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

RESEARCH REPORT

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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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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:

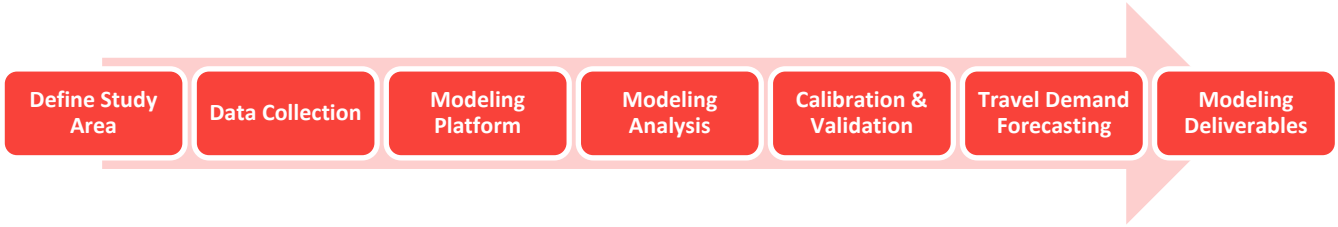
- Complex signal timing or operations (such as transit signal priority and preemption strategies)
- Complex geometrics

- 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

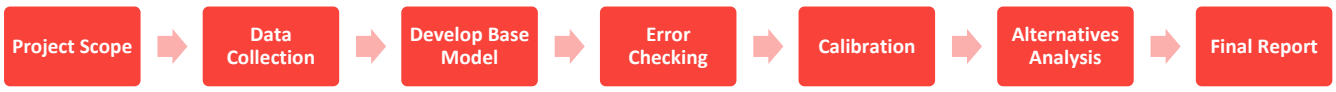
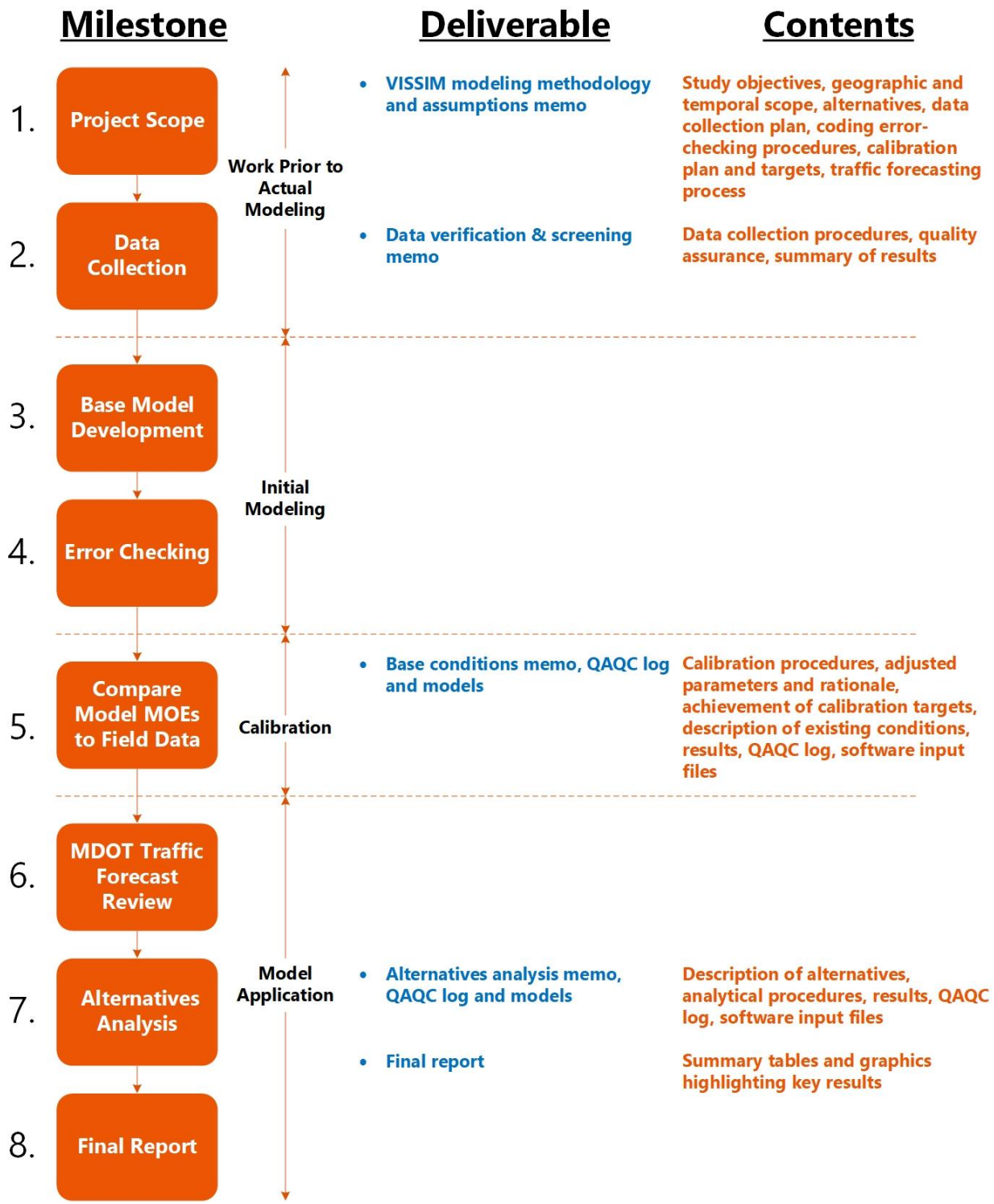


Figure 3 provides project managers with an overview of the relationship between VISSIM milestones and expected deliverables during a project. The various memos and reports that are generated as part of the project should at a minimum be reviewed by the project manager and representatives of MDOT's Congestion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

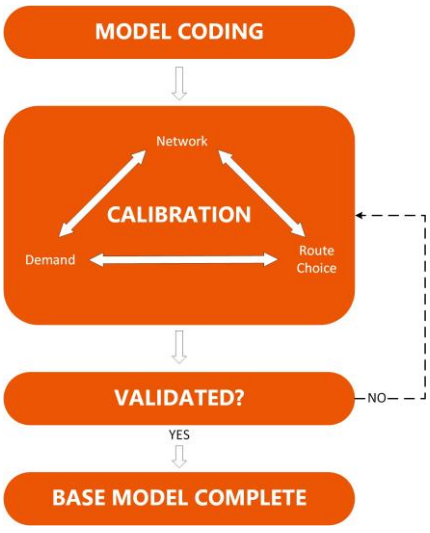
FREEWAY						
Conservative				**Aggressive**		
Description	**Name**	**#**	**Link Type**	**#**	**Name**	**Description**
Can be used at segments where reduction in throughput is required. Significant factors include increased CC1 and CC2 values.	Freeway Basic Conservative	101	Basic	103	Freeway Basic Aggressive	**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

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