the model parameters to match the local characteristics, running the model, and checking MOEs. If MOEs are acceptable, the model is calibrated. Otherwise, the model is to be modified until the MOEs are acceptable. Achieving this, however, may require a high level of effort. NDOT developed this "Recommended Calibration Process" to provide guidance on calibration of CORSIM models. Models that are calibrated following this process will generally be acceptable to NDOT. The main steps in the calibration process are as follows:

- Select calibration MOEs and locations to be calibrated.
- Determine the calibration strategy.
- Determine the minimum required number of model runs.
- Perform calibration following the strategy to obtain an acceptable match.

The calibration process is generally illustrated in Figure 2.

Figure 2: Calibration Process Flowchart



Adapted from the *Traffic Analysis Toolbox Volume IV* (1).

7.2.1 Selection of Calibration MOEs

In project scoping, the calibration MOEs and locations for model calibration must be identified. Calibration is typically performed for key locations in the network. Calibrating every location in the network is neither practical nor necessary.

The selection of calibration MOEs is limited to those that can be practically collected in the field. Below is a list of potential calibration MOEs. Section 4.3 provides guidance on how to collect the calibration MOE data in the field. For calibration, a minimum of two MOEs from the following list shall be selected in addition to traffic volumes. At least one of these MOEs is to be associated with surface streets modeled in the study limits.

- Capacity and saturation flow rate at key bottlenecks[5]
- Traffic volumes
- Travel time
- Speed
- Intersection delay at key intersection approaches
- Queues at key locations

NDOT requires a minimum of two MOEs, in addition to Traffic Volumes, to be selected as calibration MOEs.

There is not a specific method or specific calibration parameter to calibrate traffic volumes. In general, calibrating traffic volumes are needed only if the model includes parallel streets or a network of streets with multiple routes within the model. In such cases, the industry recommendation is to enter full O-D input for FRESIM and conditional turning movements for NETSIM. Entering full O-Ds and conditional turning movements (as appropriate) are both required for NDOT acceptance. With that, the CORSIM processed volumes is expected to closely match the entered volumes regardless of the size and complexity of the network. However, it will never be identical because CORSIM is stochastic and because the CORSIM calculated volumes are based on percentages and not absolute values. Therefore, NDOT requires that the CORSIM processed volumes be compared with input volumes.

Volume comparison must be performed for all time periods within the entire modeling period. Comparison of other MOEs does not have to be performed for all time periods; but at a minimum, it must be performed for the time periods within the peak period. As an example, for a model that consists of four 30-minute time periods, with Time Period 2 and Time Period 3 reflecting the peak period, the volume comparison is performed for all four 30-minute time periods, while speed calibration may be limited to Time Period 2 and Time Period 3.

For queue calibration of a particular movement, calibrating the lane with the longer queue is sufficient. However, the queue (modeled and depicted in CORSIM) on the other lane(s) should visually reflect the field conditions.

[5] CORSIM does not output a number called "capacity" or "saturation flow." The modeler is to use "vehicles out" output for capacity at the bottleneck location on freeways and "vehicles discharged by lane" output for capacity at intersections. Capacity calibration must focus on bottlenecks at freeways and the few key intersections at surface streets.

7.2.2 Determining the Number of Model Runs (Multiple Runs)

CORSIM models are to be run multiple times with different random seeds in order to minimize the impact that the stochastic nature of the simulation could have on the results. Results from individual runs may vary by 25 percent, and higher variations may be expected for facilities operating at or near capacity.

A statistical test must be conducted for two selected calibration MOEs to determine the required minimum number of runs. Determining the required minimum number of runs depends on two primary variables, the variance in the mean of selected MOEs and the tolerable error. The minimum NDOT-acceptable confidence interval is 95 percent. The formula for the sample size calculation is illustrated below.

$$n = \frac{(Z)^2(\sigma)^2}{(e\overline{X})^2}$$

Where:
n is the minimum number of model runs required;
Z is the critical ***Z*** statistic (for a 95-percent Confidence Interval, ***Z*** = 1.96);
σ is the standard deviation calculated on the basis of the conducted model runs for the given performance measure;
******e*** is the Tolerance Error calculated from field data variability; and
$\overline{X}$ is the mean calculated on the basis of the performed model runs for the given MOE.

* $$\frac{Error\ 'E'}{Field\ Mean} = Tolerance\ \%\ 'e' \qquad E = Z\left(\frac{\sigma}{\sqrt{n}}\right)$$

Where:
Z is the critical Z statistic (for a 95-percent Confidence Interval, Z = 1.96);
σ is the standard deviation calculated based on field data; and
n is the sample size (number of observations in the field).

Source: *Guidance on the Level of Effort Required to Conduct Traffic Analysis Using Microsimulation* (5)

As described in the definition for the tolerance error "e," this test is based on the sampling error of the field data. In other words, the selected tolerance error is based on field data. This test is required by FHWA for calculating the required number of runs and is detailed in FHWA's *Guidance on the Level of Effort Required to Conduct Traffic Analysis Using Microsimulation* (5). Modelers should refer to this document for further information. Following are key notes/guidance for applying this test on NDOT projects:

- Minimum number of model runs are to be calculated using two different calibration MOEs, typically volume and speed, and for multiple locations.

- The following is required to be followed when selecting the tolerable error for various calibration MOEs.
  - For freeway and arterial volumes, conduct the test for locations where multiple day hourly data are collected (minimum three days). If multiple day hourly data are not collected as part of the project, conduct the test for locations where there is an available NDOT count station. Use data from typical weekdays (Tuesday, Wednesday, and Thursday) if the analysis is for a typical weekday, which is usually the case.
  - For travel time, conduct the test at key segments using the data from multiple travel time runs.
  - For speeds, conduct the test at key segments/locations using the data from multiple travel time runs/field sensors.
  - For delays, conduct the test at key locations using data from multiple observations.
  - For queues, conduct the test at key locations using data from multiple observations.
- Models are required to be initially run 10 times to determine the required number of runs. The "highest number of runs" calculated from the selected two calibration MOEs will be the required number of runs for all models. However, if the calculated "highest number of runs" is less than 10, 10 runs is the minimum required number of runs (i.e., 10 model runs is the minimum number of runs acceptable to NDOT even if the calculated number of runs is less than 10).
- The tests must be performed for each analysis period separately (usually AM and PM). Different number of runs may be required for different time periods. For example AM models may require 12 runs, whereas PM models may require 15 runs.

7.2.3 Statistical Methodology for Acceptable Match

Once the MOEs to be calibrated are selected and the key locations to be calibrated are identified, calibration targets for those MOEs are to be identified to determine whether the models replicate the performance measures observed in the field. The purpose of setting calibration targets is to set a stopping point to the calibration process and consider the model calibrated. This is because it is virtually impossible to make the model match field conditions exactly. Table 6 shows the statistical methodology to be used to compare model results to field conditions for each calibration MOE listed in Section 7.2.1. NDOT requires the targets shown in Table 6 to be met for a model to be considered calibrated. The z-test is a popular statistical test used to compare two populations (in this case field data and model output) to determine if the difference is statistically significant. The application of the z-test in this context is explained in FHWA's *Guidance on the Level of Effort Required to Conduct Traffic Analysis Using Microsimulation* (5).

Table 6: Calibration Targets Required by NDOT

Calibration MOE	Description	Target
Capacity at Key Bottlenecks	Percent difference between field measured capacity and CORSIM simulated capacity	10%
Traffic Volumes	Percent difference between input field volumes and CORSIM simulated volumes for all segments and intersection approaches	5% for 85% of the cases
	GEH Statistic* for for all segments and intersection approaches	GEH<5 for >85% of the cases
	Difference between input field volumes and CORSIM simulated volumes for flows > 8,000 vph	Within 400 vph of field volumes for >85% of the cases
Travel Time	Comparison between observed segment travel time and CORSIM simulated travel time	z-test result "Do Not Reject" **at key segments**
Speed	Comparison between observed segment/sensor speed and CORSIM simulated segment/detector speed	z-test result "Do Not Reject" **at key segments/locations**
Intersection Delay	Comparison between field measured intersection delay and CORSIM intersection delay	z-test result "Do Not Reject" **at key locations**
Queues	Percent difference between observed queue lengths and CORSIM simulated queue lengths	20%

* $GEH = \sqrt{\frac{2(M-C)^2}{M+C}}$ M = Model volume; C = Field count

vph = vehicles per hour.

For z-test application, see *Guidance on the Level of Effort Required to Conduct Traffic Analysis Using Microsimulation* (5).

7.2.4 Calibration Strategy

CORSIM has numerous parameters that can be divided into two main categories, Non-Adjustable parameters and Adjustable parameters (3). Non-Adjustable parameters are those that the modeler is certain about and does not wish to adjust. Conversely, Adjustable parameters are those that the modeler is less certain about and willing to adjust. Calibration involves modifying the Adjustable parameters (calibration parameters). One key to performing calibration is to limit the size of Adjustable parameters to a minimum number. If the actual field data are entered to the extent possible, the observed data will then be considered Non-Adjustable, which leaves the set of Adjustable parameters to a minimum.

Adjustable parameters can be further divided into global (i.e., parameters applicable to the whole network) and link-level parameters (i.e., parameters that affect the simulation on a localized basis). In general, global parameters are to be adjusted first and link-level parameters second.

MOEs may be calibrated simultaneously if necessary, and it is not required to finish calibrating one MOE before moving on to the next MOE. Changing a calibration parameter to calibrate a certain MOE may result in the need to re-calibrate a previously calibrated MOE because calibration parameters may impact multiple MOEs. The goal is for the selected calibration MOEs to match actual conditions within acceptable thresholds. The specifics of calibration strategy are determined by the modeler as long as general guidelines provided in the Guidelines are followed.

It is important to not adjust too many parameters. It is best to accomplish calibration with as few modifications as possible. Field measured data are to be entered to the extent possible. If actual field data are entered, the need for adjusting additional parameters is oftentimes minimal. The importance of good field measured data cannot be overemphasized.

In addition to calibrating the selected MOEs (volumes plus the two selected calibration MOEs), matching the conditions observed during field inspection is also an important part of calibration. For example, if it is observed that failure to yield at an entrance ramp is high, then the anticipatory speed is to be reduced to replicate this condition.

Table 7 lists candidate calibration parameters to be adjusted during calibration. These are the key parameters that the model is most sensitive to and can have the most significant impact on results. The Guidelines do not provide descriptions of these parameters, and the recommended references are to be consulted for that purpose. Instead, key notes and issues regarding NDOT interests are provided.

Table 7: Key Calibration Parameters

FRESIM	NETSIM
Global Parameters:	**Global Parameters:**
Car following sensitivity factor	Acceptable gap in oncoming traffic (left and right turns)
Lag acceleration and deceleration time	Cross-street acceptable gap distribution (near and far side)
Pitt car following constant	Time to react to sudden deceleration of lead vehicle
Time to complete a lane change	Distribution of driver familiarity with paths
Link Parameters:	Spillback probabilities
Car following sensitivity multiplier	**Link Parameters:**
Warning sign locations	Mean discharge headway
Anticipatory lane changes	Mean start-up delay
Mean free-flow speed	Mean free-flow speed

Key notes/issues regarding calibration parameters:

- Do **not** modify the global free-flow speed parameter (free-flow speed multiplier).
- Do **not** modify the mean start-up delay at the global scale (start-up delay multiplier).
- Do **not** modify the mean discharge headway at the global scale (discharge headway multiplier).
- Warning sign locations (reaction points) are to be coded in the base model development stage based on actual field conditions to the extent possible. However, because reaction points can have a significant impact on system performance around on-ramps and off-ramps, modification to warning sign locations can be considered if it helps reach calibration targets. Note that these are not the location of actual signs on the roadway.

They are the location where vehicles start to react to upcoming geometry changes. *Traffic Analysis Toolbox Volume IV* (1) has good guidance on reaction points.

- Mean free-flow speed can be modified as a last resort, and it is to be used only at low levels of congestion. Adjusting free-flow speeds to match observed speeds during congested conditions must be avoided.
- In addition to matching the values for selected MOEs (within target), adjusting the model to match operational observations from the field inspection is also part of calibration. For example, if the yielding behavior at an entrance ramp area is aggressive (i.e., if very little cooperation is given by the mainline vehicles to allow the merging traffic), anticipatory lane change speed may be reduced to replicate this situation. If vehicles tend to line up for an exit ramp far in advance of the ramp, then the warning sign location is to be moved further upstream. Basically, the model is designed to behave like the real-world conditions, so any specific situation observed in the field is to be applied to the model as well. Because a thorough understanding of the field conditions is invaluable for the calibration process, performing field inspection is an NDOT requirement, and a summary of field inspection findings must be included in the technical memorandums and/or reports submitted to NDOT.

7.2.5 Guidance on Specific Cases

The following are to be noted for specific cases:

- For modeling future roads that do not exist, calibration parameters are to be applied based on available CORSIM models of similar roadways in the vicinity. The applicable calibration parameter values should be transferred by the modeler into the proposed roadway model. If applicable calibration parameters are not available for transfer, calibration is to be performed for a similar roadway in the vicinity; and then the appropriate calibration parameter values should be transferred over. It is noted that only the global parameters can be transferred.
- For rural roads that will become urbanized in the future (or will experience significant changes of land use, facility type etc.), a similar strategy for applying calibration parameters to roads that do not exist is to be followed – use an existing roadway that the proposed roadway may be expected to be similar to in design and operating characteristics.
- The modeler must not calibrate to a construction condition, unless the purpose is to model the construction condition. Construction is not a typical condition (just as one would <u>not</u> calibrate to adverse weather or incident conditions etc.). Calibration MOE data (speed, queues etc.) are not to be collected during construction or when an incident has occurred. If the entire project area is under construction, calibration is to be performed based on similar roadways within the vicinity. If the entire project area is <u>not</u> under construction, at least some calibration MOE data for those areas not under construction are to be collected for calibration of those locations.

NDOT staff is available to discuss specific/unique situations, and NDOT concurrence may be solicited on decisions and assumptions in such situations.

8.0 RESULTS AND TECHNICAL DOCUMENTATION

The CORSIM output data and results are to be presented in a manner that is complete and easily understood without having to run or peruse the CORSIM model files. Preparation of both tabular and graphical displays is necessary. Decisions, procedures, and assumptions made during the analysis process must be documented clearly.

8.1 SELECTION OF MOEs

Candidate MOEs for evaluation are to be selected at the beginning of the project and included in the Methodology Memorandum. Results must be based on multiple MOEs, not just the service measure and resulting level of service (LOS). *Traffic Analysis Toolbox Volume IV* (1) provides a list of the MOEs that CORSIM can produce. Table 8 presents a list of typical candidate MOEs for freeway, arterial, and system-wide performance. Selection of the appropriate MOEs depends on the project objectives, needs, and stakeholder's priorities.

Table 8: Typical Candidate MOEs

FRESIM	NETSIM	System-wide Performance
Volumes	Volumes	Vehicle miles traveled (VMT)
Density	Control delay	Vehicle hours traveled (VHT)
Speed	Queue length	Average Speed
	Phase failure	Vehicle hours of delay (VHD)
	Queue spillbacks	
	Speed	

Specific objectives/criteria relating to each MOE must be stated. Examples of such objectives are as follows:

- Provide an LOS of D or better along freeways based on the most recent HCM density thresholds.
- Provide freeway speeds at minimum of 50 mph.
- Provide volume throughputs that are within five percent of the demand volumes.
- Provide for ramp operations that do not generate queues or spillbacks that degrade operations on the freeway or major arterials.
- Provide for arterial operations that do not result in phase failure or spillback along intersection approaches.
- Provide an overall intersection LOS of E or better at study intersections based on the most recent HCM control delay criteria.

It is noted that determining HCM LOS from direct CORSIM output is not accurate. As an example, for freeway density, CORSIM output is based on all vehicles (vphpl), while HCM LOS is based on passenger car units (pcphpl). Direct determination of HCM LOS is possible if the modeler performs a vehicle trajectory analysis in CORSIM. A vehicle trajectory analysis can be performed using a CORSIM post-processor, such as Vehicle Trajectory Analysis for Performance of Evaluation (VTAPE). If such a post-processor is not used, a disclaimer must be included stating that the LOS indicated is not the equivalent HCM LOS. The LOS based on direct CORSIM output may be called an "estimated LOS" rather than HCM LOS, and sufficient notes/warnings are required so that the LOS is not misinterpreted by a reader/reviewer.

LOS criteria are to be selected based on NDOT, Metropolitan Planning Agency (MPO), and/or local agency policy. LOS criteria are to be included in the Methodology Memorandum for approval. Note that it is possible to have different criteria for freeways and arterials (e.g., LOS D for freeways and LOS E for arterials). It is also typical to have more strict criteria for the overall intersection LOS compared to the LOS for each movement or approach. For example, the LOS criteria for the overall intersection may be LOS D, although it may be acceptable to have movements operating at LOS E. Occasionally, it may be acceptable to have an LOS F for a minor approach that accommodates very few vehicles. For example, mitigation may not be necessary if the LOS is F for a movement with only five vehicles.

Note that LOS may not be the most important criteria. NDOT considers several other MOEs, not just LOS. There will be situations where engineering judgment will be required if the results show a segment is operating at or near the acceptable LOS threshold. For example, a freeway segment with a density of 35.1 pcphpl is not really that different from a segment that is operating at 34.9 pcphpl, although the former corresponds to LOS E and latter to LOS D.

NDOT staff is available to discuss specific/unique situations and decisions and NDOT concurrence may be solicited.

When addressing operations of freeway merge/diverge/weave areas, link output (i.e., average across all lanes) shall not be used. Densities are to be extracted for each lane and the results reported following the methodology described in *HCM 2010* (4).

8.2 DOCUMENTING THE RESULTS

Results (i.e., the MOEs) are to be reported for each time period within the peak period. Decisions will be based on the worst case results. For example, for a two hour modeling period with 30-minute time periods, the peak period corresponds to Time Period 2 and Time Period 3, while Time Period 1 reflects the build up to the peak conditions and Time Period 4 reflects the dissipation of the peak conditions. In this example, the results for both the second and third time periods are to be reported. The modeler, however, needs to confirm that the worst case results are not from the last time period (dissipation of peak). The entire simulation output needs to be examined to confirm that the reported time periods are indeed representing the actual peak conditions when motorist-experienced measures are at their worst.

Final Results must be reported based on the average of multiple runs. The required number of runs that were determined during the calibration process is to be applied for all alternatives and scenarios. It is to be confirmed that the number of runs used is adequate for the subject scenario based on the same tolerance error "e" used during calibration. As noted, 10 model runs are the minimum number of runs acceptable to NDOT.

When reporting results, both speeds and densities are to be rounded to the nearest whole number.

8.3 EVALUATION OF ALTERNATIVES

For alternatives analysis, the same set of random seeds is to be used for all alternatives.

To have an "apples to apples" comparison, congestion is not to extend beyond the geographic and temporal limits of the model to allow for the entire demand to be captured.

The start and end point of the models are to be the same for all alternatives.

8.4 SUMMARY OF REQUIRED DELIVERABLES FOR NDOT REVIEW

Below is list of deliverables to be submitted to NDOT:

- Methodology Memorandum and Methodology Memorandum Content Checklist
- Technical Memorandum(s) and/or Traffic Report that addresses the following:
    - Existing conditions
    - Data collection summary
    - Traffic forecasts (usually requires a separate memorandum)
    - Minimum Criteria for Review of CORSIM Models Checklist
    - Calibration approach and assumptions (may require a separate memorandum)
    - O-D tables
    - Coded Input Data Checklist
    - Alternatives analysis
    - Summary tables and graphics (see *Advanced CORSIM Training Manual* (2) and *Guidance on the Level of Effort Required to Conduct Traffic Analysis Using Microsimulation* (5) for examples of several summary tables and graphics)
    - Acceptance letters for Methodology Memorandum and Traffic Forecast Memorandum
- Link-node diagram and lane schematic
- CORSIM electronic files:
    - Input files (trf), output files (csv), random seed files (rns) for all runs

The Final Traffic Report is required to be signed and sealed by a professional engineer licensed to practice in Nevada.

Technical memorandum(s) and traffic report(s) must be submitted electronically (PDF on a CD/DVD) and as hard copy. The majority of the Appendix content can be submitted on a CD/DVD. Direct CORSIM output is to be submitted as electronic files, and a hard copy is not preferred. Table 9 lists the typical Appendix items required to be provided as well as the method of submittal (electronic vs. hard copy).

Table 9: Appendix Contents and Method of Submittal

Appendix Item	Method of Submittal
CORSIM models	Electronic files (trf, csv, and rns) for all runs on a CD/DVD - providing hard copy output is not required*
Other software output (HCS, Synchro, TEAPAC, TRANSYT 7F, etc.)	Electronic files and PDFs of results worksheets on a CD/DVD
Crash data	PDF or excel format on a CD/DVD.
Methodology Memorandum Checklist	Hard copy**
Minimum criteria for review of CORSIM Models Checklist	
Response to comments, letters, etc.	
Relevant approval letters	
Link-node diagram	
Lane schematics	
Multiple time period calculations	
Origin-destination (O-D) tables	
Coded Input Data Checklist	
Any calculations and tables/exhibits	
Turning movement count data	
Tube count data	
Traffic control data (signal timing, ramp meter)	
Traffic forecasting calculations***	
Approved Methodology Memorandum	PDF on a CD/DVD
Approved Traffic Forecast Memorandum	
Prior technical memorandums, if any	
NDOT count station volume data	
Travel time data	
Reference documents (maps, etc.)	
Travel demand model output data***	

*One exception to this is any post-processed output that is not in the main body of the report, such as density, flow, and speed charts or any tables/charts related to sensitivity testing. Those should be provided as hard copy.

**All "hard copy" items should also be included on the CD/DVD as a PDF.

***Not required if there is an approved Traffic Forecasting Methodology Report

Note: This is not an all-inclusive list. There may be other project-specific items that are not listed here. The decision on method of submission for those items can be discussed with NDOT.

REFERENCES

1. Traffic Analysis Toolbox Volume IV: Guidelines for Applying CORSIM Microsimulation Modeling Software, Federal Highway Administration, January 2007
2. Advanced CORSIM Training Manual, Minnesota Department of Transportation, January 2008
3. Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software, Federal Highway Administration, July 2004
4. Highway Capacity Manual, HCM 2010, Transportation Research Board
5. Guidance on the Level of Effort Required to Conduct Traffic Analysis Using Microsimulation, FHWA, January 2012

BIBLIOGRAPHY

1. CORSIM Reference Manual, Version 6, 2010, McTrans
2. CORSIM User’s Guide, Version 6, 2010, McTrans
3. TSIS User’s Guide, Version 6, 2010, McTrans
4. TRAFED User’s Guide, Version 6, 2008, McTrans
5. TRAFVU User’s Guide, Version 6, 2009, McTrans
6. Traffic Analysis Toolbox Volume VI: Definition, Interpretation, and Calculation of Traffic Analysis Tools Measures of Effectiveness, Federal Highway Administration, January 2007
7. Identifying and Assessing Key Weather-Related Parameters and Their Impacts on Traffic Operations Using Simulation, Federal Highway Administration, September 2004
8. Field Observations for Modeling, Minnesota Department of Transportation, December 2004
9. Louisiana Department of Transportation Microsimulation Guidelines, December 2008
10. Recommended Guidelines for the Calibration and Validation of Traffic Simulation Models, Ronald T. Milam, AICP & Fred Choa, P.E., Fehr & Peers Associates, Inc., April 2001
11. A Practical Procedure for Calibrating Microscopic Traffic Simulation Models, Hourdakis, J., P. Michalopoulos, and J. Kottommannil, Transportation Research Record 1852, January 2003
12. Variations in Capacity and Delay Estimates from Microscopic Traffic Simulation Models, Zong Z. Tian, Thomas Urbanik II, Roelof Engelbrecht, and Kevin Balke, Transportation Research Record 1802, January 2007

Methodology Memorandum Content Checklist

Item	Description	Check
Project Description and Background	Brief information about the project (purpose, general study area, etc.)	
Technical Guidance and Standards	Technical guidance and standards to be followed along with their version (HCM, MUTCD, NDOT Access Management Standards, etc.)	
Traffic Analysis Tools	Software to be used along with their version (CORSIM, HCS, TRAFFIX, etc.)	
Study Limits	Geographic limits of the analysis. This is to be consistent with the NDOT CORSIM Modeling Guidelines. List all study intersections to be included.	
Analysis Years	Design, opening and interim years.	
Analysis Scenarios	Existing, No-Action, Build - describe build alternatives to the extent possible.	
Analysis Periods	Modeling periods and multiple time periods description . The use of multiple time periods should conform to NDOT CORSIM Modeling Guidelines.	
Existing Conditions	Description of existing conditions and/or how existing analysis will be performed.	
Data Sources	List of sources of data and relevant information.	
Traffic Operations Analysis Calculations/Assumptions	Signal timing/phasing, i.e., whether to use optimized timing or actual timing data, peak hour factors, etc.	
Truck Percentages	Truck percentage to use for existing and future scenarios and their calculation/estimation.	
Storage Length Calculation Method	How the turn bay lengths will be calculated.	
Level of Service Threshold	LOS standard for each facility type. For intersections, document the details of the criteria (by movement, by approach, by overall intersection) and explain source or basis of the selected LOS standard.	
Traffic Forecasts	General methodology for projecting traffic forecasts. Note that a separate Traffic Forecast Memorandum is needed for NDOT Traffic Information Division approval of the projected volumes per NDOT Traffic Forecasting Guidelines. Note if the Traffic Information Division approved the traffic forecasts.	
CORSIM Coding and Analysis Assumptions	Documentation of support tools (if to be used) for intersection timing/optimization (such as Synchro, TRANSYT-7F, TEAPAC etc), pre-timed versus actuated control for signals, free-flow speeds (measured versus estimated/assumed). Coding items, such as O-Ds, conditional turning movements, handling weave/merge/diverge, and node numbering convention are to conform to the NDOT CORSIM Modeling Guidelines. HOV lanes, express lanes/managed lanes, and ramp meters are to be addressed.	
Calibration Approach	Calibration approach is to follow the methodologies described in the NDOT CORSIM Modeling Guidelines.	
Calibration MOEs, Locations, Targets	Calibration MOEs, locations to be calibrated and targets for acceptable match.	
Selected MOEs for Evaluation	List of MOEs for evaluation and alternatives analysis along with the selected threshold for successful operations. Clearly state if intersection/arterial MOEs will be reported from CORSIM output or from the signal timing tool used.	
Additional item(s)	Any unique item(s) that is appropriate to be discussed/approved by NDOT.	
Comments:		

Minimum Criteria for Review of CORSIM Models Checklist

Criteria	**Met?**
Latest version of CORSIM is used (as of project start date).	
Models run without errors on a balanced traffic network that has reached equilibrium.	
Balanced traffic volumes from approved traffic forecasts are used.	
References are documented.	
Approved Methodology Memorandum is followed.	
Analysis years are as per approved Methodology Memorandum.	
Model geographical limits are as per approved Methodology Memorandum.	
Analysis time periods are as per approved Methodology Memorandum.	
Truck percentages are as per approved Methodology Memorandum.	
Node numbering conforms to NDOT CORSIM Modeling Guidelines.	
Origin-Destination (O-D) tables are developed and entered for all freeway entrances and exits.	
Conditional turning movement volumes are entered at each appropriate location.	
Grades of 4 percent or more are coded if longer than 1,000 ft.	
Freeway radii less than 2,500 feet are entered for mainline links, flyover ramps, and loop ramps.	
Model is calibrated consistent with the requirements of NDOT CORSIM Modeling Guidelines.	
Calibration is completed for the MOEs listed and approved in the Methodology Memorandum.	
All calibration targets listed in the approved Methodology Memorandum are met.	
All changes to calibration parameters are documented.	
Results are based on calculated number of runs (minimum 10 runs).	
For alternative comparison, same set of random seeds are used.	
Results are based on several MOEs, not just the service measure and the resulting LOS.	
MOEs for merge/diverge/weaving areas are reported based on “by-lane” data following HCM methodology.	
Start and end points for all alternatives are the same.	
Each assumption, calibration or non-calibration related, is documented throughout the modeling process.	
Comments:	

Revised September, 2012

This page intentionally left blank.

Error Checking - Coded Input Data Checklist

Item	Check
Check time periods and durations to ensure all time periods are specified correctly.	
Verify fill time is long enough for network to become fully loaded.	
Check vehicle entry headway type to ensure correct type is selected.	
Check basic network connectivity. (Are all connections present?)	
Check node numbers against node numbering convention.	
Check link geometry (lengths, number of lanes, free-flow speed, facility type, curves, grades. etc.).	
Check truck percentages at each entry node.	
Check entered volumes against volume data (entry volumes and turning movements).	
Check identified sources and sinks for traffic.	
Check origin-destination (O-D) input against developed origin-destination (O-D) matrices.	
Check conditional turning movements.	
Check intersection controls (control type, control data).	
Check data pertaining to ramp meters, HOV lanes, and other special lanes/requirements.	
Check data pertaining to traffic operations and management (incidents, parking, bus operations).	