*Sponsoring Organization:*
*Michigan Department of Transportation*

# Development of a Michigan-Specific VISSIM Protocol for Submissions of VISSIM Modeling

RESEARCH REPORT

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WSP MICHIGAN INC.

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**16. Abstract**

The guidance developed as part of this research project communicates and lays out the expectations for VISSIM model development and deliverables so that both the vendor and the Michigan Department of Transportation (MDOT) can move through modeling projects in congruence based on current best practices. This will provide consistency in vendor deliverables, facilitate more efficient MDOT reviews, and reduce the risk of budget overruns and delays to project schedules due to misunderstood expectations. The guidance also defines a consistent methodology for MDOT to review and evaluate models and provides a clear roadmap to MDOT project managers unfamiliar with the VISSIM modeling process, giving them the tools necessary to successfully manage a modeling project with a clear understanding of protocol and anticipated modeling outcomes.

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## DISCLAIMER



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# EXECUTIVE SUMMARY

VISSIM is the traffic microsimulation software developed and maintained by Planung Transport Verkehr AG (PTV). VISSIM modeling is generally a labor-intensive effort to develop a calibrated and validated model that accurately reports measures of effectiveness (MOEs). As is the case with most microsimulation software, there are many points in the model development process where assumptions need to be made and agreed upon between the model developer and the reviewing agency to ensure final deliverables meet client expectations. Having an agency guidance document can greatly aid in this process. The Michigan Department of Transportation (MDOT) commissioned this research project to determine best practices in VISSIM model development and subsequently prepare a protocol resource document based on these best practice findings to guide model developers, model reviewers and MDOT project managers.

The guidance developed as part of this research project communicates and lays out the expectations for VISSIM model development and deliverables so that both the vendor and MDOT can move through modeling projects in congruence based on current best practices. This provides consistency in vendor deliverables, facilitates more efficient MDOT reviews, and reduces the risk of budget overruns and delays to project schedules due to misunderstood expectations. The guidance also defines a consistent methodology for MDOT to review and evaluate models and provides a clear roadmap to MDOT project managers unfamiliar with the VISSIM modeling process, giving them the tools necessary to successfully manage a modeling project with a clear understanding of protocol and anticipated modeling outcomes.

# INTRODUCTION

## BACKGROUND

The Michigan Department of Transportation (MDOT) is a leader in using operational and forecast modeling tools to analyze the state transportation network and develop solutions to operational issues. For example, MDOT developed guidelines for modeling and performing signal optimizations with the macrosimulation software Synchro that have been used as a template and adopted by other agencies across Michigan and the nation.

As operational issues become more complex, the use of microsimulation models has emerged as a primary tool for modeling and analyzing these complexities. MDOT has primarily used VISSIM software for microsimulation modeling to assess the impacts of various alternative strategies for freeway and complex surface street projects. These projects include the M-1 streetcar (QLINE) on Woodward Avenue in Detroit, different active traffic management (ATM) strategies on US-23 and I-96, bus rapid transit impacts on Grand River Avenue in Lansing, and various complex interchange and corridor alternatives.

The guidance developed as part of this research project will clearly communicate and lay out the expectations for VISSIM model development and deliverables so that both the vendor and MDOT can move through modeling projects in congruence based on current best practices. This will provide consistency in vendor deliverables, facilitate more efficient MDOT reviews, and reduce the risk of budget overruns and delays to project schedules due to misunderstood expectations. The guidance will also define a consistent methodology for MDOT to review and evaluate models and provide a clear roadmap to MDOT project managers unfamiliar with the VISSIM modeling process, giving them the tools necessary to successfully manage a modeling project with a clear understanding of protocol and anticipated modeling outcomes.

## RESEARCH PROBLEM AND MOTIVATION

Currently, MDOT has no standard process or guidelines for VISSIM model development or deliverables. This can lead to unclear expectations and a lack of consistent modeling assumptions and deliverables by vendors in Michigan.

Statewide, MDOT has only a few licenses for VISSIM, and the vendor model reviews are largely performed by the MDOT Congestion and Reliability Unit. With limited licenses and review staff, the inconsistency in model assumptions and deliverables from vendors can lead to lengthy MDOT model reviews with significant comments, resulting in an overly iterative process. This rework may impact project budgets and schedules as well as strain communications when the modeling expectations are not clearly established at the beginning of a project. In addition, many projects that utilize VISSIM modeling are led by MDOT project managers outside of the Congestion and Reliability Unit who have limited experience with and knowledge of VISSIM and who are unsure when appropriate reviews/check-ins should be requested by more experienced practitioners.

## SCOPE OF RESEARCH

Research activities consisted of a literature review and an evaluation of best VISSIM modeling practices currently implemented in the United States. The researcher developed a protocol document to guide vendors when developing VISSIM models in Michigan and established a uniform procedure for use by MDOT when evaluating and reviewing VISSIM models prepared by vendors.

The research evaluation consisted of a review of practices and protocols currently implemented at a minimum of five other state DOTs, specifically including Washington State DOT and Oregon DOT. The final deliverable consisted of a protocol document that provides the protocol, method, deliverable templates, and requirements for all VISSIM models prepared by a vendor and submitted to MDOT for review. This report identifies the reasoning and justification used in the production of the protocol document.

# LITERATURE REVIEW

A literature review was conducted to summarize VISSIM modeling best practices and protocols. In coordination with MDOT and Planung Transport Verkehr AG (PTV); the developer and distributor of the VISSIM software, WSP compiled a comprehensive list of VISSIM protocol documents from across the nation as an outcome from the literature review task.

Due to the breadth and depth of the material contained in the VISSIM protocol documents reviewed, a stand-alone literature review document was prepared and is contained in Appendix A.

## REVIEW OF PREVIOUS RESEARCH

Oregon was one of the first states to develop VISSIM guidelines, and many of the guidelines developed by other states reference the Oregon document. In addition to state-prepared documents, the Federal Highway Administration (FHWA) Traffic Analysis Toolbox was also included as part of the literature review. FHWA's *Traffic Analysis Toolbox Volume III,* while not specific to VISSIM, makes recommendations for best practices in microsimulation and provides a foundation for many subsequent state VISSIM and microsimulation documents.

A total of 15 documents were reviewed and summarized within the complete literature review located in Appendix A. These documents were sourced from 10 state agencies and FHWA. Many agencies had several documents sourced for the literature review. The following is the list of agencies whose documents were reviewed.

Federal Agencies

1. FHWA

State Agencies

1. California Department of Transportation
2. Florida Department of Transportation
3. Maryland Department of Transportation
4. Minnesota Department of Transportation
5. Nevada Department of Transportation
6. Oregon Department of Transportation
7. Pennsylvania Department of Transportation
8. Virginia Department of Transportation
9. Washington State Department of Transportation
10. Wisconsin Department of Transportation

## CRITICAL FACTORS

Each document's goal was to provide a structure and guidance for microsimulation traffic analysis projects. The way these objectives were achieved varied in several significant facets depending on the agency's project management process, data collection infrastructure, preferred microsimulation software, and the agency's microsimulation knowledge or experience.

The core themes discussed universally were identified as integral components to a microsimulation guidance document due to the frequency and depth of their discussion. These subject areas were identified as critical sections to be included in the *Michigan VISSIM Protocol Manual.* They included the following:

1. Project Understanding and Scoping
2. Data Collection and Development
3. Model Development
4. Model Calibration and Validation
5. Reporting and Documentation
6. Model Reviewing and Result Evaluation

The specific details falling within each of the core sections are discussed in detail in Appendix A.

# METHODOLOGY

This project falls outside the traditional research project typically conducted for MDOT. It is nontraditional in the sense that there is no formal experimental design or equipment, and it does not contain a hypothesis to be tested. The final deliverable of this research process was to produce a Michigan-specific VISSIM protocol document using the best practices outlined in the literature review.

## PROCEDURES

Several tasks were established in the proposal for this research project to ensure free-flowing communication throughout the project. It was paramount to have MDOT's feedback during the intermediate tasks to ensure that the final deliverable met the requirements and needs of MDOT.

To promote communication and collaboration, regular meetings were held throughout the project, and quarterly progress reports were submitted to MDOT tracking the status of the tasks described below.

### REVIEW AND SYNTHESIZE AVAILABLE LITERATURE

The first and undoubtedly most important task was the collection of other agencies' VISSIM and microsimulation guidance documents. These documents influenced the structure of the *Michigan VISSIM Protocol Manual* and the technical best practices included in the final document.

### DEVELOP REPORT OUTLINE

Using the summarized literature review in Appendix A as a guide, an outline for what would ultimately become the VISSIM modeling protocol document for MDOT was prepared.

The outline identified the various sections and subsections of the report, focusing on VISSIM model development, model measures of effectiveness (MOE) reporting and review/evaluation methodology. The outline also indicated what content was recommended for inclusion in the main body of the report and what content was intended to be presented in the report's appendices.

The outline was provided to MDOT for review in electronic format in advance of a status meeting where MDOT comments were reviewed in person with the project team. A finalized outline was created after addressing MDOT comments, and this outline was used for all subsequent tasks.

### DEVELOP DRAFT MODEL DEVELOPMENT PROTOCOL

Following the outline, a detailed VISSIM model development protocol document was prepared incorporating the best practices identified in the literature review. The protocol guides the reader from start to finish in preparing VISSIM models and final deliverables for MDOT, identifying clear expectations and assumptions specific to Michigan that need to be included in the modeling effort. Key MDOT review checkpoints are also described in the protocol. The protocol text was created to be concise and to provide clear direction so that the modeling process can be understood by vendors preparing the models as well as by MDOT project managers who are managing projects that have a VISSIM modeling component.

### DEVELOP MODEL MEASURES OF EFFECTIVENESS AND DELIVERABLE TEMPLATES

In addition to the guidance text of the *Michigan VISSIM Protocol Manual*, templates for the different VISSIM model metrics and measures of effectiveness (MOEs) were developed. The format of these templates was based on the best practices research as well as the WSP team's own experience in having prepared many of these templates for VISSIM models in the past.

One of the most time-consuming parts of an agency's review is verifying the validation of a model. A standard format was created for displaying the validation metrics, which typically include two or more of the following metrics: volume served, average travel speeds, average travel times, observed queuing and observed delays. Separate templates were created for reporting MOEs for surface streets and for freeways (such as delay, density, level of service, queue length, travel time, average speed, and throughput vs. demand).

## DEVELOP MODEL REVIEW AND EVALUATION FORMS

The development of a documented methodology for reviewing vendor-submitted VISSIM deliverables will improve efficiency and consistency in MDOT reviews while also improving the overall quality of the final deliverables. A methodology for performing reviews of vendor-prepared VISSIM models and deliverables was created including guidance on how the deliverables are to be submitted to MDOT and in what format for review. As part of the review methodology, a prompt sheet, checklists and templates were developed to aid MDOT staff in performing reviews. The benefits of having a repeatable verification and review methodology include more efficient and consistent reviews, reduced risk during an audit (by showing consistent review processes and proof that a review was completed), a benchmark for changing the review process if the software changes, and a reference point for which review process was used if an older model is utilized later.

## PREPARE RESEARCH REPORT

This research report is the last task of this project. Its purpose is to provide MDOT with documentation of the reasoning and justification used in the development of the protocol document. This report documents which methods and/or best practices were selected when there were multiple options and provides a roadmap of the resources and best practices referenced for each section of the *Michigan VISSIM Protocol Manual*.

# FINDINGS

The purpose of the *Michigan VISSIM Protocol Manual* is to provide guidelines and recommendations for VISSIM modeling projects in the state of Michigan. WSP and MDOT used their combined experience with VISSIM to determine the appropriate practices to include in the *Michigan VISSIM Protocol Manual*. These decisions were influenced by many factors, including the frequency a best practice was cited in the literature review as well as its adherence to FHWA guidance, ease of implementation, and value added in streamlining the VISSIM project delivery process.

## PROJECT UNDERSTANDING

The *Michigan VISSIM Protocol Manual* was broken into two main sections. The goal of Section 1 is to aid MDOT project managers in determining whether VISSIM is the correct analysis tool, defining a VISSIM project scope, and understanding VISSIM milestones and deliverables. The goal of Section 2 is to provide guidance in model development, model summary and model review processes. The following provides a summary of the various sections from the *Michigan VISSIM Protocol Manual* and the resources used to develop each section.

### WHEN TO USE MICROSIMULATION

FHWA and many other state DOTs have developed guidance on the selection of proper traffic analysis tools. It is important to pick the right analysis tool for the project's analysis needs, and due to the complexity and data/labor intensity typical of a microsimulation analysis, it is not always the most efficient or cost-effective tool. Simpler deterministic software packages such as FHWA's Highway Capacity Software may provide analysis capabilities and the level of detail that are sufficient to meet project analysis needs.

Seven criteria outlined by FHWA were selected as an appropriate aid to steer MDOT project managers in selecting the correct analysis software. These criteria are:

1. Ability to analyze the geographic scope or study area, such as an isolated intersection, single roadway, corridor or network.
2. Capability of modeling various facility types, such as freeways, high-occupancy lanes, ramps and arterials.
3. Ability to analyze various travel modes, such as single-occupancy vehicles, buses, trains and nonmotorized traffic.
4. Ability to analyze various traffic management strategies and applications, such as ramp metering, signal coordination and incident management.
5. Capability of estimating traveler responses to traffic management strategies, including route diversion, mode shift and induced demand.
6. Ability to produce and output performance measures, such as safety measures, efficiency, mobility, productivity and environmental measures.
7. Cost-effectiveness for the task from an operational perspective. Parameters that influence cost-effectiveness include tool capital cost, level of effort, ease of use, hardware requirements, data requirements and animation.

In addition to the above seven criteria, instances where VISSIM excels as an analysis tool were listed to further aid project managers. VISSIM is best applied for high-resolution operational analysis, where the nuances of the scenario to be tested fall outside the capabilities of other software packages. This may include:

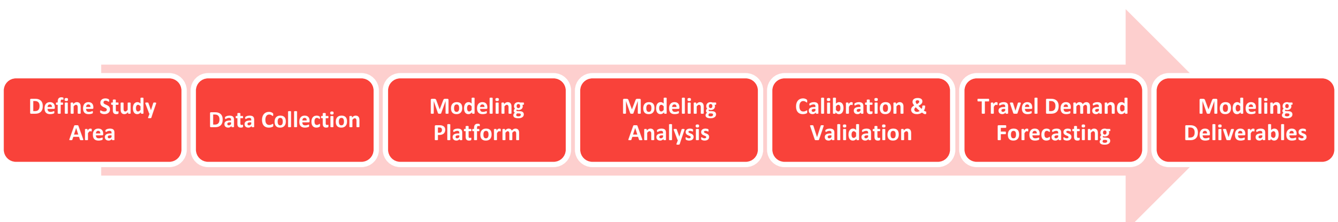
- Complex signal timing or operations (such as transit signal priority and preemption strategies)
- Complex geometrics

- Traffic flow and interaction through closely spaced intersections
- Managed lane operations
- Transit operations
- Ramp metering and ATM strategies
- Roundabouts
- Curbside operations
- Connected vehicle/autonomous vehicle operations
- Interactions between nonmotorized and motorized modes of travel

## MODEL SCOPE DEVELOPMENT

A properly developed VISSIM project scope is critical to a successful project. It is important that the work tasks are clearly defined and that the parties responsible for completing them are identified. Figure 1 highlights the critical elements in developing a VISSIM modeling scope of work.

*Figure 1: Scope of Work Critical Elements*




Ultimately, project managers creating a scope of work for a VISSIM modeling analysis will want to answer the following questions:

- ***WHY*** – Why is the analysis needed?
- ***WHAT*** – What questions should the analysis answer?
- ***WHO*** – Who are the intended reviewers and recipients of the results?
- ***HOW*** – How should results be presented?

## PROJECT MANAGEMENT

Project management of a VISSIM analysis requires establishing clear objectives, defining a solid scope of work and schedule, monitoring milestones and reviewing deliverables. The general workflow is shown in Figure 2.

*Figure 2: VISSIM Analysis Workflow*

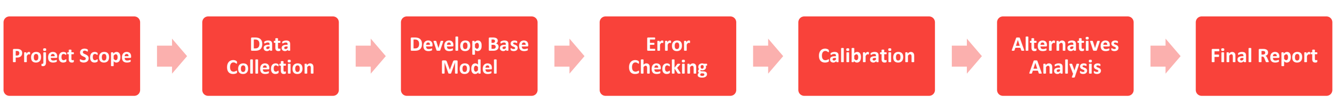
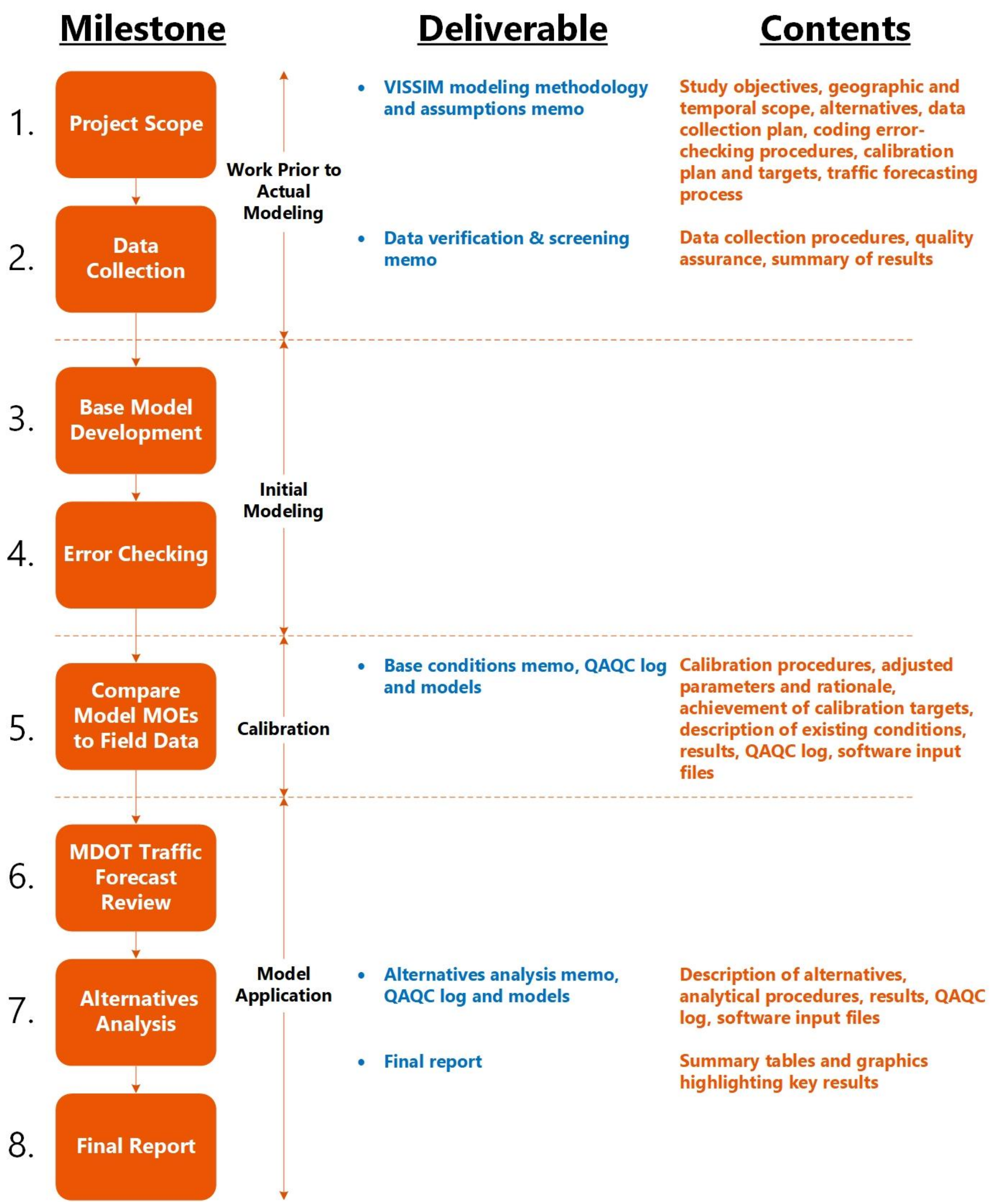


Figure 3 provides project managers with an overview of the relationship between VISSIM milestones and expected deliverables during a project. The various memos and reports that are generated as part of the project should at a minimum be reviewed by the project manager and representatives of MDOT's Congestion and Reliability Unit.

*Figure 3: VISSIM Analysis Milestones and Deliverables*



## VISSIM PROTOCOL PROCESS

The second section of the *Michigan VISSIM Protocol Manual* provides guidance on preparing VISSIM models within the state of Michigan. The language in this section was tailored to model developers and is technical in nature. The guidelines outlined below were selected to provide consistency through approved coding techniques.

### GEOGRAPHIC AND TEMPORAL MODEL SCOPE

To limit subsequent expansion of VISSIM modeling efforts, selecting proper geographic and temporal limits is essential to successful project delivery. FHWA provides the following guidance: “The geographic and temporal scopes of a microsimulation model should be sufficient to completely encompass all of the traffic congestion present in the primary influence area of the project during the target analysis period (current or future).”

The guidance in this section of the manual mirrors the guidance used in many other state agencies. The geographic scope should extend at least one interchange or intersection on either side of the primary study area. The temporal scope should include the time before congestion (pre-peak), during congestion (peak), and after congestion has completely dissipated (post-peak). This time could vary from a single hour to a multi-hour model depending on the traffic conditions. MDOT has access to the Regional Integrated Transportation Information System (RITIS), which is recommended as an aid when determining both geographic and temporal scope.

### DATA COLLECTION AND DEVELOPMENT

The geometric and traffic control data required for VISSIM modeling is standard across all reviewed VISSIM protocol documents. Aerial images and site visits are typical sources of information. The exact data requirements of a VISSIM project will vary based on the model’s purpose.

Traffic volume data is often dependent on the data collection capabilities within a state and access to historical data sets. The requirements for up-to-date traffic volume data need to be flexible enough to allow for instances where new data is skewed by nearby construction or other outside factors.

The best practice that is preferred by FHWA and other state agencies is that all traffic data should be collected on the same day at all locations throughout the entire study area. Where this is not possible, data that is less than three years old may be used without data quality verification. In instances where data less than three years old is not available, a sensitivity analysis needs to be conducted to determine if regional or local traffic growth rates are accounted for.

Good data is required for a successful analysis, and poor data will confuse the analysis and make it difficult to achieve meaningful analysis results. Verification should include checking that weather, incidents or construction did not influence the data collected (unless that is the project’s purpose). Checking data discrepancies 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.

### MODEL DEVELOPMENT

The *Michigan VISSIM Protocol Manual* was not intended to be a tutorial on how to code VISSIM models. Its purpose is to establish preferred coding techniques when there are multiple acceptable approaches and to define acceptable assumptions.

#### DRIVING BEHAVIORS

Vehicle behavior parameters can be varied in almost an infinite combination, with a subsequent wide spectrum of model results. The two key driver behavior models are the vehicle following model and the lane change model.

The suggested ranges for the component parameters are a starting point and can be adjusted outside of these ranges if needed. The ranges for the Wiedemann 99 model that defines freeway traffic (see Table 1) are the same as the ranges used by the Maryland, Oregon and Washington State DOTs.

*Table 1: Wiedemann 99 Vehicle Following Parameters*

| Parameter | | Default | Unit | Suggested Range | |
|---|---|---|---|---|---|
| | | | | Basic Segment | Merging/Diverging |
| **CC0** | Standstill Distance | 4.92 | ft | 4.5 – 5.5 | > 4.92 |
| **CC1** | Headway Time | 0.9 | s | 0.85 – 1.05 | 0.90 – 1.50 |
| **CC2** | Following Variation | 13.12 | ft | 6.56 – 22.97 | 13.12 – 39.37 |
| **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 | |

The suggested ranges for the Wiedemann 74 vehicle following parameters that define surface street traffic are illustrated in Table 2. These parameters were sourced from Maryland DOT. Oregon and Washington State DOTs did not define a discrete acceptable range, instead providing guidance only on the impact of the parameters on the resulting saturation flow rates. In general, a greater parameter value will result in a lower saturation flow.

*Table 2: Wiedemann 74 Vehicle Following Parameters*

| **Surface Street Car Following Model Parameters Suggested Range** | | | |
|---|---|---|---|
| **Parameter** | **Default Value** | **Unit** | **Suggested Range** |
| Average Standstill Distance | 6.56 | ft | 3.28 – 6.56 |
| Additive part of safety distance | 2.00 | - | 2.0 – 2.2 |
| Multiplicative part of safety distance | 3.00 | - | 2.8 – 3.3 |

The available lane changing parameters are the same for both freeway and surface streets and are applied on the same link-type basis as the vehicle following parameters. The default lane change parameters are a good starting point, just like the default vehicle following parameters. However, some parameters may need to be changed in the calibration process to match real-world driving behavior, specifically when modeling merging, diverging and weaving areas.

The lane change parameters selected for the *Michigan VISSIM Protocol Manual* (see Table 3) are from the Washington and Oregon VISSIM guidance documents.

*Table 3: Suggested Lane Change Parameters*

| General Behavior | Free Lane Selection | | | |
|---|---|---|---|---|
| **Necessary Lane Change (route)** | **Own** | **Unit** | **Trailing Vehicle** | **Unit** |
| Maximum deceleration | -15 to -12 | $ft/s^2$ | -12 to -8 | $ft/s^2$ |
| -1 $ft/s^2$ per distance | 150 - 250 | ft | 150 - 250 | ft |
| Accepted deceleration | -2.5 to -4 | $ft/s^2$ | -1.5 to -2.5 | $ft/s^2$ |
| Waiting time before diffusion | | | 200 | s |
| Min. headway (front/rear) | | | 1.5 - 2 | ft |
| To slower lane if collision time above | | | 0.0 – 0.5 | s |
| Safety distance reduction factor (SDRF) | | | 0.25 – 1.00 | - |
| Maximum deceleration for cooperative braking | | | -8.0 to -15 | $ft/s^2$ |
| Overtake reduced speed area | | | Unchecked | - |

## DRIVER BEHAVIOR SUMMARY

The nomenclature suggested for use in naming discrete driving behaviors is based on the Maryland DOT guidance; however, names were simplified to keep the number of utilized driving behaviors to a minimum (see Table 4).

*Table 4: Driver Behavior Application Summary*

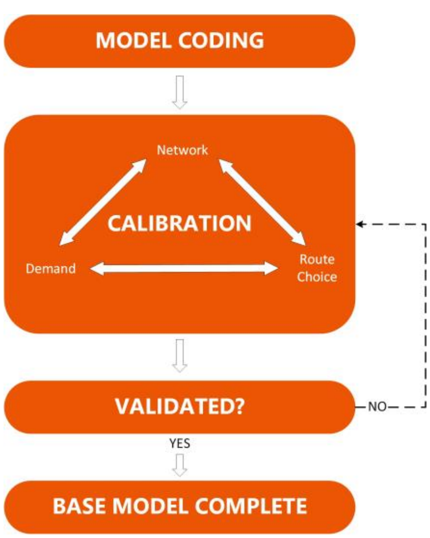
| FREEWAY | | | | | | |
|---|---|---|---|---|---|---|
| **Conservative** | | | | **Aggressive** | | |
| **Description** | **Name** | **#** | **Link Type** | **#** | **Name** | **Description** |
| **Can be used at segments where reduction in throughput is required. Significant factors include increased CC1 and CC2 values.** | Freeway Basic Conservative | 101 | Basic | 103 | Freeway Basic Aggressive | **Throughput is higher than default and simulates aggressive behavior. Significant factors include reduction of SDRF, higher lane change parameters and increased maximum deceleration for cooperative braking.** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Can be used at segments where reduced throughput is desired at merge/diverge/weave segments. Lane change parameters are reduced along with higher SDRF.** | Freeway Lane Change Conservative | 102 | Merge/ Diverge/ Weave | 104 | Freeway Lane Change Aggressive | **Model is suitable for simulating aggressive lane changing links. Significant parameters are lower CC1, higher accepted deceleration, lower SDRF, and higher maximum deceleration for cooperative braking.** |
| **ARTERIAL** | | | | | | |
| **Conservative** | | | | **Aggressive** | | |
| **Description** | **Name** | **#** | **Link Type** | **#** | **Name** | **Description** |
| **Used for simulating conservative driving on arterial segments. Lane change parameters are kept low and SDRF is default.** | Arterial Basic Conservative | 201 | Basic | 202 | Arterial Basic Aggressive | **Model can be used for simulating aggressive arterial segments. Significant factors include lower SDRF and higher maximum cooperative braking value.** |

## CALIBRATION AND VALIDATION

Calibration is the process used to achieve adequate reliability or validity of the model by establishing suitable parameter values so that the model replicates local traffic conditions as closely as possible (see Figure 4). Calibration is often a time-consuming process, but one that cannot be overlooked. The modeler should make all efforts to keep the set of adjustable parameters as small as possible to minimize the effort required to calibrate.

*Figure 4: Model Validation and Calibration Process*



## SIMULATION RUNS

Prior to reviewing outputs from a model against validation criteria, the modeler must first determine if the outputs from any individual run of the simulation model are reliable. As microsimulation models are stochastic in nature, there will be variation in MOEs with different random number seeds. Because there is variation, multiple runs are generally conducted with the results averaged to determine representative MOEs. The amount of variation between individual runs will determine how many runs should be conducted to arrive at a statistically significant average. Volatile networks with excessive congestion typically require more runs than more stable networks that operate at near free-flow speeds and produce more consistent results across model runs. To determine the number of runs that should be conducted, an initial sampling of the model outputs (consisting of several simulation runs) is required. All of the VISSIM guidance documents reviewed for this project required a minimum of 10 runs to generate a large enough sample size, but this must be verified by calculation.

A statistical calculation based on a 95% confidence level is typical but can be altered if necessary. The chosen confidence level along with the selected confidence interval will be used to determine the number of runs required to ensure that the results reported are representative of the true mean of the model (see Equation 1).

*Equation 1: Required Simulation Runs*

$$N = \left(2 * \ t_{0.025,N-1}\frac{S}{R}\right)^2$$

**NOTE:**

- $R$ = 95 percent confidence interval for the true mean
- $t_{0.025,\,N-1}$ = Student's t-statistics for 95 percent confidence (two-sided error of 2.5 percent with $N$–1 degrees of freedom)
- $S$ = Standard deviation of selected MOE sample
- $N$ = Number of required simulation runs

It is not practical to test the statistical significance of the average of every data output. This calculation should only be conducted for the MOEs that are deemed most important to the outcome of the project. Typical MOEs selected to determine the required number of simulation runs include throughput volume or corridor travel times.

## VALIDATION TARGETS

Having validation criteria for at least two different MOEs is a best practice; this was consistent across all the reviewed guidance. It is strongly recommended that the following MOEs be used for validation criteria for all traffic models:

- Traffic volumes
- Speed/travel times

These MOEs are suggested to be prioritized given their influence on the many other operational characteristics of the transportation network, such as density and delay. Field data for these MOEs are also relatively quick to obtain.

The goal is to get the best match possible between model estimates and field measurements. However, there is a point of diminishing return to the amount of time and effort that can be put into eliminating error in the model.

A universal measure to compare field data and model output data is the GEH formula, which is utilized by several other state agencies (see Equation 2).

*Equation 2: GEH Statistic*

$$GEH = \sqrt{\frac{2(m-c)^2}{m+c}}$$

**NOTE:**

- $m$ = output traffic throughput volumes from the simulation model (veh/h/ln)
- $c$ = traffic throughput volumes based on field data (veh/h/ln)

The calibration criteria selected (see Table 5) is from Washington State DOT; it is more stringent in its targets than the criteria utilized by Oregon.

*Table 5: Throughput Traffic Volume Calibration Criteria*

| **Criteria** | **Acceptable Targets** |
|---|---|
| GEH < 3.0 | All MDOT facility segments within the calibration area |
| GEH < 3.0 | All entry and exit locations within the calibration area |
| GEH < 3.0 | All entrance and exit ramps within the calibration area |
| GEH < 5.0 | At least 85% of applicable local roadway segments |
| Sum of all segment flows within the calibration area | Within 5% |

Speed is a very useful second proof of validation metric. This metric usually pertains to freeway segments because it is difficult to measure speed data on arterials. Virginia and Washington allow for model validation based on spot speed data displayed in the form of a heat map. This graphical display of speeds is useful in comparing simulation vehicle speeds against probe vehicle speed data (e.g., RITIS). In the absence of this data, field-collected speeds or segment space mean speed determined from travel time runs may be used for validation.

The goal of using speed heat maps for validation is to match the spatial extent and duration of congestion resulting from bottlenecks (see Figure 5 for an example). Models are deemed acceptable based on the visual acceptance between the simulated speeds heat map and the observed speeds heat map. Final approval of simulated model speeds will be conducted by MDOT.

*Figure 5: Example of a Speed Heat Map*

| Route (Dir.) | Mainline / Ramp | | RITIS Speed (mph) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 900-1800 | 1800-270 | 2700-360 | 3600-450 | 4500-540 | 5400-630 | 6300-720 | 7200-810 | 8100-900 | 9000-990 | 9900-108 | 10800-11 | 11700-12 | 12600-13 | Average |
| I-94 (EB) | BEGIN EB 94 | Mainline | 65 | 67 | 68 | 63 | 66 | 66 | 67 | 66 | 66 | 65 | 65 | 64 | 65 | 64 | 65 |
| | EB 94 (AA-Saline) | Mainline | 66 | 68 | 71 | 67 | 64 | 68 | 67 | 66 | 68 | 68 | 66 | 64 | 65 | 63 | 66 |
| | EB 94 | Mainline | 66 | 68 | 71 | 67 | 64 | 68 | 67 | 66 | 68 | 68 | 66 | 64 | 65 | 63 | 66 |
| | EB 94 | Mainline | 66 | 68 | 71 | 68 | 64 | 66 | 64 | 66 | 64 | 67 | 66 | 65 | 66 | 61 | 66 |
| | EB 94 (State St) | Mainline | 66 | 68 | 68 | 70 | 65 | 56 | 61 | 62 | 68 | 65 | 68 | 66 | 66 | 62 | 65 |
| | EB 94 | Mainline | 66 | 68 | 68 | 70 | 65 | 56 | 61 | 62 | 68 | 65 | 68 | 66 | 66 | 62 | 65 |
| | EB 94 | Mainline | 65 | 65 | 66 | 65 | 66 | 57 | 63 | 64 | 65 | 65 | 67 | 65 | 64 | 66 | 64 |
| | EB 94 (US-23) | Mainline | 64 | 67 | 65 | 66 | 66 | 65 | 64 | 72 | 65 | 68 | 67 | 66 | 65 | 67 | 66 |
| | EB 94 | Mainline | 66 | 65 | 64 | 65 | 63 | 59 | 59 | 62 | 65 | 64 | 63 | 63 | 64 | 65 | 63 |
| | EB 94 (Michigan Ave) | Mainline | 73 | 65 | 74 | 65 | 69 | 68 | 62 | 62 | 65 | 67 | 67 | 66 | 67 | 67 | 67 |
| | EB 94 | Mainline | 73 | 65 | 74 | 65 | 69 | 68 | 62 | 62 | 65 | 67 | 67 | 66 | 67 | 67 | 67 |
| | EB 94 (Huron St) | Mainline | 68 | 69 | 64 | 69 | 68 | 67 | 64 | 67 | 67 | 67 | 67 | 66 | 68 | 64 | 67 |
| | EB 94 | Mainline | 68 | 69 | 64 | 69 | 68 | 67 | 64 | 67 | 67 | 67 | 67 | 66 | 68 | 64 | 67 |
| | EB 94 | Mainline | 64 | 67 | 65 | 67 | 67 | 66 | 63 | 63 | 64 | 64 | 65 | 65 | 65 | 63 | 65 |
| | END EB 94 (US-12) | Mainline | 67 | 69 | 65 | 67 | 68 | 67 | 66 | 65 | 65 | 66 | 67 | 66 | 66 | 66 | 66 |
| I-94 (WB) | BEGIN WB 94 | Mainline | 65 | 66 | 67 | 53 | 32 | 29 | 65 | 65 | 64 | 66 | 65 | 65 | 66 | 66 | 59 |
| | WB 94 (US-12) | Mainline | 64 | 64 | 63 | 41 | 27 | 36 | 49 | 63 | 61 | 59 | 67 | 65 | 66 | 65 | 56 |
| | WB 94 (Huron St) | Mainline | 64 | 64 | 63 | 44 | 19 | 51 | 30 | 52 | 49 | 48 | 64 | 67 | 65 | 64 | 53 |
| | WB 94 | Mainline | 64 | 64 | 63 | 44 | 19 | 51 | 30 | 52 | 49 | 48 | 64 | 67 | 65 | 64 | 53 |
| | WS 94 | Mainline | 64 | 65 | 64 | 36 | 25 | 44 | 23 | 35 | 32 | 33 | 64 | 67 | 64 | 63 | 48 |
| | WB 94 (Michigan Ave) | Mainline | 63 | 65 | 64 | 24 | 25 | 19 | 15 | 17 | 17 | 31 | 61 | 67 | 65 | 63 | 42 |
| | WB 94 | Mainline | 63 | 65 | 64 | 24 | 25 | 19 | 15 | 17 | 17 | 31 | 61 | 67 | 65 | 63 | 42 |
| | WB 94 | Mainline | 61 | 64 | 62 | 18 | 24 | 15 | 15 | 16 | 16 | 27 | 52 | 63 | 60 | 61 | 40 |
| | WB 94 (US-23) | Mainline | 56 | 50 | 59 | 20 | 28 | 20 | 23 | 22 | 21 | 34 | 35 | 42 | 40 | 56 | 36 |
| | WB 94 | Mainline | 56 | 50 | 59 | 20 | 28 | 20 | 23 | 22 | 21 | 34 | 35 | 42 | 40 | 56 | 36 |
| | WB 94 SB US-23 On | Mainline | 56 | 50 | 59 | 20 | 28 | 20 | 23 | 22 | 21 | 34 | 35 | 42 | 40 | 56 | 36 |
| | WB 94 | Mainline | 63 | 62 | 59 | 44 | 53 | 45 | 44 | 48 | 49 | 51 | 30 | 33 | 31 | 56 | 48 |
| | WB 94 (State St) | Mainline | 61 | 63 | 62 | 57 | 62 | 54 | 61 | 57 | 58 | 59 | 55 | 47 | 56 | 60 | 58 |
| | WB 94 | Mainline | 61 | 63 | 62 | 57 | 62 | 54 | 61 | 57 | 58 | 59 | 55 | 47 | 56 | 60 | 58 |
| | WB 94 | Mainline | 61 | 64 | 63 | 62 | 64 | 59 | 63 | 61 | 61 | 62 | 62 | 62 | 61 | 61 | 62 |
| | WB 94 (AA-Saline) | Mainline | 62 | 65 | 65 | 64 | 65 | 61 | 67 | 60 | 65 | 63 | 65 | 65 | 63 | 63 | 64 |
| | END WB 94 | Mainline | 62 | 65 | 67 | 64 | 67 | 65 | 68 | 62 | 64 | 63 | 67 | 67 | 63 | 65 | 65 |

| Route (Dir.) | Mainline / Ramp | | VISSIM Speed (mph) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 900-1800 | 1800-270 | 2700-360 | 3600-450 | 4500-540 | 5400-630 | 6300-720 | 7200-810 | 8100-900 | 9000-990 | 9900-108 | 10800-11 | 11700-12 | 12600-13 | Average |
| I-94 (EB) | BEGIN EB 94 | Mainline | 69 | 68 | 68 | 68 | 68 | 67 | 68 | 68 | 68 | 68 | 69 | 69 | 69 | 69 | 68 |
| | EB 94 (AA-Saline) | Mainline | 69 | 68 | 68 | 68 | 67 | 66 | 67 | 67 | 67 | 68 | 68 | 69 | 69 | 68 | 68 |
| | EB 94 | Mainline | 68 | 68 | 67 | 67 | 65 | 60 | 67 | 66 | 67 | 68 | 68 | 68 | 69 | 68 | 67 |
| | EB 94 | Mainline | 68 | 67 | 66 | 66 | 61 | 59 | 63 | 64 | 64 | 66 | 67 | 68 | 68 | 68 | 65 |
| | EB 94 (State St) | Mainline | 68 | 68 | 67 | 68 | 65 | 66 | 66 | 66 | 66 | 67 | 68 | 68 | 69 | 68 | 67 |
| | EB 94 | Mainline | 68 | 68 | 67 | 67 | 63 | 54 | 66 | 66 | 66 | 67 | 68 | 68 | 68 | 68 | 66 |
| | EB 94 | Mainline | 68 | 68 | 67 | 66 | 63 | 62 | 67 | 66 | 66 | 67 | 68 | 68 | 68 | 68 | 67 |
| | EB 94 (US-23) | Mainline | 68 | 68 | 67 | 66 | 65 | 64 | 66 | 66 | 65 | 67 | 68 | 68 | 68 | 68 | 67 |
| | EB 94 | Mainline | 68 | 68 | 68 | 68 | 67 | 67 | 68 | 68 | 68 | 68 | 69 | 69 | 69 | 69 | 68 |
| | EB 94 (Michigan Ave) | Mainline | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 69 | 69 | 69 | 69 | 68 |
| | EB 94 | Mainline | 68 | 68 | 68 | 68 | 68 | 67 | 68 | 68 | 68 | 68 | 69 | 69 | 69 | 69 | 68 |
| | EB 94 (Huron St) | Mainline | 68 | 68 | 68 | 67 | 67 | 67 | 67 | 67 | 67 | 68 | 68 | 69 | 69 | 69 | 68 |
| | EB 94 | Mainline | 68 | 68 | 68 | 67 | 67 | 66 | 67 | 67 | 67 | 68 | 68 | 69 | 69 | 69 | 68 |
| | EB 94 | Mainline | 68 | 68 | 68 | 67 | 67 | 66 | 68 | 67 | 68 | 68 | 69 | 69 | 69 | 69 | 68 |
| | END EB 94 (US-12) | Mainline | 68 | 68 | 68 | 67 | 68 | 67 | 68 | 68 | 68 | 68 | 69 | 69 | 69 | 69 | 68 |
| I-94 (WB) | BEGIN WB 94 | Mainline | 69 | 68 | 68 | 69 | 68 | 69 | 64 | 52 | 59 | 64 | 65 | 69 | 69 | 68 | 66 |
| | WB 94 (US-12) | Mainline | 69 | 67 | 67 | 67 | 67 | 57 | 24 | 18 | 31 | 40 | 53 | 67 | 68 | 68 | 55 |
| | WB 94 (Huron St) | Mainline | 69 | 67 | 67 | 66 | 63 | 18 | 9 | 12 | 15 | 21 | 36 | 59 | 68 | 67 | 45 |
| | WB 94 | Mainline | 69 | 67 | 66 | 66 | 42 | 8 | 9 | 13 | 15 | 19 | 26 | 52 | 68 | 67 | 42 |
| | WS 94 | Mainline | 69 | 68 | 67 | 66 | 15 | 9 | 11 | 17 | 18 | 22 | 27 | 46 | 68 | 68 | 41 |
| | WB 94 (Michigan Ave) | Mainline | 68 | 66 | 65 | 35 | 8 | 7 | 8 | 13 | 14 | 15 | 18 | 41 | 68 | 67 | 35 |
| | WB 94 | Mainline | 68 | 67 | 66 | 12 | 6 | 6 | 7 | 10 | 11 | 11 | 13 | 28 | 60 | 68 | 31 |
| | WB 94 | Mainline | 66 | 60 | 25 | 9 | 7 | 6 | 8 | 12 | 13 | 13 | 16 | 23 | 46 | 61 | 26 |
| | WB 94 (US-23) | Mainline | 66 | 63 | 57 | 57 | 59 | 60 | 57 | 51 | 36 | 28 | 39 | 34 | 47 | 58 | 51 |
| | WB 94 | Mainline | 54 | 42 | 42 | 54 | 57 | 57 | 48 | 39 | 22 | 19 | 27 | 23 | 28 | 40 | 39 |
| | WB 94 SB US-23 On | Mainline | 64 | 59 | 57 | 62 | 64 | 64 | 59 | 49 | 25 | 21 | 29 | 26 | 28 | 49 | 47 |
| | WB 94 | Mainline | 68 | 67 | 65 | 66 | 67 | 67 | 66 | 63 | 58 | 53 | 39 | 28 | 27 | 36 | 55 |
| | WB 94 (State St) | Mainline | 66 | 64 | 60 | 65 | 65 | 66 | 63 | 60 | 60 | 57 | 57 | 57 | 57 | 59 | 61 |
| | WB 94 | Mainline | 69 | 68 | 67 | 68 | 67 | 68 | 67 | 65 | 65 | 65 | 65 | 65 | 64 | 65 | 66 |
| | WB 94 | Mainline | 67 | 67 | 65 | 66 | 66 | 66 | 66 | 64 | 64 | 64 | 65 | 64 | 64 | 64 | 65 |
| | WB 94 (AA-Saline) | Mainline | 69 | 68 | 68 | 68 | 68 | 68 | 68 | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 68 |
| | END WB 94 | Mainline | 69 | 68 | 68 | 68 | 68 | 68 | 68 | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 68 |

The travel time criteria are separated into two facility types: uninterrupted flow and interrupted flow.

Travel time routes that span a long distance, such as through multiple freeway interchanges, should be broken into multiple segments for validation purposes. The overall travel time route of the corridor should also be validated.

Modelers should ensure that an adequate sample size of travel time data is available for comparison with average model outputs. When available, probe vehicle data sources should be used to provide a large sample size over multiple days. Alternatively, field travel time runs may be conducted, though project budgets may limit the number of runs to below that which would be considered a statistically significant sample size. The travel time data should align with the period of travel time validation (peak hour or peak period).

The travel time validation criteria are as follows (as taken from Virginia DOT):

- 85% of the travel time routes and segments, or a select number of critical routes and segments shall be within the following thresholds:
  - ± 30% for average observed travel times on arterials
  - ± 20% for average observed travel times on freeways

These travel time criteria were also in the Wisconsin and California DOT requirements.

## EVALUATING MODELS

Graphical and tabular presentations of MOEs should be carefully created to help convey the results. Presentation and format of reported outputs should target a nontechnical audience while allowing a technical reviewer the ability to verify the results of the analysis. Many of the state agencies provided sample templates for the presentation of model results, including several tabular formats that effectively display MOEs for both freeway and arterial networks.

## DOCUMENTATION AND DELIVERABLES

The deliverables throughout the life cycle of a VISSIM project include electronic modeling files, interim technical memorandums and a final report. Technical memorandums are interim reports that document technical issues relevant to the analysis process. Each submitted memorandum will allow MDOT and other stakeholders the opportunity to review and understand the analysis methodologies and results before the final report is drafted. The interim memorandums allow for verification and correction of model development at key points in the process. MDOT and other reviewing agencies should review and concur with the content of the technical memorandums before the model development team proceeds to the next deliverable.

The expected technical memorandums are as follows:

- VISSIM Modeling Methodology and Assumptions Memo
- Data Verification and Screening Assessment Memo
- Calibration and Validation Memo
- Base Conditions Memo
- Alternatives Analysis Memo

# TOOLS AND CHECKLISTS

Tools and checklists were widely used by all the agencies, ranging from checklists and templates to simple software tools to simplify calibration and validation. The following templates and checklists were selected to provide assistance during a

VISSIM project life cycle. Reference documents utilized in the development of each checklist are cited in the following section.

- VISSIM Scoping Checklist
- VISSIM Models Prompt List
- VISSIM Comment Log
- Reviewing Agency Checklist
- Simulation Run Confidence Template
- GEH Link Volume Validation Template
- Speed Validation Template
- MOE Samples
- Memorandum Samples

## MICHIGAN VISSIM PROTOCOL SOURCE GUIDE

This section provides a roadmap to the various resources cited in the development of each major section of the *Michigan VISSIM Protocol Manual* and is meant to provide a quick reference for revisions in the future.

1. VISSIM Protocol Overview
    a. Purpose of This Manual
    b. When to Use Microsimulation
        i. Dowling, R., J. Holland, A. Huang. *Guidelines for Applying Traffic Microsimulation Modeling Software.* California Department of Transportation.
        ii. *Protocol for Vissim Simulation.* Washington State Department of Transportation, 2014.
        iii. *Traffic Analysis Toolbox Volume II: Decision Support Methodology for Selecting Traffic Analysis Tools.* Publication FHWA-HRT-04-039. FHWA, U.S. Department of Transportation, 2004.
    c. Model Scope Development
        i. *Protocol for Vissim Simulation.* Washington State Department of Transportation, 2014.
        ii. *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software.* Publication FHWA-HRT-04-040. FHWA, U.S. Department of Transportation, 2004.
    d. Project Management
        i. *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software.* Publication FHWA-HRT-04-040. FHWA, U.S. Department of Transportation, 2004.
    e. Reviewing Deliverables
        i. Dowling, R., J. Holland, A. Huang. *Guidelines for Applying Traffic Microsimulation Modeling Software.* California Department of Transportation.
        ii. *General Modeling Guidelines.* Minnesota Department of Transportation, 2018.

iii. *Traffic Operations and Safety Analysis Manual (TOSAM) - Version 1.0.* Virginia Department of Transportation, 2015.

2. VISSIM Protocol Process

    a. VISSIM Version Selection

        i. *Traffic Engineering, Operations and Safety Manual.* Wisconsin Department of Transportation, 2018.

    b. Geographic and Temporal Model Scope

        i. *Analysis Procedures Manual Version 1.* Oregon Department of Transportation, 2018.

        ii. *CORSIM Modeling Guidelines.* Nevada Department of Transportation, 2012.

        iii. Dowling, R., J. Holland, A. Huang. *Guidelines for Applying Traffic Microsimulation Modeling Software.* California Department of Transportation.

        iv. *Protocol for Vissim Simulation.* Washington State Department of Transportation, 2014.

        v. *Traffic Analysis Handbook: A Reference for Planning and Operations.* Florida Department of Transportation, 2014.

    c. Data Collection and Development

        i. *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software.* Publication FHWA-HRT-04-040. FHWA, U.S. Department of Transportation, 2004.

    d. Model Development

        i. *Protocol for Vissim Simulation.* Oregon Department of Transportation, 2011.

        ii. *Protocol for Vissim Simulation.* Washington State Department of Transportation, 2014.

        iii. *PTV VISSIM 10 User Manual.* PTV AG, 2018.

        iv. *Traffic Analysis Handbook: A Reference for Planning and Operations.* Florida Department of Transportation, 2014.

        v. *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software.* Publication FHWA-HRT-04-040. FHWA, U.S. Department of Transportation, 2004.

        vi. *Vissim Modeling Guidance.* Maryland Department of Transportation, 2017.

    e. Error Checking

        i. *Protocol for Vissim Simulation.* Oregon Department of Transportation, 2011.

        ii. *Protocol for Vissim Simulation.* Washington State Department of Transportation, 2014.

        iii. *Traffic Operations and Safety Analysis Manual (TOSAM) - Version 1.0.* Virginia Department of Transportation, 2015.

    f. Model Calibration and Validation

        i. *CORSIM Modeling Guidelines.* Nevada Department of Transportation, 2012.

        ii. *General Modeling Guidelines.* Minnesota Department of Transportation, 2018.

        iii. *Protocol for Vissim Simulation.* Oregon Department of Transportation, 2011.

iv. *Protocol for Vissim Simulation.* Washington State Department of Transportation, 2014.

v. *Traffic Operations and Safety Analysis Manual (TOSAM) – Version 2.0.* Virginia Department of Transportation, 2020.

g. Future Year Models

i. *Protocol for Vissim Simulation.* Oregon Department of Transportation, 2011.

ii. *Protocol for Vissim Simulation.* Washington State Department of Transportation, 2014.

iii. *Traffic Analysis Handbook: A Reference for Planning and Operations.* Florida Department of Transportation, 2014.

h. Reported Measures of Effectiveness

i. Dowling, R., J. Holland, A. Huang. *Guidelines for Applying Traffic Microsimulation Modeling Software.* California Department of Transportation.

ii. *Protocol for Vissim Simulation.* Oregon Department of Transportation, 2011.

iii. *Protocol for Vissim Simulation.* Washington State Department of Transportation, 2014.

iv. *Traffic Analysis Handbook: A Reference for Planning and Operations.* Florida Department of Transportation, 2014.

i. Deliverables

i. *General Modeling Guidelines.* Minnesota Department of Transportation, 2018.

ii. *Protocol for Vissim Simulation.* Oregon Department of Transportation, 2011.

iii. *Protocol for Vissim Simulation.* Washington State Department of Transportation, 2014.

3. Appendices

a. VISSIM QAQC Templates

i. *Protocol for Vissim Simulation.* Oregon Department of Transportation, 2011.

ii. *Protocol for Vissim Simulation.* Washington State Department of Transportation, 2014.

b. VISSIM Model Validation Template

i. *Protocol for Vissim Simulation.* Washington State Department of Transportation, 2014.

c. VISSIM Model MOE Sample (Surface Street)

i. WSP Created

d. VISSIM Model MOE Sample (Freeway)

i. *Traffic Analysis Handbook: A Reference for Planning and Operations.* Florida Department of Transportation, 2014.

e. Technical Memorandum Samples

i. WSP Created

# DISCUSSION

In a traditional research project, this section would discuss the validity of the hypothesis and the implications of the collected data. In this case, there is no hypothesis to test, and the validity of the *Michigan VISSIM Protocol Manual* will be proven over time. The use of this document by MDOT and vendors during the delivery of VISSIM projects will provide the evidence that this document is useful and is achieving its goal of facilitating the development of higher-quality VISSIM models in a structured manner.

## FACTORS AND IMPLICATIONS AFFECTING THE RESULTS

There are two major factors that could impact the usefulness of the *Michigan VISSIM Protocol Manual*. One of the main factors is if a significant change is made to the VISSIM software itself by the developer. Major updates could impact network coding or the collection of model results. Additionally, if the underlying assumptions for the algorithms that control vehicle behavior are drastically changed, this would require a revision to the established calibration and validation criteria outlined in the *Michigan VISSIM Protocol Manual*. It is recommended that MDOT conduct a review of the release notes for each version update to determine the impact, if any, on the guidance and information in the *Michigan VISSIM Protocol Manual*.

VISSIM is often used on the national freeway network, and ultimately the FHWA must approve the design and analysis that is conducted on these facilities. Currently, the FHWA Traffic Analysis Toolbox provides guidance on microsimulation and is a significant source for many state agency guidance documents, including the *Michigan VISSIM Protocol Manual*. If in the future FHWA were to make significant changes to its microsimulation guidance, the *Michigan VISSIM Protocol Manual* would need to be updated accordingly as well to ensure it is still in compliance with FHWA's suggested modeling practices for freeway modeling analysis.

# CONCLUSIONS

VISSIM modeling is generally a labor-intensive effort to develop a calibrated and validated model that accurately reports measures of effectiveness. With any microsimulation software, there are many points in the model development process where assumptions need to be made and agreed upon between the model developer and the reviewing agency to ensure that the final deliverables meet client expectations.

The guidance developed as part of this research project lays out the expectations for VISSIM model development and deliverables so that both the vendor and MDOT can move through modeling projects in congruence based on current best practices. This will provide consistency in vendor deliverables, facilitate more efficient MDOT reviews, and reduce the risk of budget overruns and delays to project schedules due to misunderstood expectations. The guidance also defines a consistent methodology for MDOT to review and evaluate models and provides a clear roadmap to MDOT project managers unfamiliar with the VISSIM modeling process, giving them the tools necessary to successfully manage a modeling project with a clear understanding of protocol and anticipated modeling outcomes.

## RECOMMENDATIONS FOR FURTHER RESEARCH

VISSIM is highly complex and versatile software that can accurately model a wide range of unique intersection designs, transit operations, managed lanes and nonmotorized modes. Additional research may be necessary as new and unique interchange and intersection designs become more commonplace. For instance, there are several ways in which roundabouts can be coded that may require additional guidance than what is provided in the *Michigan VISSIM Protocol Manual*. Feedback from vendors as they use the *Michigan VISSIM Protocol Manual* will be critical in answering this type of question.

Managed lanes and other active traffic management strategies are becoming more prevalent in Michigan. Further research may be necessary as the frequency of traffic analysis projects involving these complex facilities increases. The amount of technical skill and expertise required to model one of these facilities is much greater than for conventional facilities, and these projects may require more guidance from MDOT to ensure that quality models are delivered.

As VISSIM software updates happen on a frequent basis, there will be a need to evaluate and update the *Michigan VISSIM Protocol Manual* intermittently in the future.

## RECOMMENDATIONS FOR IMPLEMENTATION

The *Michigan VISSIM Protocol Manual* is currently being implemented; it is hosted on MDOT's Traffic and Safety/Standards and Special Details website for download by vendors. Two webinars were conducted to familiarize MDOT staff and vendors with the manual.

The two meetings were conducted January 9 and 10, 2020, and were hosted by WSP.

1. Introduction to MDOT VISSIM Protocol document: Web conference attended by MDOT project managers and FHWA.
2. Introduction to MDOT VISSIM Protocol document: Hosted virtually and at the MDOT Earle Center for vendors to attend in person or via teleconference.

# BIBLIOGRAPHY


1. *Analysis Procedures Manual Version 1.* Oregon Department of Transportation, 2018.
2. *Analysis Procedures Manual Version 2.* Oregon Department of Transportation, 2018.
3. *CORSIM Modeling Guidelines.* Nevada Department of Transportation, 2012.
4. Dowling, R., J. Holland, A. Huang. *Guidelines for Applying Traffic Microsimulation Modeling Software.* California Department of Transportation.
5. *General Modeling Guidelines.* Minnesota Department of Transportation, 2018.
6. *Protocol for Vissim Simulation.* Oregon Department of Transportation, 2011.
7. *Protocol for Vissim Simulation.* Washington State Department of Transportation, 2014.
8. *PTV VISSIM 10 User Manual.* PTV AG, 2018.
9. *Traffic Analysis Handbook: A Reference for Planning and Operations.* Florida Department of Transportation, 2014.
10. *Traffic Analysis Toolbox Volume II: Decision Support Methodology for Selecting Traffic Analysis Tools.* Publication FHWA-HRT-04-039. FHWA, U.S. Department of Transportation, 2004.
11. *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software.* Publication FHWA-HRT-04-040. FHWA, U.S. Department of Transportation, 2004.
12. *Traffic Engineering Manual.* Publication 46 (2-12). Bureau of Maintenance and Operations, Pennsylvania Department of Transportation, 2014.
13. *Traffic Engineering, Operations and Safety Manual.* Wisconsin Department of Transportation, 2018.
14. *Traffic Operations and Safety Analysis Manual (TOSAM) - Version 1.0.* Virginia Department of Transportation, 2015.
15. *Traffic Operations and Safety Analysis Manual (TOSAM) – Version 2.0.* Virginia Department of Transportation, 2020.
16. *Vissim Modeling Guidance.* Maryland Department of Transportation, 2017.

# APPENDIX A: Literature Review

2019

# Development of Michigan Specific VISSIM Protocol

LITERATURE REVIEW

DATE: 7-25-2019

# Table of Contents

# INTRODUCTION

VISSIM is the microsimulation software developed and maintained by PTV. VISSIM modeling is generally a labor-intensive effort to develop a calibrated and validated model which accurately reports measures of effectiveness (MOEs). With any microsimulation software, there are many points in the model development process where assumptions need to be made and agreed upon between the model developer and the reviewing agency to insure final deliverables meet client expectations. Currently, the Michigan Department of Transportation (MDOT) has no standard process or guidelines for VISSIM model development or deliverables. This can lead to unclear expectations and a lack of consistent modeling assumptions and deliverables by vendors here in Michigan.

As a result, MDOT initiated research project OR18-011 to develop Michigan specific VISSIM modeling protocol. This document is the literature review of twelve other protocol documents from around the United States, including the states of Washington and Oregon as requested by MDOT. This literature review of these documents developed by state and federal agencies highlights and discusses differences in requirements and key components to the modeling process and identifies best practices.

# LITERATURE REVIEW

The literature review details findings from each stage of a VISSIM modeling project; from project understanding and scoping conducted before modeling begins through model development and final review of deliverables.

## PROJECT UNDERSTANDING

It is essential to the successful delivery of a VISSIM modeling project to have a clear and defined project description (1). This is often completed by the project sponsor before a project is fully developed. This process is used to clarify the intent and intended outcome of the project while preparing the RFP or other project scoping documents. The project objectives should be able to answer the following questions outlined in Caltrans (4).

- Why is the analysis needed?
- What questions should the analysis answer?
- Who is the intended recipient/decision maker for the results?

Oregon DOT provides a problem statement template to assist in creating the work plan or for creating a scope of work for contracted tasks (2).

Information on geometrics, safety, volumes, past studies, prior projects, and other analysis performed are useful tools to gain general knowledge of the study area. The analyst should consult or coordinate with the project team to complete the problem statement to reach internal agreement on key project goals early in the process.

### WHEN TO USE VISSIM

VISSIM is one of many analysis tools available to public agencies to conduct traffic studies. The advanced microsimulation features and 3D animation capabilities of VISSIM make it an attractive option. However, VISSIM may not always be the most cost-effective tool or fit the projects schedule (9). VISSIM's level of complexity and outputs may not be necessary for some projects. Simpler deterministic software packages such as Synchro, SIDRA, or HCS may provide the level of detail and analysis capabilities to meet the need of the project. To facilitate the decision about what analysis tool is a best fit for a study, several guidelines have been developed by different agencies. In the case of multiple agencies, a matrix of possible analysis tools versus type of analysis is utilized to guide the project team in selecting an appropriate tool (1, 8, 12, 13). Many agencies use the FHWA materials as guidance for tool selection including Pennsylvania DOT (13).

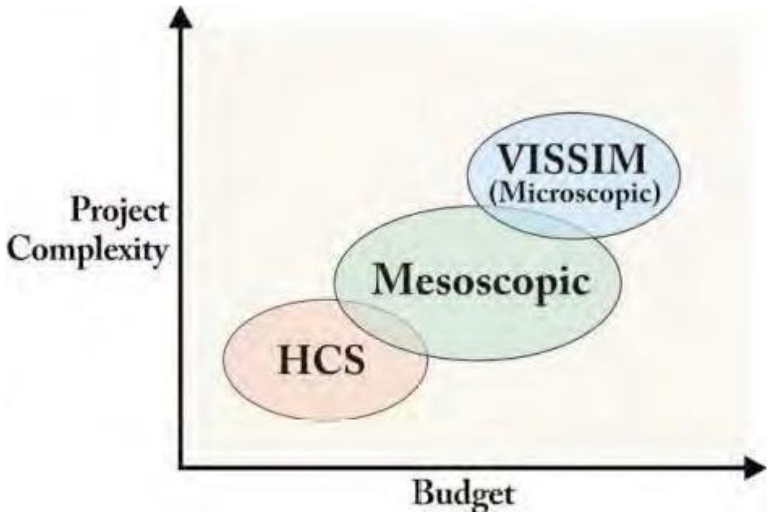



*Figure 1: Analysis Tools Comparison (1)*

FHWA Traffic Analysis Toolbox Volume II recommends the first step of traffic analysis tool selection is the identification of the analytical context of the project. The project can fall into one of three phases, which include: planning, design, or operations/construction. In addition, seven criteria are outlined to help identify the analytical tools that are most appropriate for a project. The project's goals or objectives and the relevance of each criterion may differ. In summary, the seven criteria are as follows (3):

1. Ability to analyze the geographic scope or study area. Including isolated intersection, single roadway, corridor, or network.
2. Capability of modeling various facility types, such as freeways, high-occupancy lanes, ramps, arterials, etc.
3. Ability to analyze various travel modes, such as single-occupancy vehicles, bus, train, and non-motorized traffic.
4. Ability to analyze various traffic management strategies and applications, such as ramp metering, signal coordination, incident management, etc.
5. Capability of estimating traveler responses to traffic management strategies, including route diversion, mode shift, and induced demand.
6. Ability to produce and output performance measures, such as safety measures, efficiency, mobility, productivity, and environmental measures.
7. Tool/cost-effectiveness for the task from an operational perspective. Parameters that influence cost-effectiveness include tool capital cost, level of effort, ease of use, hardware requirements, data requirements, animation, etc.

FHWA provides a table of relevance of each of previously stated seven criteria regarding seven traffic analysis tool categories. The seven analytical tool categories outlined by the FHWA are as follows (3):

1. Sketch-Planning Tools
2. Travel Demand Models
3. Analytical/Deterministic Tools
4. Traffic Signal Optimization Tools
5. Macroscopic Simulation Models

6. Mesoscopic Simulation Models

7. Microscopic Simulation Models

| Analytical Context/ Geographic Scope | Analytical Tools/Methodologies | | | | | | |
|---|---|---|---|---|---|---|---|
| | Sketch Planning | Travel Demand Models | Analytical/ Deterministic Tools (HCM-Based) | Traffic Optimi-zation | Macroscopic Simulation | Mesoscopic Simulation | Microscopic Simulation |
| **Planning** | | | | | | | |
| Isolated Location | ○ | ○ | ● | ∅ | ○ | ○ | ○ |
| Segment | ● | ○ | ● [1] | ○ | ∅ | ∅ | ∅ |
| Corridor/ Small Network | ∅ | ● | ○ | ○ | ∅ | ∅ | ∅ |
| Region | ∅ | ● | N/A | N/A | N/A | N/A | N/A |
| **Design** | | | | | | | |
| Isolated Location | N/A | N/A | ● | ● | ● | ∅ | ● |
| Segment | N/A | ○ | ● | ∅ | ● | ● | ● |
| Corridor/ Small Network | N/A | ∅ | ○ | ○ | ● | ● | ● |
| Region | N/A | ∅ | N/A | N/A | ○ | ○ | ∅ |
| **Operations/Construction** | | | | | | | |
| Isolated Location | N/A | N/A | ● | ● | ● | ∅ | ● |
| Segment | ∅ | ○ | ● | ● | ● | ● | ● |
| Corridor/ Small Network | N/A | ∅ | ○ | ∅ | ● | ● | ● |
| Region | N/A | ∅ | N/A | N/A | ∅ | ○ | ∅ |

**Notes:** ● Specific context is generally addressed by the corresponding analytical tool/methodology.
∅ Some of the analytical tools/methodologies address the specific context and some do not.
○ The particular analytical tool/methodology does not generally address the specific context.
N/A The particular methodology is not appropriate for use in addressing the specific context.
[1]For linear networks

*Figure 2: Relevance of Traffic Analysis Tool Categories with Respect to Geographic Scope (3)*

In a similar manner as FHWA, Caltrans outlines best traffic analysis tool by stage of travel analysis process. The four stages of traffic analysis are outlined as land use, travel demand, system operations, pollutant emissions, and air quality. Ultimately the selection of the best analysis tool is determined by the level of detail required and the technical capabilities of each software (4).

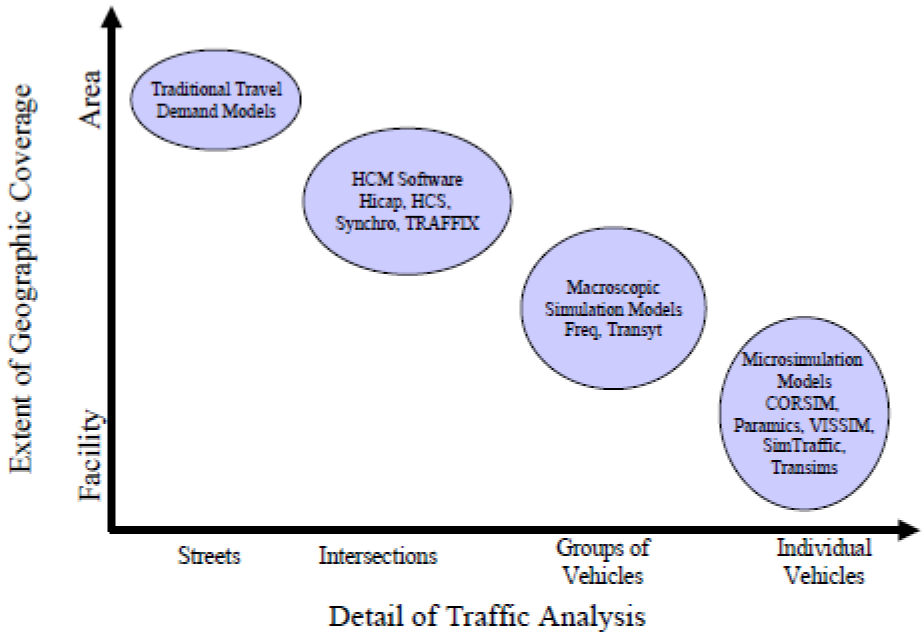



*Figure 3: Caltrans Traffic Analysis Tool Selection (4)*

Florida DOT outlines the data inputs needed for different analysis tools. The data requirements can vary greatly from tool to tool greatly influencing cost and level of effort.

| 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 | |

*Figure 4: Input Data for Different Analysis Tools (8)*

Overall, the project team may determine that more than one analysis tools may be necessary for many projects. The least complex and data intensive tool reasonable should be used for any given project. The use of the latest software version should be used no matter the tool selected.

## PROJECT SCOPING

The purpose of establishing a scope of work for a transportation study is to define critical parameters. An effective scope of work should always produce a completed study that satisfies the needs of the corresponding project. It is important that the work tasks be clearly defined and that the party responsible for completing them is identified. Oregon DOT provides a scoping checklist to assist the development of project scope (7). The following sections highlight the critical steps in developing a scope of work.

### PROJECT BOUNDARY DEFINITION

The project area boundary depends on the zone of influence of the surrounding traffic network. Washington DOT defines "zone of influence" as the project boundary where analysis will occur and includes the study area as well as a surrounding buffer area (1). The zone of influence may be greater than the minimum study area boundaries and should be determined with the input of the appropriate analysts and stakeholders of the project. The analyst should not finalize the spatial limits of the traffic model until field observations document the extent of congestion and length of vehicle queues within the study area (12). The following are general guidelines for determining the zone of influence based on facility type.

#### FREEWAYS AND RAMPS TERMINALS

Washington DOT recommends that VISSIM network extends at least one interchange, or at least two more miles outside of the study area (1). Additional interchanges may need to be included, especially in areas where interchanges are closely spaced (15). Special caution should be given when modeling system interchange areas and areas of significant weaving. The distance required to capture correct weaving behavior depends greatly on the surrounding interchanges' configuration and the level of congestion.

The network should extend far enough to prevent vehicle queues from spilling back out of the network. Also, any upstream bottlenecks that meter traffic coming into the study area should be included. The additional area modeled in the zone of influence is not in the study area. Therefore, MOE's do not need to be reported for the zone of influence. However, it is recommended that the reporting of the calibration should include the entire zone of influence. The areas outside of the study area should be coded per the VISSIM protocol but exceptions can be made to keep projects within budget and time constraints. Any special coding should be discussed to ensure no influence on the study area in either the base year or future year models.

The VISSIM network should include ramp terminal intersections as part of the project and to ensure proper modeling, at minimum, one intersection outside of the study intersections if within half-mile spacing. All intersections that have significant influence on the arrival pattern or lane choice of vehicles entering the network shall be modeled, including unsignalized intersections. Similarly, to the freeway zone of influence, these additional intersections do not need performance measures reported (1).

#### ARTERIALS

VISSIM networks that include arterial surface streets will have similar requirements to those described for ramp terminals. The VISSIM model should extend, at minimum, one intersection outside of the study intersections if within half-mile spacing (5,8). If the next intersection is beyond a half-mile, the project team should determine if it should be included. Again, all intersections including unsignalized intersections influencing the arrival patterns or the lane choice should be included in the model. This typically requires extending the network to the next intersection with a major cross street.

Bottlenecks causing queue spillback into study intersections and upstream bottlenecks that meter traffic into the study area should be included. Ideally, all network boundaries should be segments with free flow traffic conditions and be long enough to prevent queues from spilling out of the network (5).

For projects that include a proposal to modify or add a traffic signal on a coordinated signal corridor, the study area should consider including the entire coordinated corridor (8). This allows for the determination whether the new or modified traffic signal operations impacts another intersection or the bandwidth of the corridor.

## PROJECT STUDY PERIOD

The model study period is the seeding period plus model duration. Model duration is determined by the observed congestion duration and the length of vehicle queues in the field. The study period should begin prior to the onset of congestion and extend through the peak hour and continue until congestion starts to dissipate.

### SEEDING PERIOD

The seeding period should be the longest of following three criteria to allow for full vehicle saturation of the network. The guidelines set by FHWA Traffic Analysis Toolbox are as follows (6):

1. A minimum of 10 minutes.

2.. Equal to or greater than twice the estimated free flow travel time from one end of the network to the other.

3. Vehicle queue lengths in the model at the end of the seeding period replicate real-world observations at that time of day.

Maryland DOT sets the seeding period criteria a minimum of 15 minutes to 30 minutes for large networks (10).

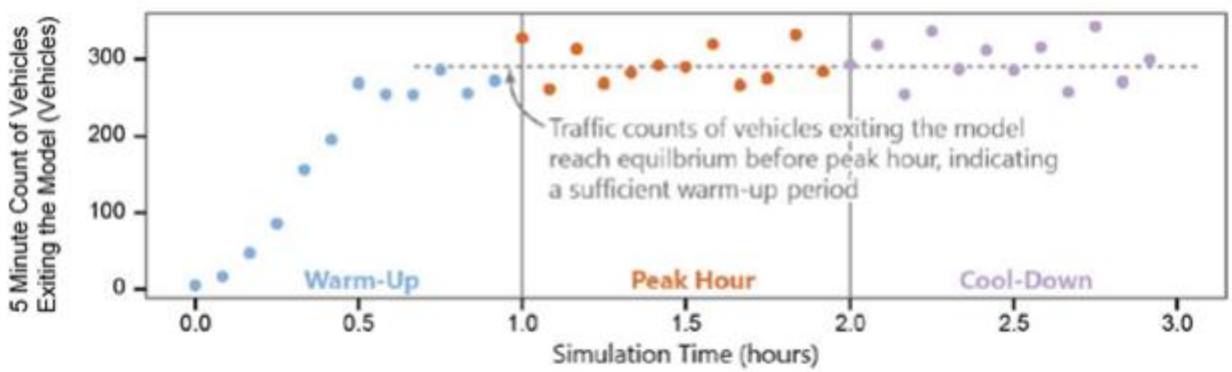



*Figure 5: Warm-up Duration Verification Example (12)*

### MODEL DURATION

Field observation and analysis of queue and vehicle count data should be used to determine the time period that should be modeled. To emulate a peak hour factor a simulation should define volume bins in 900 second increments (7). In both freeway and arterial projects, the typical study period should include congestion build up, continue through the peak period, and end once congestion or queues dissipate (4, 8).

## PROJECT SCHEDULE AND STAFFING PLAN

Multiple check-in points and deliverables representing key points in the model development must be completed before the next stage can begin. Frequent check-ins will help avoid having to make revision in multiple network files in response to comments.

Project scheduling for VISSIM projects are difficult due to the linear nature of the process and can often can't be quickened by increasing the number of staff. To maintain consistency between scenarios, it is recommended that one modeler at a time be working on the network. A flow chart of model development can be used to structure and organize model delivery.

Requesting a detailed staffing plan ensures the reviewing agency knows who is working on the models and to help assure that models are being developed sequentially and not in parallel. At least one modeler located within the state in which the project is occurring increases the understanding of the study area and can facilitate field observations.

## PROJECT METHODS AND ASSUMPTIONS PLAN

Both Oregon and Washington DOT require the development document to provide summary of the methodology for completing the project and any known assumptions (1,7). Any VISSIM specific assumptions made during model development are to be documented as well.

## VISSIM SOFTWARE UPDATES

A decision should be made at the start of the project as to which version of VISSIM should be used and documented in the scope. Keeping a model relevant and useful often requires upgrading it to the latest release of the simulation software. PTV Group typically releases major updates to the VISSIM software once a year in addition to minor updates, to address software bugs/errors, as often as once a month. These releases may or may not affect a specific simulation model but it is important to understand that no matter how small a change, any change could influence the results and validity of a model (12).

### TYPES OF UPGRADES AND WHEN TO UPGRADE

Some projects may take 12 months or longer to complete and as such a software package may go through one or more updates. These updates usually occur for one or more of the following reasons (12):

- Software bug or error fix
- Feature addition
- Major version release

Before upgrading to a new model version, the analyst shall consult with the owner. When determining whether to upgrade, be cognizant of the version of the software that the team has available to them to review the models (it may not be possible to open/use one version of the software in another version). Generally, the analyst should update the model to apply the bug fix as soon as possible. If the software update includes new or enhanced features, the modeling team may decide that the new features would benefit the project. If the benefit of adding the additional feature outweighs any potential implications (e.g., additional time/resources needed to revise the model), updating the model to apply the new features may be justified. Since major version releases of the software typically involve larger changes to the analysis methodologies, upgrading the traffic model to a new version may introduce new problems and the analyst is encouraged to hold off on upgrading the model to a later date (12).

Depending on the software package and the extent of the software modifications, upgrading the traffic model to the newest software version/release may cause a previously calibrated model to fall out of validation. Therefore, the analyst should verify that the model still meets the validation thresholds (12).

## MILESTONES AND DELIVERABLES

Clear and definable milestone and deliverables need to be established during the scoping process. An example of deliverables by milestone for a microsimulation project is provided by Caltrans and Wisconsin DOT (14). Virginia DOT also follows a similar scoping process starting with identification of the project purpose, need and objective (9).

| Milestone | Deliverable |
| --- | --- |
| A. Definition of Project Scope | 1. Project Scope and Schedule<br>2. Proposed Data Collection Plan |
| B. Data Collection | 3. Data Collection Results Report<br>4. Proposed Model Coding Quality Assurance Plan |
| C. Model Coding and Quality Assurance | 5. Coded and Error Checked Model files<br>6. Proposed Calibration Procedures with Calibration Targets. |
| D. Calibration | 7. Calibration Test Results Report<br>8. Proposed Alternatives Analysis Procedures |
| E. Alternatives Analysis | 9. Alternatives Analysis Report |
| F. Documentation | 10. Final Report compiling all prior reports. |

*Figure 6: Example Milestone and Deliverables (4)*

## DATA COLLECTION AND DEVELOPMENT

Most state microsimulation protocol documents outline the required data need for microsimulation. It is important that calibration and demand data be collected simultaneously if possible (8).

The following sections outline commonly required data sets in many of the available state guidelines that strives to be representative, it may not necessarily all inclusive.

### GEOMETRIC DATA

Detailed geometric data must be collected for all types of models for the entire study area. Much of the data is available via aerial photographs and construction drawings. A field visit is required to verify this data and it is preferred that this by completed by modelers.

Geometric data to be collected must include:

- Number and width of lanes
- Significant grades that could affect flow rates (>3%, <-3%)
- Lengths of roadway segments
- Lengths of storage bays and tapers

Additional geometric data that may need to be collected depending on the project may include:

- Locations and dimensions of freeway ramp tapers
- Details of user specific lanes (e.g., High Occupancy Vehicles [HOV], Truck, Bus, Bikes)
- Sidewalk and bike locations and widths
- Crosswalk locations, widths, and lengths raised median, pedestrian refuges, and islands parking locations and dimensions
- Transit facility locations
- Roundabout inscribed diameter, circulating lane width, entry angles
- Freight rail crossing locations and number and duration of crossing events

- Acceleration and deceleration lengths for ramps and turn lanes
- Curve and super elevation (e.g., sharp curves that may affect vehicle speed)
- Radii at intersections for turning vehicles
- Sight distance at conflict points, for example: how far upstream a driver stopped at a stop sign can see on the cross street to make a gap acceptance decision

## CONTROL DATA

Control data must be collected for both arterials and freeways for all locations within the study area. These will all be used as input to the model and are checkpoints that control the flow and movement of vehicles. Data to be collected should include:

- Posted speed or speed limits and free flow speeds
- Intersection controls
- Traffic signal characteristics
- Signal timing / time of day plans (e.g., cycle length, green time, and pedestrian minimum times). Time of day plans should be obtained from either the region or local agencies, when available.
- Movement permissions (e.g., right turn on red, no turn on red, U-turn permitted, protected/permitted phasing, overlaps)
- Stop bar locations
- Detection zones

Some models may require that the following control/operational data be collected:

- Rail crossing control and usage
- Ramp meter timing
- Freeway guide sign locations
- Transit signal priority parameters
- Toll plaza information (e.g. capacity, number of booths, etc.)

## TRAFFIC VOLUME DATA

For both arterial and freeway models, traffic volume data must be collected. Volume data should be collected during the peak month and day of the week excluding weeks that contain holidays (1, 7).

Unmet demand is typically referred to as the number of vehicles that are destined to travel through a network at a specific time period but cannot do so due to capacity constraints (9). When collecting data in congested networks, data collection and observation locations must consider how to capture throughput and vehicle demand. Upstream data collection of any major bottlenecks may be necessary to capture true demand. Traffic counts should be collected at the less congested entry points into the network to capture the vehicle arrival/demand profile. Care should be taken to avoid balancing traffic counts collected on either side of a known bottleneck location.  Models should replicate existing traffic conditions; therefore, for instances when unmet demand occurs during existing conditions, factors such as traffic volume and maximum queues should be replicated (9).

Vehicle classification counts should be collected at a minimum of one location in the study area. Vehicle classification counts may need to be collected at more locations depending on the purpose and location of the model (1). Wisconsin DOT details a process for calculating and estimating truck percentages for use in microscopic (CORSIM) models (14).

## ORIGIN-DESTINATION DATA

Origin-Destination data (O-D) may be important for correctly coding lane-changing, weaving, and related types of driver behavior in a VISSIM model. O-D data is often difficult to collect and subsequently historically expensive. The following sources may be utilized:

- Travel Demand Models
- MAC ID/Bluetooth surveys
- License Plate Surveys

In development of the O-D tables, Caltrans recommends for small study areas (under 5 miles in length) that the traditional gravity model can used to estimate and assign trips between origins and destinations (4).

## TRAVEL TIME DATA

Travel time data is critical and must be collected for all VISSIM models. The two methods most commonly used in Washington State are floating car runs and MAC ID/Bluetooth data collection (1).

Floating car runs are the most common method for collecting travel time data (1,4). Data is collected by either a GPS unit record location and time or by having a passenger record data with a stop watch. It is recommended a minimum of 10 travel time runs be collected in each direction for each hour to be simulated for both freeways and arterials (1). Although, under free flow conditions, as few as 3 runs can establish a reliable mean travel time (4).

For complex corridors with long travel times, a statistical calculation outlined in the FHWA's Traffic Analysis Toolbox to determine the required number of travel time runs in order to reach a certain confidence interval may be required (1,4).

$$N = \left( 2 * t_{0.025,N-1} \frac{s}{R} \right)^2$$

Notes:

- R = 95-Percent confidence interval for the true mean (acceptable margin of error approved by WSDOT, e.g. +/- 5 seconds, +/- 10%)
- T0.025,N-1 = Student's t-statistic for 95-percent confidence - two-sided error of 2.5 percent (totals 5 percent) with N-1 degrees of freedom (for four runs, t = 3.2; for six runs, t = 2.6, for 10 runs, t = 2.3) (Note: There is one less degree of freedom than car runs when looking up the appropriate value of t in the statistical tables)
- S = standard deviation of the floating car runs
- N = number of required floating car runs

*Figure 7: Number of Required Floating Car Runs*

## SPOT SPEED DATA

Collecting spot speed data can help set the desired speed for that segment of the network. Spot speed data during peak periods can also provide data for the calibration process. The data should be collected when there is no influence from weather, incidents and/or other factors (1).

In the absence of any spot speed data a speed near the posted speed may be used as the free-flow condition or during the calibration process.

### FREEWAYS

Spot speed data should be collected at multiple locations in the project areas as determined in the scoping process. Archived traffic data may be a resource for spot speed data that can provide historical information on traffic speed variations over much longer periods of time. Archived speed data can be used to provide graphical speed plots at specified locations throughout the day. Speed plots are useful tools in model development and calibration.

### ARTERIALS

Spot speed data is not required on small grids with closely spaced intersections or short travel distances. Spot speed data can only be collected in areas of free-flow conditions, which may not exist in some arterial networks. If vehicles are able to reach free-flow conditions, spot speed data is useful in setting desired speed in VISSIM.

## QUEUING DATA

Queue observations should be conducted during the scoping process to determine if queuing data needs to be collected. Queuing data is not required but should always be used as a visual comparison to verify that the VISSIM model is replicating field conditions. If possible, queueing data should be collected at the same time as other data.

### FREEWAYS

Archived traffic data may be a resource that can provide congestion maps that indicate the approximate time and extent of vehicle queueing. Visual inspection of freeway queuing should always be compared with the VISSIM model.

### ARTERIALS

If quantitative queueing data is required, queue lengths should be collected by recording the maximum queue at some given interval. This interval could be the cycle length for a critical intersection or 120 seconds as a default (1).

## LANE UTILIZATION DATA

The need for lane utilization data must be determined through field inspection of traffic operations during the scoping process. If lane imbalances could affect the calibration of the VISSIM model, lane utilization data should be collected during the study period. Areas where lane utilization data may also be collected are:

- Lane drop locations
- Multiple turn lanes
- Truck climbing lanes
- Weaving sections
- Managed lanes

- Closely spaced intersections

## TRANSIT DATA

Transit data collection and detail is dependent on the problem statement. For all arterial models were transit currently exists or is proposed to be implemented, the location of the transit stops in the study area and transit headways must be compiled. For freeway models, transit headways and park and ride must be compiled.

If an arterial VISSIM model is being built to focus on the evaluation of transit operations, further transit data may be required including:

- Transit vehicle acceleration and deceleration
- Headway data
- Number of boarding and alighting passengers
- Boarding and alighting time per passenger
- Dwell time at transit stop
- Number of passengers on transit entering the network
- Boarding and alighting location on transit vehicle
- Transit signal priority
- Schedule variability
- Transit gate-crossing time:
    - Vehicle clearance time
    - Gate closing time
    - Transit crossing time
    - Gate opening time

## CAPACITY AND SATURATION FLOW DATA

Many agencies don't require the collection of capacity and saturation flow rate due to the extensive amount of other data that is collected and input into VISSIM. Although, Caltrans recommends that saturation flow rate be measured per HCM at all signalized intersections which are operating at 90% of their existing capacity (4).

## DELAY DATA

Delay can be computed from floating car runs or from delay studies at individual intersections. Although, floating cars are somewhat biased estimators of intersection delay on surface streets with coordination as only the delay from the favorable progression will be collected (4).

## FUTURE DEMAND FORECASTS

Forecasts of future demand are best obtained from the local regional transportation planning agency. Trend line forecasts based on historical data are also a reasonable second choice (4).

Care must be takin when determining future year demand. Regional model forecasts are often not very well constrained and trend line forecasts are totally unconstrained. This can result in an analyst attempting to model a future condition that is not feasible. Traffic volumes may need to be adjusted to spread traffic volumes from over-capacity time periods to adjacent time periods. Therefore, it is critical to select a traffic analysis tool that can account for multiple time period analyses (9). Consideration should be given for peak period travel demand spreading in order to create reasonable volume inputs for microsimulation (7).

In some instances, the no-build condition can have known capacity constraints that prohibit the forecasted demand from being modeled (9). It is possible, under these circumstances, that a no-build future demand could differ from a build future demand (with capacity constraints removed). Estimating the excess demand at inbound bottlenecks and reducing demand inbound at gateways can assist in producing reasonable future demand (4).

## QUALITY ASSURANCE

The use of good data can lead to good analysis results and poor data yield bad results. Verification should include checking that weather, incidents or construction did not influence the data collected. Checking variation of the data, 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 (8).

# MODEL DEVELOPMENT

To limit the variability in coding techniques and to simplify the review process, VISSIM simulation coding guidelines are described in the following sections.

## GENERAL NETWORK PARAMETERS

The network shall be created in English units. The use of scaled aerial imagery or as-build files should be used to code links.

Simulation resolution of 10 steps per second is preferred (1, 7, 8). Caltrans recommends that the simulation resolution not be changed once the model has been calibrated to prevent differing model results (4). Increasing the model resolution increases the computation load of the model and can increase the simulation duration.

## TRAFFIC COMPOSITIONS

The “Car” and “HGV” distribution fleet found in the NorthAmericanDefault.inp is acceptable in the absence of any other vehicle classification data (1, 8). If vehicle makeup changes are made to the vehicle fleet, the AASHTO vehicle classifications are to be followed (7).

| # | AASHTO Vehicle Class | VISSIM 3D Model | |
|---|---|---|---|
| | | Tractor | Trailer |
| 4 | Buses | bus.v3d | |
| 5 | 2 Axle, 6 Tire, Single Unit Trucks | van.v3d | |
| 6 | 3 Axle Single Unit Trucks | truck.v3d | |
| 7 | 4 or more Axle Single Unit Trucks | HGV_flatbed_truck.v3d | |
| 8 | Four or Fewer Axle Single-Trailer Trucks | HGV_wb40_tractor.v3d | HGV_wb40_trailer.v3d |
| 9 | Five-Axle Single-Trailer Trucks | HGV_wb50_tractor.v3d | HGV_wb50_trailer.v3d |
| 10 | Six or More Axle Single-Trailer Trucks | HGV_wb65_tractor.v3d | HGV_wb65_trailer.v3d |
| 11 | Five or fewer Axle Multi-Trailer Trucks | HGV_wb67d_tractor.v3d | HGV_wb67d_trailer.v3d<br>HGV_wb67d_trailer_ conn.v3d<br>HGV_wb67d_trailer.v3d |
| 12 | Six-Axle Multi-Trailer Trucks | HGV_wb50_tractor.v3d | HGV_wb67d_trailer.v3d<br>HGV_wb67d_trailer_ conn.v3d<br>HGV_wb67d_trailer.v3d |
| 13 | Seven or More Axle Multi-Trailer Trucks | HGV_wb50_tractor.v3d | HGV_wb40_trailer.v3d<br>HGV_wb67d_trailer_ conn.v3d<br>HGV_wb40_trailer.v3d |

*Figure 8: Suggested 3D Models by AASHTO Vehicle Class for Heavy Vehicles*

Vehicle fleet data can be obtained from the local state department of transportation and national data from various car manufactures (4). It is possible to generate updated vehicle performance specifications from these sources in a manner similar Wisconsin DOT for CORSIM applications.

If HOV operations are required by the study, an HOV category should be added to the Vehicle Types and the “Car” model distribution shall be used as the category and vehicle model. A global estimate of HOV vehicles in the traffic stream can be obtained from the regional travel demand model or from occupancy counts.

## NETWORK CODING

Links should proceed the through the corridor with similar geometry and not be unnecessarily segmented. A connector is a type of link used to join two areas of a link or join two different links. Connectors have characteristics that affect driver behavior, specifically lane changing. The following sections outline the suggested coding techniques and preferences outlined in many state guidelines. Oregon DOT provides additional coding guidance in a network setup guide (5).

### FREEWAY MERGE, DIVERGE AND WEAVE CODING

Freeway links may need to be split based on HCM Freeway Facilities definition of analysis segments (8).

To properly code merging and weaving sections, these points should be followed (1,7):

- The effective merging area should include the entire auxiliary lane (or lane drop) to the farthest extent of the auxiliary lane taper and capture the full effective length utilized by vehicles. Vehicles in VISSIM will utilize the extra link length when necessary, which more accurately models the utilization of the taper area.
- The merges or weaving section should be one link with the number of lanes equal to the number of lanes on the main freeway plus the number of lanes merging onto the freeway.
- There should only be one connector downstream of the merge link or at the end of a lane drop section.
- There should be two connectors upstream of the merge link, one for the ramp link and one for the main freeway link.
- One of two options should be implemented to avoid unrealistic lane changes on mainline into the acceleration lane:

- Ensure that the “Lane Change” distance, in the downstream connector is longer than the length of the merge area.

  OR
- Indicate “no lane change” for the appropriate lane, using the Link dialog box

In order to code diverging sections, first identify whether the diverge section is functioning as a parallel or taper ramp. To function as a parallel ramp diverge area in VISSIM, the ramp typically extends 700 ft or more (1).

For coding a parallel Freeway Exit Ramp diverge area, these points should be followed (1,7):

- The effective diverging area should include the entire auxiliary lane (or drop lane) starting at the taper and continuing to the painted gore point.
- The diverge section will be one link with the number of lanes equal to the number of lanes on the main freeway plus the number of lanes diverging off the freeway.
- There should only be one connector upstream of the diverge link
- There should be two connectors downstream of the diverge link, one for the ramp link and one for the main freeway link.

For coding a taper Freeway Exit Ramp diverge area, these points should be followed:

- There is no need to break the main freeway link with a connector
- There should be one connector placed at the painted gore point connecting the main freeway link to the ramp link.

## ARTERIALS

There are two options for coding turning bays. The first option is coding a turning bay similar to the merging and weaving areas. In this option connectors start at the beginning of the taper and end at the point the bay reaches its full width. The section of roadway adjacent to the turn bay should be one link with the number of lanes equal to the number of lanes on the mainline plus the number of turn lanes. To ensure no unrealistic lane changes between the through and turning vehicles, these points should be followed (1):

- Break link with turn bay about 50 ft from the stop bar
- In the link with the turn bay closest to the intersection code, “no lane change” both in and out of the turn bay, in the Link Data dialog box.
- In the link with the turn bay farther from the intersection, code “no lane change” only out of the turn bay, in the Link Data dialog box.
- In the Connector dialog box for the connector attached to the end of the turn bay, enter an emergency stop to be about the length of the turn bay minus 35 ft. In the same dialog box enter the lane change to be well beyond the length of the turn bay, this should point back to the location that it would be logical for a vehicle to consider turning left (ex: location of a directional sign).

The second option is coding a turning bay as a separate parallel links where vehicles enter the turn bay at the beginning of the bay, which helps ensure that no unrealistic lane changing occurs between the through and turning vehicles. In this option connectors should also start at the beginning of the taper and end at the point the bay reaches its full width (not necessarily where the striping begins).

### UNIQUE INTERSECTIONS

Detailed coding instructions are outlined in coding of roundabout in both the Oregon and Washington DOT guidelines.

### HIGH OCCUPANCY VEHICLES, HIGH OCCUPANCY TOLL AND TRUCK ONLY LANES

It is necessary to have appropriate geometric segments and their corresponding lane closures in order to capture realistic driver behavior.

## TRAFFIC CONTROL

VISSIM traffic control measures such as signals, stop signs, and yield conditions should be modeled as closely to real-world conditions as possible. Traffic signal timing from field or local agency time of day plans should be used to code signals in VISSIM. Conflict areas or priority rules should be used at all intersections to correctly replicate vehicle interactions. Adjustments to gap times and other conflict area and priority rules parameters may be required.

### RAMP METERS

Ramp meters can be coded using Vehicle Actuated Signal Controller Program (VAP) which is written to replicate the speed/density logic. If field data indicates that the ramp meter operates at a fixed rate during the study period, or if the project is not focused on ramp meter operations, a fixed time signal controller can be used.

### SIGNAL CONTROLLER SETTINGS

The Ring Barrier Controller (RBC) is the preferred method for coding traffic signals (1, 7, 8). It includes all the parameters of a real-world signal controller and accurately models actuated-coordinated signal operations. The frequency of the RBC file be a factor of the simulation resolution.

The preferred method for coding future signal timing is to optimize signal timing using SYNCHRO or another optimization package and manually code the signal timing into the RBC. It is not required that future timings be developed in SYNCHRO.

### UNSIGNALIZED INTERSECTIONS

At intersections operating with stop control, code stop signs at the same location as the stop bars in the field in addition to the conflict areas at the actual vehicle conflict zone. A conflict area and priority rule should not be used for the same conflict or movement.

## SPEED CONTROL CODING

To control the speed of vehicles in VISSIM, a “speed decision” or “reduced speed” on the network link is utilized. Desired speed decisions change the desired speed of vehicles that cross it and should be used when significant free-flow speed changes due to posted speed limits, geometric changes, topography, or facility changes. Reduced speed areas are temporary zones with a reduced speed and should be used to code small sections where vehicles have a significant change in speed. Typically, speed control is used due to vertical or horizontal curvature of the roadway.

Desired speed decisions and/or reduced speeds areas should never be used to mimic congestion in the calibration areas. The only locations where speed control coding can be used to replicate congestion from bottlenecks is at the very ends of models.

### FREEWAYS

Spot speed data or archived speed data used to code the desired speed decisions. This data used can be used to create a speed profile that can be inputted into VISSIM.

### ARTERIALS

Due to lack of true free flow condition on most arterial networks, detailed speed profiles are generally not necessary. A speed profile that is linearly plus and minus five mph of the posted speed is sufficient.

For turn movements at intersections, reduced speed areas should be used for both left and right turn movements. Suggested values for the reduced speed distributions for cars are 15 mph for left turns and 9 mph for right turns, the reduced speed distribution for HGV is slightly less, at 10 mph for left and 5 mph for right turns (1,7). The location and length of a reduced speed area is typically localized to the apex of the curve.

## VEHICLE INPUTS

Vehicle inputs should be coded in 15-minute demand increments. However, hour increments may be acceptable if volumes are consistent throughout the hour. Each input location should have specific truck percentages. For freeway networks, a global estimate of HGV vehicles in the traffic stream can be estimated from regional travel demand model or classification counts. Default input setting of “exact” is recommended (1).

If a project is transit oriented, bus volumes should not be included in the vehicle input. Bus volumes will be inputted at public transit lines with defined frequencies (10).

## VEHICLE ROUTING DECISIONS

Vehicle routes should also be coded in 15-minute demand increments. Again, hour increments may be acceptable if volume are consistent throughout the hour. There are three different methods for coding vehicle routing: static, dynamic, and origin-destination.

### STATIC ROUTES

Traffic volumes in smaller networks with adequate intersection spacing can be coded intersection-to-intersection turning movement routing decisions. Routing decisions should be placed as far upstream on a link as possible to allow for maximum lane changing distance.

If intersections or decision location are spaced too closely, it may be necessary to route vehicles through multiple intersections to eliminate unrealistic turning movements (10).

### DYNAMIC ROUTING

Dynamic routes are used to reroute traffic if a certain condition occurs, such as parking lot becomes full or a gated crossing is blocked. Vehicles can be reassigned using a VAP script.

### ORIGIN-DESTINATION BASED VEHICLE ROUTING

A vehicle should be assigned one complete route upon entering the network that continues until the vehicles leave the network. It is acceptable to have separate O-D matrices for each roadway type. VISSIM Dynamic Traffic Assignment can be used to generate the O-D Routes.

## DRIVER BEHAVIOR

Driving behavior in VISSIM consist of two behavior models:

- Car following model
- Lane change model

Parameters within these models can be adjusted during the initial coding process or the calibration process.

## CAR FOLLOWING PARAMETERS (WIEDEMANN 99 MODEL – FREEWAY TRAFFIC)

For freeway links and connectors, the Wiedemann 99 model should be selected for car following model.

The suggested ranges for calibration parameters for Maryland, Oregon and Washington DOT's can be seen below. Florida DOT uses a slight iteration of parameters.

| | | | | Suggested Range | |
|---|---|---|---|---|---|
| | | Default | Unit | Basic Segment | Merging/ Diverging |
| CC0 | Standstill Distance | 4.92 | Ft | 4.5 - 5.5 | > 4.92 |
| CC1 | Headway Time | 0.9 | S | 0.85 - 1.05 | 0.90 1.50 |
| CC2* | Following Variation | 13.12 | ft | 6.56 - 22.97 | 13.12 - 39.37 |
| 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/s2 | Use default | |
| CC8 | Standstill Acceleration | 11.48 | ft/s2 | Use default | |
| CC9 | Acceleration at 50 mph | 4.92 | ft/s2 | Use default | |

***Adjustments to CC2 default should only be made after CC0 and CC1 parameters have been adjusted and it is concluded those adjustments do not accurately replicate field conditions.**

**Table 2 - Wiedemann 99 Car Following Parameters (U.S. Customary Unit)**

*Figure 9: Washington DOT Wiedemann 99 Parameters (1, 7, 10)*

## CAR FOLLOWING PARAMETERS (WIEDEMANN 74 MODEL – ARTERIAL TRAFFIC)

For most arterial links and connectors, the Wiedemann 74 car following model should be applied. There are three parameters available for this model: average standstill distance, additive part of safety distance, and the multiplicative part of safety distance.

As with the freeway model, the default parameters are a good starting point. The first parameter, "Average Standstill Distance," corresponds to the CC0 parameter in the freeway Wiedemann 99 behavior model. The other two Wiedemann 74 parameters work together to determine the target desired safety distance (which has a direct relationship with saturation flow rate). A greater parameter value will result in a greater desired safety distance, thus reducing the saturation flow rate.

The suggested ranges for calibration parameters for Maryland DOTs can be seen below.

| Arterial Car Following Model Parameters Suggested Range -Wiedemann 74 model | | | |
|---|---|---|---|
| **Parameter** | **Default value** | **Unit** | **Suggested Range** |
| Average standstill distance | 6.56 | feet | 3.28 to 6.56 |
| Additive part of safety distance | 2.00 | - | 2.0 to 2.2 |
| Multiplicative part of safety distance | 3.00 | - | 2.8 to 3.3 |

*Figure 10: Wiedemann 74 Car Following Parameters (10)*

### LANE CHANGING PARAMETERS

The available lane changing parameters are the same for both freeway and arterial links and are applied on the same link type basis as the car following model. Oregon, Washington, and Maryland DOTs provide guidance and lane changing parameters.

The waiting time before diffusion should be set to 200 seconds for both freeway and arterial links (1).

SUGGESTED RANGES

| General Behavior / Necessary Lane Change (route) | Free Lane Selection / Own | Unit | Trailing Vehicle | Unit |
|---|---|---|---|---|
| Maximum deceleration: | -15 to -12 | ft/s2 | -12 to -8 | ft/s2 |
| -1 ft/s2 per distance: | 150 to 250 | ft | 150 to 250 | ft |
| Accepted deceleration: | -2.5 to -4 | ft/s2 | -1.5 to -2.5 | ft/s2 |
| Waiting time before diffusion: | | | 200 | s |
| Min. headway (front/rear): | | | 1.5 to 2 | ft |
| To slower lane if collision time above: | | | 0 to 0.5 | s |
| Safety distance reduction factor: | | | 0.25 to 1.00 | |
| Maximum deceleration for cooperative braking: | | | -8 to -15 | ft/s2 |
| Overtake reduced speed areas: | | | D* | |

* Leave box un-checked

*Figure 11: Washington DOT Lane Change Parameters (1,7)*

### OTHER PARAMETERS

The Maryland DOT guidance outlined additional driver behavior parameters that can be effective during calibration. These parameters consist of advanced merging, combing static routing decisions, and cooperative lane change.

### GEOMETRIC DRIVER REACTION CODING

Geometric driver reaction coding is controlled by the “lane change distance” which is defined on connectors. A good starting point is to set back the distance so that it concurs with the guide sign locations or based on field observations. The lane change distance can also be defined “per lane” to better represent freeway lane changes. In order for lane change distance to be effective, the routing decision needs to be set at a distance upstream that is greater than the lane change distance.

## DRIVING BEHAVIOR SUMMARY

The driving behaviors can be sorted based on their application to different facility types and the basis of conservative or aggressive driving conditions.

Maryland DOT provided the following table to provide guidance to modelers in selecting parameters during model development and calibration (10).

| CONSERVATIVE | | | | AGGRESSIVE | | |
|---|---|---|---|---|---|---|
| | | | **FREEWAY** | | | |
| **Description** | **Name** | **#** | **LINK TYPE** | **#** | **Name** | **Description** |
| Model can be used at segments where reduction in throughput is required. Throughput reduction observed was 20%. Significant factors include increased CC1 value whereas the lane change parameter values are kept low. | **Freeway Basic Conservative I** | **101** | **BASIC** | **105** | **Freeway Aggressive I** | Throughput achieved is higher than the above model. Significant factors include SDRF at 0.10, high lane change parameter values and a high value for Maximum deceleration for cooperative braking (-20.00 ft/s2) |
| Throughput reduction is greater compared to the first model. Observed throughput reduction was nearly 30%. Significant factor is the CC2 value of 27 ft. | **Freeway Basic Conservative II** | **102** | | **106** | **Freeway Aggressive II** | Model can be used where desired throughputs are high. Model simulates aggressive behavior. Lane change parameter values are high. Significant factors include low CC1 value, SDRF at 0.20 and high Cooperative braking deceleration rate. |
| Model simulates merge segments with reduced throughput of around 15%. Model's significant factors include a low CC1 value and reduced value for lane change parameters. This makes the vehicle change lanes with reduced deceleration rate but travel with reduced headway | **Freeway Merge Conservative** | **103** | **MERGE** | **107** | **Freeway Merge Aggressive** | Model is suitable for simulating aggressive merging traffic. Higher throughput was observed. Model has a low CC1 value of 0.9 and increased lane change parameter values enabling the car to change lanes aggressively. Safety distance reduction factor is 0.20 |
| The model can be used at segments where reduced throughput is desired at weaving segments. Throughput reduction observed was around 25%. The model has reduced values for 'Lane change' parameters. Look back and look ahead distance values are high. | **Freeway Weave Conservative** | **104** | **WEAVE** | **108** | **Freeway Weave Aggressive** | This model simulates aggressive weaving and diverging with high deceleration rate and reduced headway. Model has increased look back distance. Accepted deceleration rate is high, results in fast deceleration of the vehicles. Higher throughput achieved. Significant factors are SDRF at 0.20 and cooperative braking being -20 ft/s2. |
| | | | **ARTERIAL** | | | |
| **Description** | **Name** | **#** | **LINK TYPE** | **#** | **Name** | **Description** |
| Model is used for simulating conservative driving on arterial segments. Throughput reduction observed was around 15%. The lane change parameters values are kept low and SDRF is 0.60 | **Arterial Basic Conservative I** | **201** | **BASIC** | **205** | **Arterial Aggressive I** | Model can be used for simulating Aggressive arterial segments. Significant factors include SDRF at 0.10, car following model parameter values are low and maximum cooperative braking value is also high |
| Throughput reduction is higher than the above model (around 18%). Maximum deceleration is kept high and look ahead distance value is high | **Arterial Basic Conservative II** | **202** | | **206** | **Arterial Aggressive II** | Higher throughput is achieved when compared to the above model. Model simulates aggressive behavior with values of lane change parameters being high. |
| Model can be used for conservative driving on arterial segments where reduced throughput is desired. Throughput reduction observed was around 13% Additive and multiplicative part of safety distance values are 2.30 and 3.4 respectively | **Merge Arterial Conservative** | **203** | **MERGE** | - | *Note*: **Arterial Aggressive I & II above are also suitable for arterial merge/weave segments to increase throughputs and simulate aggressive lane changing.** | |
| Model can be used for conservative driving on weaving arterial segments. Model provides low throughput, around 18% with high weaving. | **Weave Arterial Conservative** | **204** | **WEAVE** | - | | |

All percent changes by behavior types are estimates and may vary depending on the scenario they are applied to.

*Figure 12: Driving Behavior Summary Table (10)*

## NON-AUTO MODES CODING

Non-auto modes may include but not limited to: Heavy Rail, Light Rail, Transit, Streetcar, Pedestrians, and Bicycles. Unless any of these modes are the primary focus of the project, default parameters may be used.

## ERROR CORRECTION

The process to identify known software errors is to, double check inputs, run the model, and review the VISSIM error files that is generated. For quality assurance, a person independent from the model development should review the model.

## VERIFY VISSIM INPUTS

Color coding links by attributes is a useful tool in visually identifying discrepancies. A thorough quality control review should occur during development of the base model (9). The following example checklist shows the inputs to be verified to ensure the accuracy of the coded data:

1 Geometry, speed and control checks

a. Check basic network connectivity (any missing connectors?)
b. Check link geometry (lengths, number of lanes, link types, etc.)
c. Check free-flow speed coding (location of desired speed decisions and reduced speed areas, check for link/connector coding to ensure speed decision points are properly placed and that they influence vehicle speed as intended)
d. Check desired speed distributions
e. Check coding and placement of intersection controls to ensure vehicles are reacting as intended
f. Check for prohibited turns, right turn on red restrictions, lane closures, and lane use restrictions
g. Check conflict area settings

2 Vehicular demand checks

a. Check vehicle compositions at each entry link/node/zone
b. Verify Vissim freeway link demand volumes against traffic counts flow maps
c. Verify Vissim arterial routing decisions including connector look back distances match turning movement input data
d. Check vehicle occupancy distribution (if modeling HOVs)
e. Check O-D zone/parking lot coding and placement in the network
f. Check contents of O-D trip matrices

3 Vehicle type and behavior

a. Check traffic compositions
b. Check vehicle model distributions
c. Check vehicle types and vehicle classes
d. Check link types for appropriate behavior model

*Figure 13: Washington DOT VISSIM Input Checklist (1, 7)*

## ANIMATION CHECKING

Many errors become apparent when the simulation model is running. The model should be observed for full seeding and simulation time at key congestion points to determine realism. If observed behavior appears unrealistic, then the following issues should be explored as potential causes (1,7):

- Error in Expectations
  - First, vehicle behavior should be verified for the location and time period being simulated before deciding that the animation is showing unrealistic vehicle behavior. Often, expectations of realistic vehicle behavior are not matched by actual behavior in the field. Field inspection may reveal causes of vehicle behavior that are not apparent when coding the network from plans and aerial photographs. These causes need to be coded into the model if the model is expected to produce realistic behavior.
- Data Coding Errors
  - The modeler should check for data coding errors that may be causing the simulation model to represent travel behavior incorrectly. Loading 50% or less of the existing demand highlights congestion that is occurring under unrealistically low demand (4, 8).
- Route Assignment Errors
  - A review of the animation may show a higher number of vehicles taking a roadway than what would be expected in the field.

## VISSIM ERROR FILES

At the end of the simulation, VISSIM provides an error file (.err) in text format that details the exact location of the error. The modeler should review each entry in the .err file and ensure that the error condition is not impacting the model results. Three error messages that signify significant issues in the model are (1,7):

- An entry link that did not generate all vehicles (congestion spillback off the network)
- A vehicle left its route because the distance between the routing decision and the first connector on its path was too short
- A vehicle was removed from the network because it had reached the maximum lane change waiting time (time before diffusion)

## MODEL VALIDATION

Two separate criteria must be met in order to justify the validity of a particular model and its usefulness in evaluating the traffic network (1, 12).

- Confidence: Ensuring that the reported model results are representative of the model
- Calibration: Matching the model results to real world conditions

Calibration and validation are part of an iterative cycle. If, after the initial round of calibration, the model results do not satisfy the validation thresholds, the analyst must conduct additional model calibration and recheck the updated model results against the validation targets. This process continues until the model results meet the validation targets and the traffic model has reached a level of fidelity that is acceptable (12, 15).

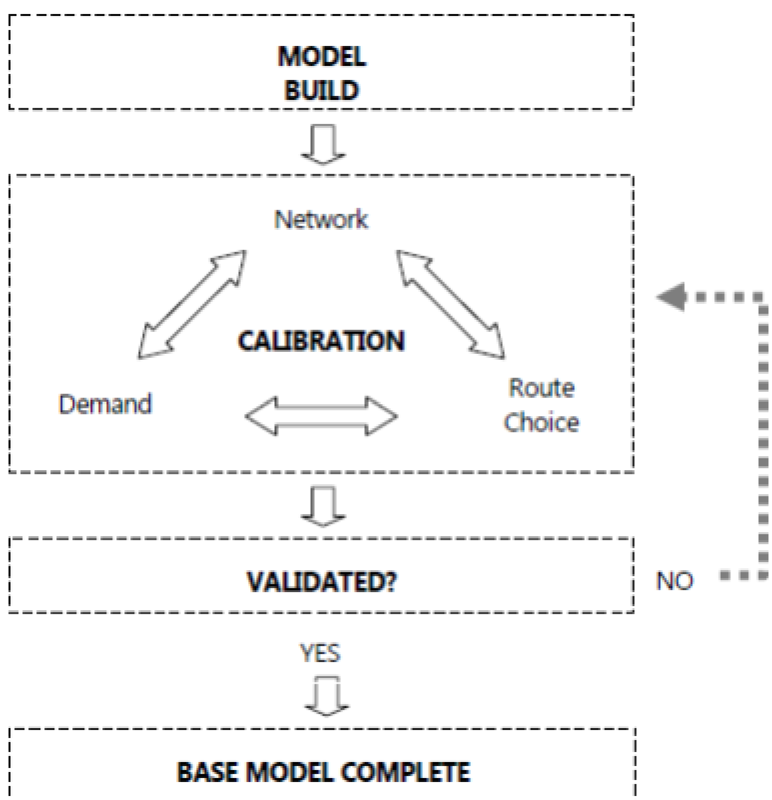


*Figure 14: Wisconsin DOT Traffic Calibration and Validation Process (12)*

## CONFIDENCE

Varying results are present in VISSIM modeling due to the use of random seed numbers. It is important to ensure that the reported results are not representative of a statistical outlier but of the true average of the model.

### SIMULATION RUNS

An initial sampling of the model outputs is required consisting of several simulation runs. The number of simulation runs must be large enough to reduce the impact of any atypical runs. While using too many runs will become overly time-intensive for analysis purposes (9). Washington DOT recommends that all model results be reported based on a minimum of 11 simulation runs (1). The use of an odd number of runs will allow the modeler to quickly identify the run that represents the median conditions which can be used to review the model or create demonstrative videos. Oregon DOT states that typically 10 runs generate a large enough sample size but must be verified by calculation (7). Virginia DOT uses a Sample Size Determination Tool based on FHWA methodology.

A statistical calculation based on a 95% confidence interval is typical but can be altered if necessary (1,4,7). The chosen confidence interval will be used to determine the number of required runs to ensure the results reported are representative of the model average. Eleven runs in most cases, will generate a large enough sample size to meet the desired confidence interval (1).

Typical MOE's tested for statistical significance are throughput volumes or travel times through the corridor.

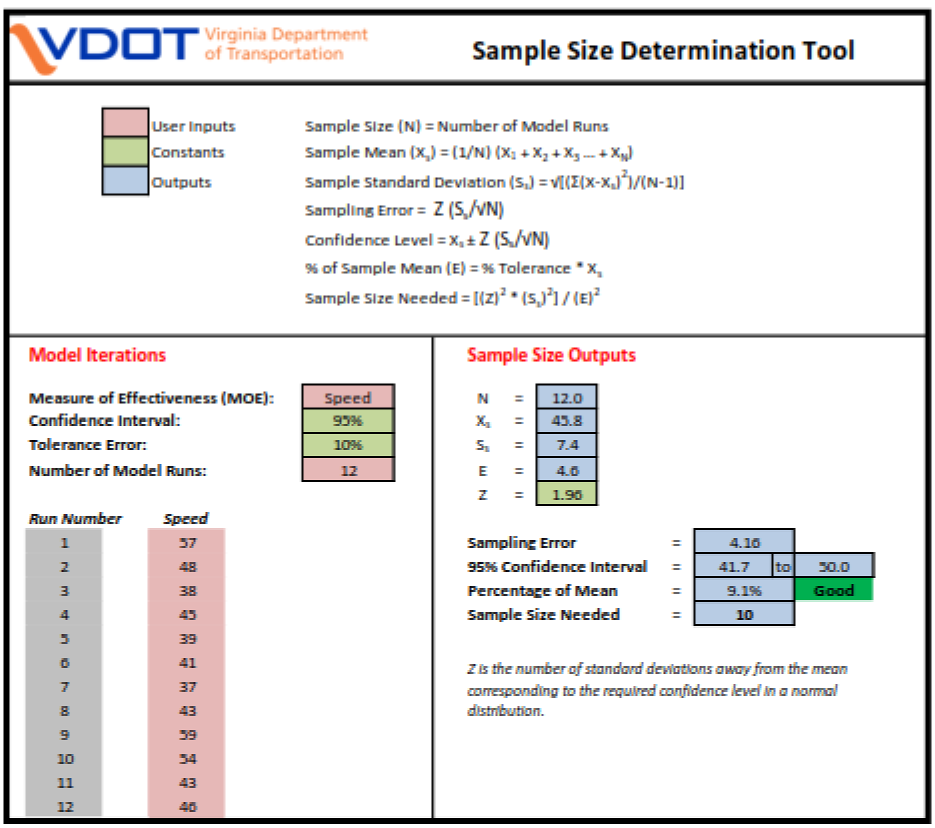



*Figure 15: Virginia DOT Simulation Run Determination Tool (9)*

### ALTERNATIVE ANALYSIS

Models used for alternative analysis may have network revisions that could vary model results significantly. Therefore, this requires the calculation for the number of runs be conducted for all alternatives.

## CALIBRATION

Calibration is the process used to achieve adequate reliability or validity of the model by establishing suitable parameter values so that the model replicates local traffic conditions as closely as possible. The calibration process is often a time-consuming process, but one that cannot be overlooked (9).

Since calibration process requires real world data to be performed, it is typically only conducted for the existing conditions models.

### CALIBRATION STRATEGY

Caltrans outlines a useful methodology to approaching calibration. Calibration parameters should be divided into two basic categories (4, 8):

1. Parameters that the modeler is reasonably certain about does not wish to adjust,

   And

2. Parameters that the modelers is less certain and willing to adjust.

The modeler should make all efforts to keep the set of adjustable parameters to as small a set as possible to minimize the effort required to calibrate. The set of adjustable parameters are divided into those that directly impact capacity (car following) and those that directly impact demand (route choice) (4).

These parameters can be further subdivided into those that affect the simulation on a global basis and those that affect the simulation on a more localized basis. The global parameters are calibrated first followed by the link-specific parameters for fine tuning.

A search strategy must be employed to identify the optimal combination of parameters that results for minimizing the squared error (4).

### MINIMUM REQUIREMENTS

There needs to be at least two calibration goals on two different MOEs to be effective. It is strongly recommended that the following MOEs be used as calibration goals for all traffic models. Wisconsin DOT breaks MOEs into primary and secondary classes for calibration. Based on model complexity the number or primary and secondary MOEs calibrated increases (12).

- Traffic Volumes
- Speed/Travel Times

### DATA LIMITATIONS

Information for different MOEs may not correlate with each other due to data sets being collected on different dates. This could make calibration of the base condition difficult. Below is a list of check-in times and questions that should be answered:

- Kickoff Meeting
  - What information is currently available?

- What data should we collect?
- Analysis Methods and Assumptions Document
  - Will any of the existing data be adjusted to represent a more specific existing condition? (i.e. adjusting to design hour volumes)
  - What impact will this change have on the calibration of the other MOEs collected?
  - What confidence and calibration targets will be used to validate the model?
- Data Collection Summary
  - Does the data gathered appear representative of the existing conditions?
- Confidence and Calibration Report
  - Did we meet all the previously identified calibration targets outlined? If not, describe why the model is still representative of the existing conditions.
  - Is the model still useful in determining the impacts of a project?

### MULTI-HOUR EVALUATIONS

Calibration criteria should only be applied to the peak hour due to limited data available during the shoulders of the peak hour.

## CALIBRATION TARGETS

The goal is to get the best match possible between model estimates and field measurements. However, there is a limit to the amount of time and effort that can be put into eliminating error in the model.

### THROUGHPUT VOLUMES

The first measure of proof of calibration is how closely throughput volumes from the field match simulation output volumes. A universal measure to compare field data is the GEH formula (1,4,7,10).

GEH statistics shall be calculated for all mainline segments and ramps identified in the scope of work (1,7). The GEH statistic must be calculated for all throughput volumes at all entry and exit locations in the calibration area of the model.

| | |
|---|---|
| **GEH < 5.0** | **Acceptable fit** |
| **5.0 <= GEH <= 10.0** | Caution: possible model error or bad data |
| **GEH > 10.0** | Unacceptable |

*Figure 16: GEH Statistic Guidelines (7)*

An example of acceptable GEH targets are as follows:

| Criteria | Acceptable Targets |
|---|---|
| GEH < 3.0 | All state facility segments within the calibration area |
| GEH < 3.0 | All entry and exit locations within the calibration area |
| GEH < 3.0 | All entrance and exit ramps within the calibration area |
| GEH < 5.0 | At least 85% of applicable local roadway segments |
| Sum of all segment flows within the calibration area | Within 5% |

*Figure 17: Washington DOT Calibration Criteria (1)*

Caltrans references the calibration criteria developed by Wisconsin DOT which is laxer in its requirements. Virginia DOT uses an iteration of the acceptability targets outlined in Figure 18.

| Criteria & Measures | Acceptability Targets |
|---|---|
| **Hourly Flows, Model vs. Observed** | |
| Individual Link Flows | |
| Within 15%, for 700 vph < Flow <2700 vph | > 85% of cases |
| Within 100 vph, for Flow < 700 vph | > 85% of cases |
| Within 400 vph, for Flow > 2700 vph | > 85% of cases |
| Total Link Flows | |
| Within 5% | All Accepting Links |
| GEH Statistic – Individual Link Flows | |
| GEH < 5 | > 85% of cases |
| GEH Statistic – Total Link Flows | |
| GEH < 4 | All Accepting Links |
| **Travel Times, Model vs. Observed** | |
| Journey Times Network | |
| Within 15% (or one minute, if higher) | > 85% of cases |
| **Visual Audits** | |
| Individual Link Speeds | |
| Visually acceptable Speed-Flow relationship | To analyst's satisfaction |
| Bottlenecks | |
| Visually acceptable Queuing | To analyst's satisfaction |

*Figure 18: Wisconsin DOT Freeway Calibration Criteria (4, 8)*

## FACILITY SPEED

Replication of driver behavior is needed, one method to match to real world conditions is to match spot speeds. This usually pertains to freeway segments because it is difficult to measure speed date on arterials.

*Uninterrupted Flow Facility Speeds*

Spot speeds in the model shall be within 3 mph of observed real world speed data on all freeway links (1). Virginia DOT allows for the visual validation of speeds using speed heat maps (11). Speed calibration is often a duplicative effort with travel time calibration (11).

| Southbound | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Location | INRIX Data (Field Data) | | | | | | | | | |
| | 6:30 - 7:00 | | 7:00 to 8:00 AM | | | | 8:00 to 9:00 AM | | | |
| I-5 to 134th | 60.3 | 60.1 | 60.0 | 60.7 | 61.7 | 60.0 | 59.5 | 59.2 | 59.6 | 60.0 |
| Between 134th Ramps | 60.4 | 60.4 | 60.4 | 60.6 | 62.1 | 60.2 | 60.1 | 60.4 | 60.3 | 60.2 |
| 134th to Padden | 60.5 | 60.5 | 60.7 | 60.8 | 61.7 | 59.7 | 58.6 | 59.8 | 59.7 | 60.0 |
| Between Padden Ramps | 61.5 | 60.2 | 60.8 | 61.8 | 60.9 | 55.4 | 53.6 | 57.1 | 58.9 | 59.6 |
| Padden to SR 500 | 60.0 | 59.5 | 59.6 | 60.9 | 59.6 | 56.7 | 56.4 | 58.1 | 59.2 | 59.4 |
| Between SR 500 Ramps | 60.9 | 60.7 | 61.6 | 62.4 | 61.8 | 60.5 | 60.4 | 60.7 | 61.1 | 61.1 |
| SR 500 to Mill Plain | 58.8 | 58.5 | 59.6 | 59.5 | 58.7 | 57.6 | 58.4 | 58.3 | 58.8 | 58.6 |
| Between Mill Plain Ramps | 60.3 | 60.3 | 60.5 | 60.8 | 60.3 | 58.8 | 59.1 | 60.1 | 60.9 | 60.8 |
| Mill Plain to SR 14 | 58.6 | 57.9 | 58.6 | 58.8 | 58.1 | 56.6 | 57.3 | 58.4 | 58.9 | 59.3 |
| Between SR 14 Ramps | 59.6 | 58.2 | 59.1 | 59.0 | 57.7 | 55.4 | 56.7 | 57.3 | 58.4 | 58.6 |
| SR 14 to Oregon | 58.1 | 56.0 | 56.9 | 56.9 | 55.2 | 53.3 | 55.1 | 56.1 | 57.3 | 57.4 |

*Figure 19: Example of Speed Comparison Table (1)*

*Interrupted Flow Speeds*

Spot speeds in the model shall be within 10% of the base free-flow speed when compared to the observed spot speed date. This threshold was based on information provided in the Highway Capacity Manual.

## TRAVEL TIME

Calibration criteria for travel times in the model should also be met for all segments and time intervals. The travel time criteria are separated into two facility types: uninterrupted flow and interrupted flow. The equations to calculate allowable travel time variation per Washington DOT are as follows (1):

| Facility Type | Equation |
|---|---|
| Free-Flowing | $\Delta = \frac{1}{\frac{1}{t} - \frac{4.4}{L}} - t$ |
| Interupted Flow | $\Delta = \frac{1}{\frac{1}{t} - \frac{0.1 * 5280\,S}{3600\,L}} - t$ |

Δ = Allowable Travel Time Variation (+/- seconds)
t = Real World Travel Time (seconds)
L = Length (feet)
S = Free Flow Speed (mph); Posted Speed may be used for FFS if unknown

*Figure 20: Travel Time Calibration Criteria (1)*

Oregon DOT defines allowable travel time variation based on the routes of less or greater than 7 minutes in duration. Modeled travel time is to be within 1 minute for routes with travel times less than 7 minutes or 15% for routes with travel time greater than 7 minutes.

Virginia DOT requires 85% of travel time routes and segments to be within 30% of observed travel times on arterials and 20% of observed travel time on freeways (11).

### CONFIDENCE AND CALIBRATION REPORT

A confidence and calibration report should be submitted with every model (1,7). The report should summarize the following:

- Basic processes and procedures followed
- Assumptions made
- Problems encountered
- Solutions devised during the study effort
- Confidence in model results
- Comparison of model results to real world data
- Identify calibration targets that were not met and why the results are still valuable

Any and all calibration parameters changed from default settings should be clearly documented with a description of reasons and how the changes improved the model replication.

## FUTURE YEAR MODELS

Volume forecasting and methodology should be documented and approved before the development of the future year models. The new traffic volume data can be submitted in graphical format for approval (1).

### MODEL DEVELOPMENT

A copy of the calibrated model shall be used to create the future year models (1,7, 8). Future no-build models should only change the traffic demand inputs and routing, signal timing, and any planned improvements. Once completed, the no-build model can be used to develop all additional alternative models. The no-build model represents a benchmark for evaluation all improvement alternatives (8).

Changes to driver behavior and parameters a future year models normally are not altered unless major changes to the network or volumes are included (1). Additional documentation of changes and assumptions should be compiled and submitted with each model.

## REPORTING

VISSIM is a data heavy application, with a wide range of output options ranging from network-wide statistics to individual intersection movement delays. Animation displays are also useful outputs of the VISSIM model when understanding model results (4). The specific data outputs required must be know from the start of the project to allow for proper model coding.

Data outputs may be reported at instantaneous rates at specific instances of time or may accumulate data over a longer time interval. Results may also be reported for specific points on a link in the network or aggregated for the entire network (4).

## ANIMATION OUTPUTS

Three type of animation videos are useful in particular if simulation runs are time consuming or tedious for large networks and long simulation periods (4). Recording videos of snapshots at selected time points in a simulation period give a sense of the model over the analysis period. Hotspot videos highlight locations of congestion and can be useful in determining start/end times of congestion. Vehicle trace videos that follow individual vehicles through the network allow for better assess the reasonableness of vehicle behavior.

The modeler may want to depict individual runs that represents “typical” conditions and/or “worst” conditions. The total vehicle travel time may be a useful indicator of typical and worst case scenarios (4).

Animation outputs can also be used as a tool to convey information to members of the public. Before showing the animation videos to an audience outside of the modeling development and/or review team, verify that the driver behavior is realistic. Most microsimulation tools now provide the option to show a 3D visualization of the model, complete with roadway infrastructure and other architectural features. While these features may help to orient the audience to the project study area, take care not to let the presentation graphics overshadow the fundamental engineering objectives of the model (12).

## REQUIRED DATA OUTPUTS

Multiple microsimulation protocols outline the possible data outputs that can be obtained in a microsimulation model. The Washington and Oregon DOT’s requires the following data outputs for all freeway and arterial models (1, 7):

- Node Evaluation
  - Throughput, Average Delay, Stops
- Queue Counters
  - Average and 95th Percentile Queues
- Data Collection Points
  - Number of Vehicles, Mean Speed
- Travel Time
  - Number of Vehicles, Travel Time

This list is not inclusive of data outputs but can serve a minimum starting point to data output requirements. Any of the stated data outputs can be statistically summarized and have the mean, mode, median, and standard deviation may be reported over the required simulation runs (4).

## OPTIONAL OUTPUT DATA

The data outputs outlined here are less commonly used and shall be determined in the scoping process. Some of the optional data outlined are as follows:

- Network Performance Evaluation
  - Vehicle Delay and Stops, Latent Demand, Vehicle-Hours Traveled, Mean System Speed
- Link Evaluation
  - Volume, Speed, Density
- Speed Contour Plots

- Emissions
- Public Transit Waiting Time

## ISOLATING THE SEEDING PERIOD

It is important that the seeding period be excluded from the reported results.

## HCM COMPLIANT LEVEL OF SERVICE RESULTS

It is often valuable when explaining microsimulation model results to the general public for the results to be in terms of HCM levels of service. The modeler should account for the distinctions between the way microsimulation software and the HCM define delay and density when assessing LOS (4). This disconnect between modeled results and HCM methodology has resulted in some agencies from not using HCM LOS (1,7).

## PRESENTATION OF RESULTS

All effort should be taken to present the traffic analysis results in a manner that is concise and understandable to the intended audience. Presentation and format of reported outputs should target a non-technical audience while allowing a technical reviewer to verify the results of the analysis (8).

Traffic analysis results can be presented in the following formats:

- Tabular format
- Graphical format

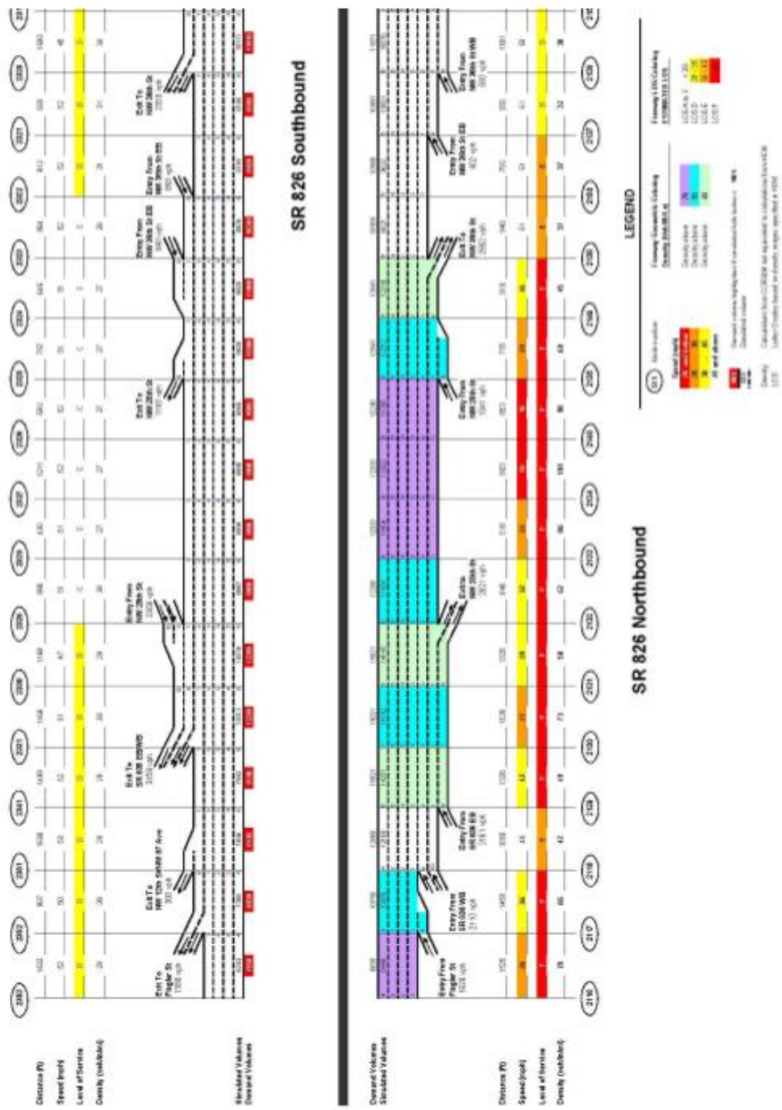



*Figure 21: Graphical Method of Presenting Results (8)*

## SAMPLE REPORT FORMAT

An example of the minimum sections required are as follows (1,7):

- Project Description
- Study Area and Model Area Description
- Scope of Work
- Description of Alternatives Analyzed
- Description of Problem Area
- Opportunities Discovered in Analysis
- Summary of Results and Recommended Decisions

## REVIEWING AND EVALUATING MODELS

This section details the typical steps used by staff when reviewing submittals. The modeler is encouraged to refer to this section before submittal of each deliverable to ensure all proper requirements have been met.

### CHECKLISTS AND PROMPT SHEETS

The use of checklists are common tools used when evaluating models. As an example, the Washington DOT provides a comprehensive checklist covering each project milestone and as well as a signal coding checklist (1, 7). Wisconsin DOT also has a Microsimulation Checklist prepared and utilizes an internal Peer Review panel to oversee complex models (12). Checklists are excellent tools and providing a structured review and a means to track comments and responses by the modelers.

**WSDOT Vissim Reviewing Checklist**:

Project:
Name of Modeler:
Name of Reviewer:

| Milestone | Protocol Section | Items to Check |
|---|---|---|
| **Scoping** | | |
| Project Problem Statement | 1.1 | ☐ The goals of the project are clearly stated |
| | | ☐ Proposed MOEs provide the necessary information to answer the Project Problem Statement |
| | | ☐ Field visit has been conducted |
| Comments: | | |
| Data Collection Plan | 2.6 | ☐ Summary of a field visit to determine data collection needs has been provided in a graphical format |
| | | ☐ Summary of real-world observations (and historical data if available) showing congestion locations have been provided |
| | | ☐ Time periods for data collection have been determined and documented |
| | | ☐ Type of data to be collected and locations that they will be collected are documented in tabular and graphical format |
| Comments: | | |

*Figure 22: Example of VISSIM Review Checklist (1)*

## ALTERNATIVE GRADING

The modeler may find that the alternatives modeled are producing similar simulation results. In order to determine if an alternative is significantly better or worse due to changes in the model and not result of random number seeds, a statistical hypothesis test can be conducted (4).

A sensitivity analysis can also be performed to develop an understanding of the robustness of the conclusions of the study to changes in underlying assumptions. This could include demand or improvements outside the study area that may increase demand within the study area.

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# APPENDIX B: Michigan VISSIM Protocol Manual

## MICHIGAN VISSIM PROTOCOL MANUAL

The Michigan-Specific VISSIM Protocol Manual communicates the expectations for model development and deliverables so that the consultant and MDOT move through modeling projects in congruence based on current best practices. This provides for consistency in deliverables, facilitate more efficient reviews, and reduces the risk of budget overruns and delays to project schedules. The protocol manual also defines a consistent methodology to review and evaluate models and provides a clear roadmap to MDOT project managers unfamiliar with the VISSIM modeling process, giving them the tools necessary to successfully manage a modeling project with an understanding of protocol and anticipated modeling outcomes.

The Michigan VISSIM Protocol Manual is broken into two main sections. The goal of Section 1 is to aid MDOT project managers in determining whether VISSIM is the correct analysis tool, defining a VISSIM project scope, and understanding VISSIM milestones and deliverables. The goal of Section 2 is to provide guidance in model development, model summary and model review processes. Specific detail is discussed in Section 2 to address: geographic and temporal model scope, data collection, driving behaviors, calibration and validation, tools and checklists, evaluating models, and documentation and deliverables.

The Michigan VISSIM Protocol Manual is a living document and the most current version is maintained by the MDOT Congestion and Reliability Unit and can be found at the link below:

https://mdotjboss.state.mi.us/TSSD/getCategoryDocuments.htm?categoryPrjNumbers=1903801,1913370&category=Operations