GEORGIA DOT RESEARCH PROJECT 22-26

Final Report

VISSIM™ SIMULATION CALIBRATION PROCEDURE

GDOT
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16. Abstract

Underlying most VISSIM™ calibration is the adjustment of the Wiedemann car following parameters used to simulate vehicle behavior within the model. The Wiedemann models directly influence a roadway segment's capacity, saturation flow, density, etc. Several key features were identified as part of this study. Through the project a calibration approach that seeks minimal changes in car following parameter settings has been developed. The developed method focuses on desired speed distribution and several key parameters of both the Wiedemann 99 and Wiedemann 74 models. Key concepts for the suggested calibration steps presented in the appendix include: car following calibration is performed at the link level; evaluation metrics include speed-flow diagrams and headway distribution; calibrated parameter sets for critical or typical links may be applied to links throughout the model; calibration includes setting of the desired speed distribution; the method seeks to limit deviations from defaults parameters, focusing on a select subset of car following parameters; and finally the approach is flexible, leveraging expert judgement of model developer and design team. The final calibration is an iterative process including: 1) checking field conditions against selected default values; 2) calibrating desired speed; 3) calibrating key Wiedemann parameters; and 4) validation. Through this focused approach the method reduces the likelihood of unrealistic parameter interaction effects and allows the simulation modeler to understand the potential impact of any calibration adjustments. While the proposed method may be applied to additional car following parameters the discussed select parameters and calibration approach should be sufficient for most modeling efforts.

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Final Report

VISSIM™ SIMULATION CALIBRATION PROCEDURE

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In cooperation with
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April 2024

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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EXECUTIVE SUMMARY

The Georgia Department of Transportation (GDOT) typically employs VISSIM™ as the preferred transportation simulation modeling tool. GDOT research project RP 18-33, VISSIM™ SIMULATION GUIDANCE, developed guidance material that enhances GDOT's ability to review and utilize VISSIM™ models. While Project RP 18-33 provided detailed guidance and checklists for model verification and validation, calibration guidance was limited to a high-level overview of concepts to aid in the review of a calibration procedure. The lack of more detailed calibration guidance for GDOT model development was noted as a weakness by both GDOT staff and outside consultants. This report fills that gap, developing detailed calibration guidance for GDOT model development. A calibration appendix associated with RP 18-33 Module 7 has been developed. This addresses a significant need within GDOT with a low barrier to implementation as the developed material may be readily utilized by GDOT staff and consultants.

Underlying most VISSIM™ calibration is the adjustment of the Wiedemann car following parameters used to simulate vehicle behavior within the model. VISSIM™ utilizes psycho-physical perception models (Wiedemann 74 and Wiedemann 99), or Action Point model, to approximate actual car-following behavior. The Wiedemann models categorize the car-following behavior of a vehicle into different states: free driving, approaching, following, and braking (PTV AG 2019). In practice, Wiedemann 74 is typically applied to signalized and low speed corridors, while Wiedemann 99 is utilized for freeways. The Wiedemann models directly influence a roadway segment's capacity, saturation flow, density, etc. Thus, it may be necessary to calibrate the model parameters to reflect field conditions.

Through the project a preferred calibration approach has been developed that seeks the fewest parameter adjustments, by the smallest increments, that provides a reasonable reflection of field conditions. The developed method focuses on desired speed distribution and several key parameters of both Wiedemann 99 and Wiedemann 74 models. Key concepts for the suggested calibration steps presented in the appendix include:

- Car following calibration is performed at the link level.
- Utilize Evaluation metrics such as speed-flow diagrams and headway distribution.
- Calibrated parameter sets for critical or typical links which may be applied to links throughout the model.
- Definition of a desired speed distribution, which reflects field speeds.
- The method seeks to limit deviations from defaults parameters, focusing calibration on CC1 and CC2 in most cases for Wiedemann 99; and ax and bxAdd = bxMult +1 for Wiedemann 74.
- The approach is flexible, leveraging expert judgement of model developer and design team.

The final calibration is an iterative process including: 1) checking field conditions against selected default values; 2) calibrating desired speed; 3) calibrating key Wiedemann parameters; and 4) validation. Through this focused approach the method reduces the likelihood of unrealistic parameter interaction effects and allows the simulation modeler to understand the potential impact of any calibration adjustments. While the proposed method may be applied to additional car following parameters, the discussed select parameters and calibration approach should be sufficient for most modeling efforts.

CHAPTER 1. INTRODUCTION

Where analytical tools such as the Highway Capacity Software™ (HCS), SYNCHRO™, etc. do not adequately represent traffic operations within a study area, or do not provide the necessary performance metric(s) required for the analysis, detailed simulation or similar approaches may be required. In such cases the Georgia Department of Transportation (GDOT) typically employs VISSIM™ as the preferred transportation modeling tool. GDOT research project RP 18-33, VISSIM™ SIMULATION GUIDANCE, developed guidance material that enhances GDOT's ability to review and utilize VISSIM™ models. To aid in the development of the necessary skills for VISSIM™ model review, RP 18-33 developed a series of eight training modules, providing a basic introduction to arterial corridor and freeway model development, as well as covering broader modeling issues, such as underlying VISSIM™ model parameters and distributions; verification, calibration, and validation; and other issues critical to a thorough model review. The RP 18-33 materials culminate with reviewer checklists.

While Project RP 18-33 provided detailed guidance and checklists for model verification and validation, calibration guidance was limited to a high-level overview of concepts to aid in the review of a calibration procedure. The lack of more detailed calibration guidance for GDOT model development was noted as a weakness by both GDOT staff and outside consultants. This report seeks to fill that gap, developing detailed calibration guidance for GDOT model development.

PROBLEM STATEMENT AND LITERATURE REVIEW

Nearly all modeling efforts include some level of calibration. However, what is meant by calibration, and what calibration should include, is not always clear. To help clarify, there are three distinct, but related, processes that should be undertaken for each model: verification, validation, and calibration. Briefly, verification is the confirmation that a model has been constructed as intended (e.g., a roadway that is 3 lanes in the field is 3 lanes in the model), validation confirms that the performance of the model satisfies expectations (e.g., the model approximately matches field conditions), and calibration is the adjustment of the underlying model parameters of a verified model to achieve a valid model that simulates particular operational characteristics within a stated range of uncertainty.

Underlying most VISSIM™ calibration is the adjustment of the Wiedemann car following parameters used to simulate vehicle behavior within the model. VISSIM™ utilizes psycho-physical perception models (Wiedemann 74 and Wiedemann 99) to approximate actual car-following behavior. The Wiedemann models categorize the car-following behavior of a vehicle into different states: free driving, approaching, following, and braking (PTV AG 2019). In practice, Wiedemann 74 is typically applied to signalized and low speed corridors, while Wiedemann 99 is utilized for freeways. However, the application of Wiedemann models by facility type is not a “hard and fast” rule. The Wiedemann models directly influence a roadway segment’s capacity, saturation flow, density, etc. Thus, it may be necessary to calibrate the model parameters to reflect field conditions. Approaches to calibration range from iterative manual approaches to the use of genetic algorithms to search for optimal parameter values. However, many of the existing approaches either act as “black boxes” or lack sufficient specificity to guide the user through the calibration procedure.

GOALS AND OBJECTIVES

The objective of this project was to develop a VISSIM™ calibration procedure for GDOT simulation projects. Key characteristics of the developed calibration method are that it is not a "black box" to the model developer and that calibration adjustments to model parameters are intuitively justifiable. Key project objectives include:

1. Define and select calibration performance metrics,
2. Identify key model parameters to be included in calibration,
3. Develop a graphical representation of the sensitivity of model results to key parameters,
4. Collect representative data to develop Georgia-specific parameter sets, and
5. Develop an iterative, step-by-step calibration procedure.

SUMMARY

This project builds upon the completed efforts of RP 18-33, VISSIM™ SIMULATION GUIDANCE. A calibration appendix associated with Module 7 has been developed. This addresses a significant need within GDOT with a low barrier to implementation as the developed material may be readily utilized by GDOT staff and consultants.

Through the project, a preferred calibration approach has been developed that seeks the fewest parameter adjustments, by the smallest increments, that provides a reasonable reflection of field conditions. The developed method focuses on desired speed distribution and several key parameters of both Wiedemann 99 and Wiedemann 74 models. It also considers calibration at a local or link level, simplifying the complexities of car following model calibration. Through this focused approach, the method reduces the likelihood of unrealistic parameter interaction effects and allows the simulation modeler to understand the potential impact of any calibration adjustments. While the proposed method may be applied to additional car following parameters the discussed parameters and calibration approach should be sufficient for most modeling efforts.

CHAPTER 2. BACKGROUND – SIMULATION MODEL CALIBRATION AND VALIDATION GUIDANCE

This project focuses on the calibration and validation of microscopic traffic simulation tools, with a particular focus on VISSIM™ ("**V**erkehr **I**n **S**tädten - **SIM**ulationsmodell') developed and maintained by the PTV Group (PTV AG 2019). VISSIM™ is widely adopted in both industry and academia, having been successfully applied to a wide variety of projects in multiple contexts across the world. That being said, it is important to point out the software-specific nature of the work presented here. While the general approaches discussed here may have some broad validity, the wide variety of software solutions available on the market and currently used in practice and research makes a universal calibration and validation approach impossible and thus the specific strategies, parameters, and trends discussed in this report are limited to those applications in which VISSIM™ is the chosen modeling tool.

AGENCY/DOT GUIDELINES

Although VISSIM™ is just one of many software solutions for microscopic simulation of traffic operations, a significant body of literature composed by a variety of actors at a national and state level has been created over the past two decades, and an analysis of the guidelines and methods produced throughout the years is a valid starting point for further studies and protocols.

USDOT/FHWA

At a US national level, FHWA's Traffic Analysis Toolbox is the primary federal guidance for model calibration and validation. This toolbox, however, is software-agnostic and as a result provides only generic guidance and direction as to what a recommended calibration and validation protocol should look like. The Toolbox currently consists of 14 Volumes and 6 additional documents. Though no substantive part of the Toolbox explicitly focuses on any microscopic simulation software, many key principles and techniques are outlined by the FHWA through this document and are thus adopted by many state DOTs.

The Toolbox does, however, address data needs and limitations, indicating the importance of contemporaneity and consistency across data collection efforts. Cluster Analysis should be used to identify the key attributes for defining the travel conditions revealed by the data, and a representative day should be identified and used for the calibration of each travel condition. (FHWA 2019) Volume III of the Toolbox also outlines the three main steps in the calibration process, which are:

1. The identification of representative days;
2. The preparation of time-dynamic variation envelopes;
3. The calibration of model variants within the acceptability criteria. (FHWA 2019)

This process should be applied to a single model run for each travel condition or cluster identified. The Toolbox also sets forth some minimum suggested elements/steps that every modeler should include in their transportation analysis process. In particular, for calibration purposes, modelers should at least consider two performance measures, one being localized (i.e., segment/intersection level) and one being system level (i.e., route/corridor level). For the verification of the quality of the calibration a set of FOUR acceptability criteria are illustrated, with each performance metric required to pass all four. (FHWA 2019)

In Volume VI the FHWA identifies seven basic measures of effectiveness (MoEs) to be considered for use in the evaluation of traffic operations performance: travel time, speed, delay, queue, stops, density, and travel time variance. Additional indicators of performance are the HCM LOS and the V/C (Volume/Capacity) ratio. (FHWA 2007) Further less common MoEs are also listed. Volume VI highlights the great variety of ways in which different tool types (macroscopic, mesoscopic, microscopic simulation tools, the HCM, etc.) and even different software products calculate these MoEs, with some not capable of outputting certain metrics and others having varying definitions of the same MoE. This is an ultimate factor that must be kept in mind when deciding which tool is the most appropriate to satisfy the modeler's transportation analysis needs.

State DOTs

Having highlighted the main points and guiding principles set forth at a federal level, the state guidelines can be discussed using the FHWA's framework as a starting point. Not all state DOTs have adopted VISSIM™ as their microscopic simulation modeling software of choice. Having said that, approximately 40% of state DOTs have specific guidance (be it a manual, guideline, or protocol) in place for the use of VISSIM™ for transportation analysis projects. Some state DOTs have gone as far as providing specific guidance for multiple software packages (e.g., Colorado DOT, Utah DOT, and Wisconsin DOT). Since the scope of this document is focused on VISSIM™ applications, the discussion in this section will be limited to the state DOT guidelines provided for VISSIM™ implementations.

An additional point that must be made before any discussion of State DOT guidelines is begun, is that the documents provided by the DOTs were published across the span of almost two decades, with the oldest guidelines dating back to around 2002. This means that, though the core principles and features of VISSIM™ have not changed, some functions that are discussed and addressed in the more recent state-DOT guidance may have not been available at the time-of-release of earlier guidance.

Calibration vs Validation

In both the broader scientific literature and DOT guidelines (at a state and federal level), many different definitions of model calibration and validation exist. This makes creating a uniform and consistent characterization of these processes problematic. The FHWA's Traffic Analysis Toolbox Volume III defines calibration as "the adjustment of model parameters to improve the model’s ability to reproduce time-dynamic system performance observed under specific travel conditions" (FHWA 2019), which is echoed by the Oregon DOT VISSIM™ Protocol, that states that 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." (OregonDOT 2011). Even internationally, the definition of model calibration maintains clear commonalities with the definitions given above: for instance, Transport for London (TfL) defines calibration as "the process of placing measurable data into a traffic model to replicate observed street conditions." (TfL 2021)

Whereas there seems to be more uniformity and agreement on what the calibration process' goals, methodologies, and strategies are, this is less true for validation. Some sources conflate calibration and validation into a single process/definition or do not explicitly mention validation at all. Those that do are, however, in general agreement. For example, the OATS (Oregon DOT Analysis and Traffic Simulation) manual states that validation is "the act of proving or corroborating, usually with a second data source or dataset, that the calibrated model can also provide realistic results under different input data/scenarios. This ensures a more robust model with realistic internal mechanics, that is less likely to be over-fit to just one dataset." (OregonDOT 2021). Similarly, TfL guidelines state that validation is "the process of comparing model output against independently measured data that was not used during the calibration process" with the objective of verifying that the "model has been correctly calibrated, and that there is therefore confidence in its ability to produce valid predictions for Proposed scenarios." (TfL 2021)

Model Classification

Most DOT guidelines, in some way, specify the need for both the infrastructure elements being modeled (freeway, arterial, intersection, etc.) and the stated purpose of the project (improving travel times, reducing queues, etc.) should be defined *before* calibrating and validating a model. This is because these two elements can greatly impact the calibration process. For example, if the VISSIM™ model being calibrated is simulating a freeway segment, the set of parameters to examine should be part of the Wiedemann 99 (car following) model. Likewise, if the project for which the model is built is geared towards minimizing delay along an arterial corridor, the model's calibration target should emphasize those of the Wiedemann 74 model. Most DOT manuals thus provide separate guidelines for arterial (or interrupted flow) facilities and freeway (or uninterrupted flow) facilities. The only state DOT guidelines that add more distinctions on top of the freeway/arterial categorization are from Wisconsin and Utah. Wisconsin DOT adds signalized and unsignalized intersection guidance, while Utah DOT gives specific information on modeling intersections and interchanges. Table 1 summarizes the proportion of DOTs who provide specific calibration and validation guidance for different facility types.

Table 1. Facility Type distinctions as included in State DOTs.

	Facility type		
	Freeway	Arterial	Other
Included	85.71%	85.71%	14.29%
Not included	14.29%	14.29%	85.71%

Measures of Effectiveness (MoEs)

Given the stated objectives of model calibration and validation, choosing which measures of effectiveness (MoEs, in some cases also called measures of performance, or MoPs) to use as a yardstick is a key step in the process. Due to the high variety of project applications which rely on DOT guidelines, this part of the process (i.e., which MoEs to calibrate/validate by) is in most cases left up to the modeler's discretion, with some DOTs going further than others in restricting their freedom to choose. Most specify a list of MoEs to consider and do nothing more, while some require a minimum number of MoEs (usually at least 2, volume and speed or travel time) leaving the option for further measures to be considered.

Based on a detailed analysis of VISSIM™ guidelines at a State level, taken as a whole DOTs consider 10 different MoEs for VISSIM™ model calibration and validation:

- Capacity
- Travel Time
- Speed
- Bottlenecks
- Volume/Density
- Queuing
- Weaving behavior
- Lane utilization
- Congestion
- Intersection Delay

Whereas some MoEs are only considered by a few DOTs, volume, travel time and speed are near-universal MoEs, recommended (and in many cases required) by almost all states examined. To a lesser degree, this is true for queuing MoEs too, as shown in Table 2 and Table 3. What is most interesting is the significant lack of uniformity in what the calibration and validation performance targets are. The only MoE for which State DOTs have some level of agreement is volume, for which the most common calibration target is:

$$\begin{cases} < 700\text{ vph, within } \pm\ 100\text{ vph} \\ 700 - 2700\text{ vph, within } \pm\ 15\%\text{ of observed volume} \\ > 2700\text{ vph, within } \pm\ 400\text{ vph} \end{cases} \qquad \text{(CDOT 2018)}$$

which is often complemented by some form of limit GEH statistic. For the other common MoEs, targets vary greatly both in form (target function) and substance (target value/threshold) depending on which guideline is considered.

Table 2. Common Measures of Effectiveness - State DOTs' VISSIM guidance.

	Measures of Effectiveness - Common			
	Travel Time	Speed	Volume/Density	Queuing
% DOTs provide target	92.86%	71.43%	92.86%	78.57%
% DOTs don't provide target	7.14%	28.57%	7.14%	21.43%

Of the less-commonly used MoEs, capacity calibration target stands out because it is specific (i.e., the threshold provided is explicit and does not refer to other MoEs) and consistent across DOTs: a typical capacity calibration target is "Modelled saturation flows values should be within 10% of observed values." (FDOT 2021) The other MoEs shown in Table 3 lack both consistency across different states and wide adoption by a majority of DOTs.

Table 3. Uncommon (< 50%) Measures of Effectiveness - State DOTs.

	Measures of Effectiveness - Uncommon (< 30% of DOTs)					
	Bottleneck	Weaving behavior	Lane utilization	Congestion	Intersection Delay	Capacity
% DOTs provide target	7.14%	21.43%	28.57%	7.14%	7.14%	14.29%
% DOTs don't provide target	92.86%	78.57%	71.43%	92.86%	92.86%	85.71%

VISSIM™ Calibration parameters.

At a fundamental level, VISSIM™ calibration involves modifying parameters in the:

- Car following models (Wiedemann 99 and Wiedemann 74, depending on context/facility type), and
- Lane change model.

The car following models account "for psychological aspects as well as for physiological restrictions of drivers' perception" and contain "a psycho-physical car following model for longitudinal vehicle movement and a rule-based algorithm for lateral vehicle movement." (PTV AG 2019). VISSIM™ is built using two separate car following models developed by Rainer Wiedemann. The Wiedemann models are applied in VISSIM™ depending on the type of infrastructure being simulated at a link/connector level:

- for freeway traffic applications with no merging areas, the link driving behavior car following model should be set to Wiedemann 99. (PTV AG 2019)
- for urban traffic and other interrupted flow facility applications (including on and off ramps), the link driving behavior car following model should be set to Wiedemann 74. (PTV AG 2019)

The Lane change model is also applied to Driving Behaviors and acts on a link/connector level. This model governs how, where, and when vehicles change lanes. VISSIM™ distinguishes between two types of lane changes:

- Necessary lane changes, which occur "if needed to reach the next connector of a route." (PTV AG 2019)
- Free lane changes, which occur "if more space on the new lane is available or if longer driving at the desired speed is required." (PTV AG 2019)

Only necessary lane change behavior is governed by the lane change model, whereas free lane changing is a function of the car following model parameter values (PTV AG 2019).

Wiedemann 99 Car Following Parameter Calibration

The Wiedemann 99 car following parameters are recommended for use on uninterrupted flow facilities (links and connectors) within VISSIM™. Existing state DOT guidelines for calibration of this parameter set are, by far, the most addressed and best documented among all of the VISSIM™ calibration procedures. All existing guidelines and protocols agree on which parameters should be considered for modification during calibration and validation, Table 4.

Table 4. Percentage of DOTs who provide ranges for Wiedemann 99 Car Following Model Parameters.

	Wiedemann 99 model parameters			
	CC0	CC1	CC2	CC3 - CC9
% DOTs provide range	100.00%	100.00%	100.00%	Default
% DOTs do not provide range	0.00%	0.00%	0.00%	Default
Value envelope	4-5.5 ft	0.7-3 sec	9.56-39.37 ft	Default

The VISSIM™ Manual states that the CC1 parameter has "a major impact on the safety distance and saturation flow rate" (PTV AG 2019). DOT guidelines add CC0 and CC2 to this list, with some specifying that "CC0 and CC1 control most of the driver following behavior." (FDOT 2021) These three parameters are fundamental for determining the saturation flow rate of the modeled facility. Per the VISSIM™ manual, the three parameters are defined as:

- CC0 (standstill distance): "The desired standstill distance between two vehicles (no stochastic variation)."

- CC1 (gap time distribution): "Time distribution from which the gap time in seconds is drawn which a driver wants to maintain in addition to the standstill distance."
- CC2 ('following' distance oscillation): "Maximum additional distance beyond the desired safety distance accepted by a driver following another vehicle before intentionally moving closer." (PTV AG 2019)

The impact of these three parameters will be discussed in detail later in this report.

Though not all analyzed guidelines provide value envelopes for parameters CC3 to CC9, some DOTs give indications on how specific parameters affect the modeling of certain traffic conditions:

- Negative and positive "following" thresholds (CC4 and CC5) are other means of calibrating break-down conditions. (FDOT 2021)
- Standstill acceleration (CC8) is a useful parameter for calibration of the recovery from breakdown conditions. (FDOT 2021)

Clearly CC3-CC9 parameters could require editing during calibration given specific circumstances. Nevertheless, there is consensus on the determination that CC0, CC1, and CC2 are the three main parameters that should be considered for any calibration of models of uninterrupted flow facilities and are thus the focus of this report.

Wiedemann 74 Car Following Parameter Calibration

If for the Wiedemann 99 car following parameters all DOT guidelines provide value envelopes and describe the effects of changes to default values, this is not the case for Wiedemann 74 car following parameters, which are used to govern driving behavior in interrupted flow conditions (i.e., arterials and freeway ramps). About one quarter of the VISSIM™ guidelines reviewed did not provide specific ranges and guidance for the calibration of Wiedemann 74 parameters (Table 5). The number of parameters that make up the Wiedemann 74 model is much smaller compared to the ones used for uninterrupted flow facilities (3 for Wiedemann 74, compared to 10 for Wiedemann 99). These parameters are defined as:

- Average standstill distance (ax): "Base value for average desired distance between two stationary cars. The tolerance lies within a range of –1.0 m to +1.0 m which is normally distributed at around 0.0 m, with a standard deviation of 0.3 m. This leads to "stochastic smearing" of ax."
- Additive part of safety distance (bxAdd): "Value used for the computation of the desired safety distance d. Allows to adjust the time requirement values."
- Multiplicative part of safety distance (bxMult): "Value used for the computation of the desired safety distance d. Allows to adjust the time requirement values. Greater value = greater distribution (standard deviation) of safety distance." (PTV AG 2019)

Per the VISSIM™ Manual, "the saturation flow [is defined] by combining the parameters Additive part of safety distance and Multiplicative part of safety distance".

Table 5. % of DOTs who provide ranges for Wiedemann 74 Car Following Model Parameters.

	Wiedemann 74 model parameters		
	Average Standstill Distance	Additive Part of Safety Distance	Multiplicative Part of Safety Distance
% DOTs provide range	66.67%	75.00%	75.00%
% DOTs do not provide range	33.33%	25.00%	25.00%
Value envelope	3.28-9.84 ft	1-3.75	2-4.75

Lane Change Model Parameter Calibration

Whereas driving behavior is either governed by the Wiedemann 99 or the Wiedemann 74 parameters, the lane change parameters apply to both interrupted and uninterrupted flow facilities. The specific definitions of each parameter can be found in the VISSIM™ Manual. When compared to the sets of car following parameters discussed in the previous sections, the variety and number of parameters which can be edited during calibration of the lane changing behavior of vehicles is much greater. Globally, 18 different parameters are discussed across the DOT guidelines for VISSIM™ implementation that were analyzed for this study. Of those 18 parameters, half are present in at least 50% of the DOT protocols (meaning that they contain specific guidance and value ranges for the parameter in question), while the rest are discussed only in a few isolated examples.

Table 6 summarizes this analysis, showing how of the numerous parameters that can be edited to modify the lane changing behavior of vehicles within the simulated environment, only 9 out of 18 were specifically addressed and recommended for consideration by a substantial number of DOTs. This observation is in keeping with the idea that, when calibrating complex models, it is essential to identify the most relevant and impactful parameters on the target MoE(s) and focus on those as calibration candidates. Given the high level of interaction between parameters (i.e., the effect of a unit change in parameter x on MoE α depends on the value chosen for the other parameters), most DOTs (and the FHWA in its Toolbox) recommend editing only a limited number of parameters, placing an emphasis on the identification of the most relevant ones for the intended purpose of the simulation. This is particularly relevant in the case of the lane change model, given the high number of editable parameters.

Table 6. Common (>50%) % of DOTs (out of 12) who provide Lane Change Parameters.

	Lane change parameters - Common								
	Maximum deceleration	$-1\,{}^{ft}/_{s^2}$ per dist.	Accepted deceleration	Waiting time before diffusion	Minimum headway (front/rear)	To slower lane if collision time is above	Safety distance reduction factor	Maximum deceleration for cooperative breaking	Overtake RSAs
Range provided	75.00%	75.00%	75.00%	66.67%	75.00%	50.00%	75.00%	75.00%	75.00%
Range not provided	25.00%	25.00%	25.00%	33.33%	25.00%	50.00%	25.00%	25.00%	25.00%
Value Envelope	-8 to -15 ft/s^2	50-250 ft/s^2	-0.5 to -12 ft/s^2	30-9999 sec	1.5-6 ft	0-0.5 sec	0.1-1	-8 to -15 ft/s^2	Unchecked/adjust to field conditions

Table 7. Uncommon (< 50%) % of DOTs (out of 12) who provide Lane Change Parameters.

	Lane change parameters - Uncommon							
	Advanced merging	Emergency stop	Lane change	Reduction factor for lane change before signal	Cooperative lane change	Vehicle routing decision look ahead	Max speed difference (cooperative lane change)	Max collision time (cooperative lane change)
Range provided	33.33%	41.67%	41.67%	16.67%	41.67%	16.67%	16.67%	8.33%
Range not provided	66.67%	58.33%	58.33%	83.33%	58.33%	83.33%	83.33%	91.67%
Value Envelope	Checked/adjust to field conditions	16.4-100 ft	656.2-5280 ft	Default	Checked /adjust to field conditions	Checked	10-20 mph	10-15 sec

Calibration and validation processes

At a general level, the calibration process for microscopic simulation models involves the following steps:

- calibration to capacity
- calibration of route choice
- calibration of system performance (FHWA 2014)

Most DOT guidelines propose a calibration process which, in some form or another, incorporates these three basic stages. Some DOT guidelines add distinctions for global and local parameter calibration (Iowa DOT, Wisconsin DOT, Michigan DOT, Colorado DOT, and others), specifying that modelers should take care to calibrate parameters that affect the model globally (car following and lane change parameters), before focusing on link-specific calibration that should be conducted on a case-by-case basis to match modeled outputs to specific field conditions. (IowaDOT 2017)This methodology improves efficiency by aiming to establish a good global level of calibration, integrated by a more in-depth fine-tuning at critical locations. On the other hand, this logically requires the identification of said critical locations beforehand, as additional field data may be required to complete the in-depth calibration of the key locations. (IowaDOT 2017)

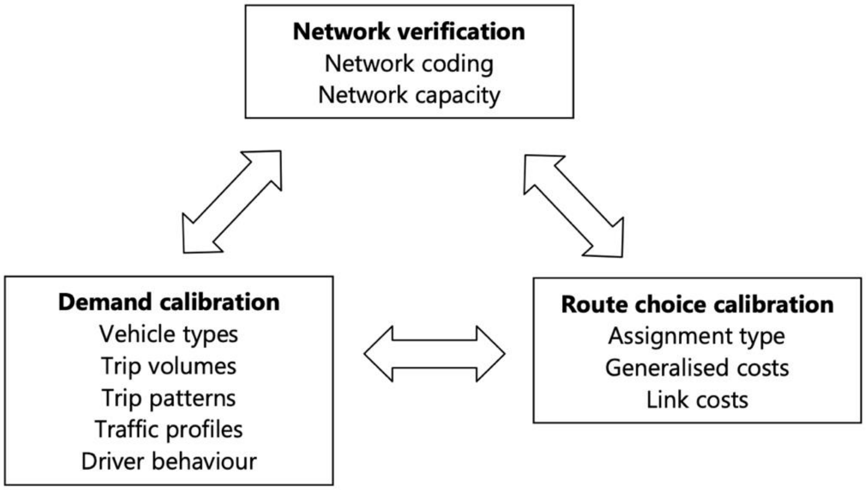
Some other DOTs add further calibration steps such as speed, travel time, queuing, weaving, and lane utilization calibration (WSDOT, ODOT, VDOT, and others): depending on which calibration targets are included in the recommended procedure (which often varies based on the project's scope and objective) the final form of each state's calibration process is unique. Though no two DOT VISSIM™ calibration processes look the same, the fact that their basic structure is consistent and replicated across the country indicates a solid methodological base for the definition of any new calibration guidance.

As for validation, the level of agreement (or even simple inclusion within provided protocols) across state DOTs is lacking. Only 1/3 of examined DOT guidelines contained specific sections for VISSIM™ model validation, with another 1/3 mentioning validation, but conflating it with calibration into a single process. When validation is included, the central theme is always that data *other than that used to calibrate the model* be employed: failing to do so negates the purpose and effect of model validation.

INTERNATIONAL PROJECTS AND GUIDELINES

The issue of model calibration in the context of traffic microscopic simulation goes well beyond the confines of the United States and has been investigated across the world. There are continuing research efforts across Europe and the UK, along with up-to-date guidelines from Australia and other countries that provide useful information and context for the creation of any future guidelines concerning model calibration and validation. Given the context and project specificity of calibration and validation procedures, coupled with the multitude of microscopic simulation software packages available on the market, the high variability described for State DOT guidelines is somewhat replicated at an international level. Though the basic definitions of "model calibration" and "model validation" remain virtually unchanged, the specifics of recommended procedures vary based on project scope, project objectives, data availability, and software in use.

Much like the FHWA's documentation, general guidelines provided by federal/national governments present a clear, but generic, methodology for model calibration and validation. The New South Wales Government Roads & Maritime Services' Traffic Modeling Guidelines(Road and Maritime Services New South Wales Government 2013), in this sense, provides a good example: the model calibration and validation portions contain a clear framework for modelers to follow, while remaining broad enough to be applicable to a host of different software packages. For instance, the model calibration/validation process shown in Figure 1 closely resembles the iterative process described in many other guidelines found in other countries and US State DOTs, and can be applied to many microscopic simulation software packages currently on the market.



(Source: Transport Road & Maritime Services 2013)

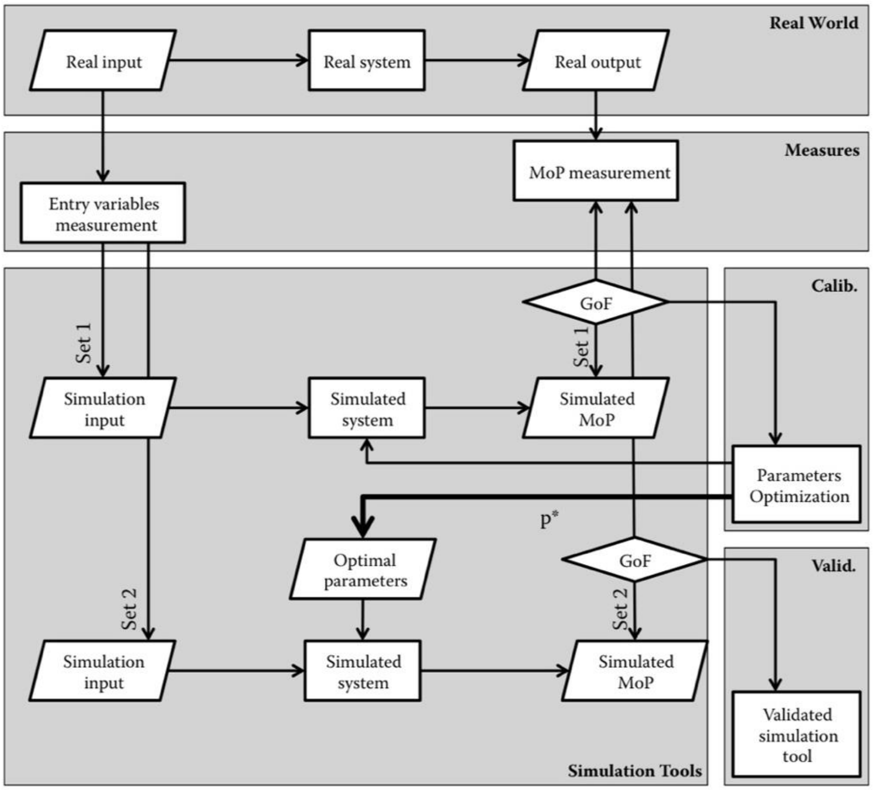
Figure 1. Illustration. Model calibration and validation process.

Another example from Australia is the Western Australia Main Roads' Operational Modelling Guidelines (Western Australia Mainroads 2021), which is an extensive document providing both general and software-specific guidelines for modelers. The guidelines include both general remarks and procedures similar to that shown in Figure 1, and software-specific information. In the VISSIM™ chapter, many of the parameter targets found across the US State DOT guidelines are reported. In the validation requirements section, special consideration is given to traffic volumes, travel times, vehicle speed, queue lengths, saturation flow, and signal timing (all of which constituted common calibration and validation quantities in many State DOT guidelines).

At a European level, two projects stand out as having meaningfully contributed to microscopic traffic simulation model calibration: MULTITUDE and CoEXist. The aim of MULTITUDE "was to develop, implement, and promote the use of methods and procedures for supporting the use of traffic simulation models, especially regarding model calibration and validation." (Daamen, Buisson et al. 2015) As part of the project, researchers noted that, on a sample of 300 respondents, more than half did not perform model calibration and remarked that "using a simulation tool without calibration and validation raises questions on the predictive capacity of the tool." (Daamen, Buisson et al. 2015) Much like many of the State DOTs' guidelines discussed in the previous sections, MULTITUDE found that there are numerous variables that modelers should consider before beginning calibration and validation of their simulation:

- Network type (size and type of facility; uninterrupted vs interrupted)
- Conditions of use (peak hour, weekends, and holidays; weather conditions; traffic conditions)
- Traffic management system (adaptive control for traffic signals; ADAS) (Daamen, Buisson et al. 2015)

As a result of the MULTITUDE project, researchers defined a general calibration and validation framework for microscopic simulation of traffic operations (Figure 2). At the core of this framework is an iterative process that leads to the calibration of the model based on predefined goodness of fit (GoF) functions for specified measures of performance (MoP). The authors specify that "the MoP choice must be [...] linked strongly with the study objectives and in agreement with the operational aspects of the study" and that "common MoPs for the calibration and validation of a traffic simulation model are time series of speeds and counts collected on a road section." (Daamen, Buisson et al. 2015)



(Daamen, Buisson, and Hoogendoorn 2015)

Figure 2. Illustration. Depiction of global framework of calibration and validation.

CoEXist was an EU-funded project with a slightly different focus: it aimed "to enable local authorities to confidently proclaim that they are “automation-ready” [through] three main outputs:

1. “Automation-ready transport modelling: A validated extension of existing microscopic traffic flow simulation and macroscopic transport modelling tools that can represent various types of CAV [Connected Autonomous Vehicles] driving logics.
2. Automation-ready road infrastructure [...]
3. Automation-ready road authorities [...]."(Rupprecht Consult and Beratung Gmb 2020)

The project was of great consequence for microscopic simulation modelers using PTV VISSIM™, as one of the outcomes of the CoEXist project was the definition of CAV-specific driving behaviors that are now included in the software itself.

CALIBRATION AND VALIDATION RESEARCH EFFORTS - ACADEMIC PAPERS

Since the release of VISSIM™ a significant volume of literature has been produced regarding calibration and validation of (traffic) microscopic simulation models. A recent review by Rrecaj and Bombol, provides a longitudinal analysis of VISSIM™ calibration and validation papers, clear trends appear in terms of:

- optimization methodologies,
- measures of consistency between simulated output and field data,
- statistical methods employed.

As for the optimization methodologies, Rrecaj and Bombol find that Genetic Algorithm (GA) is the most common and well established, with extensive literature by Byungkyu (Brian) Park and others ((Park and Qi 2004),(Park and Qi 2005)). GA was first introduced by Goldberg in 1989 (Goldberg 1989), and has been applied to a multitude of fields and simulation software tools (in transportation and beyond). Notably, other optimization methods include Monte Carlo, Evolution Algorithms, and, more recently, Sensitivity Analysis (SA) and quasi-Optimized Trajectories based Elementary Effect (Quasi-OTEE) methods. In terms of measures of consistency, Rrecaj and Bombol highlight how most studies employ either a single parameter or a multi-parameter calibration method with either a parametric or nonparametric statistical method for consistency analysis. (Rrecaj and Bombol 2015)

Hollander and Liu in a 2008 article published in Transportation conduct a similar study of multiple calibration and validation frameworks proposed in a research context, but considered a variety of software solutions beyond VISSIM™. Hollander and Liu find that there are considerable differences between frameworks in:

- "The definition of the problem itself [given that] some studies concentrate on the calibration of driving behaviour parameters only, [while] others [...] incorporate this in a broader problem, where a route choice model and/or an origin-destination matrix are calibrated too." (Hollander and Liu 2008)
- "The number of parameters being calibrated (from 3 to 19 parameters)." (Hollander and Liu 2008)
- The geographical scale of the models. "Such differences exist both in the size of the simulation network and in the spread and density of data sources over this network." (Hollander and Liu 2008)

Another important finding highlighted by Hollander and Liu is the fact that, in literature, where a larger number of parameters is considered during calibration, models "are normally calibrated using automated algorithms" which tends to have two contrasting effects: on the one hand this increases the chances of getting "more efficiently closer to an optimal solution [while also making] it harder to follow changes in the value of each parameter." (Hollander and Liu 2008) There is thus a clear tradeoff between operational efficiency and control over the optimization process when automated algorithms (such as Genetic and Evolution Algorithms, Simulated Annealing, and others) are applied to the optimal parameter set selection problem.

A major issue highlighted by multiple authors ((Antoniou, Barcelo et al. 2014), (Azevedo, Ciuffo et al. 2015)) is the correct (or optimal) selection of the subset of model parameters to calibrate. Given the large number of candidate parameters for calibration, the goals of the traffic study, and data availability, this step of the calibration (and validation) process can require significant efforts. In this regard, multiple research studies have explored the use of Sensitivity Analysis methods applied to complex simulation tools such as VISSIM™ ((Ge, Ciuffo et al. 2014), (Ge 2016)).

The increasing availability of trajectory data (collected in a variety of ways, such as drone video analysis, GPS signals, and others) has brought trajectory-enhanced and trajectory-based model calibration to the forefront of the research discussion. The FHWA commissioned an in-depth study on this topic, finding that "research results have shown that trajectory data can be quite effective for calibrating both car-following behavior [...] and lane-changing behavior." (Hale, Li et al. 2021) The authors find that, though this type of data might not yet be readily available to agencies and DOTs on all projects, it is time to start exploring methods to collect trajectory data more ubiquitously to inform microsimulation model calibration. In the interim, the authors do not want to discourage agencies from using traditional calibration methods when trajectory data are unavailable." (Hale, Li et al. 2021) The main benefit of using trajectory data in microscopic traffic simulation model calibration and validation is the fact that "improving the realism of driver behavior modeling may be one of the best available ways to improve the predictive ability of [the] models" (Hale, Li et al. 2021) and the type of information gleaned from trajectory data (headways, lane-specific information, etc.) "are best suited for determining the best input model parameters to control fine-grained driver behaviors." (Hale, Li et al. 2021) Some authors caution against a blanket implementation of trajectory-based calibration: Azevedo et al. point out how the use of trajectory data in model calibration is more relevant to applications in which " the replication of detail variables is at stake" and that "when the calibration process aims at reaching a less comprehensive model (i.e., only replicating generic aggregated network efficiency measurements) trajectory data might not bring significant improvements, especially when the driving behavior model is robust and the sensor coverage is comprehensive and well distributed." (Azevedo, Ciuffo et al. 2015)

Much in the same vein, given the intrinsic stochasticity associated with microscopic traffic simulation, the number of repeated runs required to obtain meaningful results depends on a series of factors. Hollander and Liu find that "different calibration methodologies are not equally rigorous in this respect, and the number of runs per one evaluation of the fit of a single candidate solution varies [...]." (Hollander and Liu 2008) One clear distinguishing factor is whether the modeler intends to use the results to investigate mean effects and outcomes or whether their variance is also of interest. In the first case, a common formula for the minimum number of repeated runs to perform is ((Toledo and Koutsopoulos 2004) and others):

$$R_i = \left[\frac{s_{R_0}(Y_i)t_{\alpha/2}}{d_i}\right]^2$$

where:

- $R_i =$ minimum number of replications required to estimate the mean of Y_i with tolerance d_i,
- $s_{R_0}(Y_i) =$ estimate of the standard deviation of Y_i is obtained by performing R_0 replications,
- $Y_i =$ outputs from different simulation runs (assumed normally distributed)
- $t_{\alpha/2} =$ critical value of the t-distribution at significance level α

Since an estimate of s is needed (as it is unknown prior to running the model), the most common solution is to obtain R_0 by "sequentially running the model and re-calculating s and R till the number of runs that has already been performed is found high enough." (Hollander and Liu 2008) In case multiple MoPs are selected for evaluation purposes, "the required number of replications is calculated for all measures of performance of interest. The most critical (highest) value of R_i determines the number of replications required." (Toledo and Koutsopoulos 2004)

CHAPTER 3. CALIBRATION METHOD DEVELOPMENT

INTRODUCTION

The Module 7 Appendix starts with a brief overview of Verification, Validation, and Calibration. Emphasis is placed on the important role each activity plays in the model development process and, in particular, how it is critical that a thorough verification process be completed prior to any calibration efforts. From this discussion, the appendix summarizes the overall calibration approach. Through the project a preferred calibration approach has been developed that seeks the fewest parameter adjustments, by the smallest increments, that provides a reasonable reflection of field conditions. This is recommendation is in general agreement with VISSIM™ guidance.

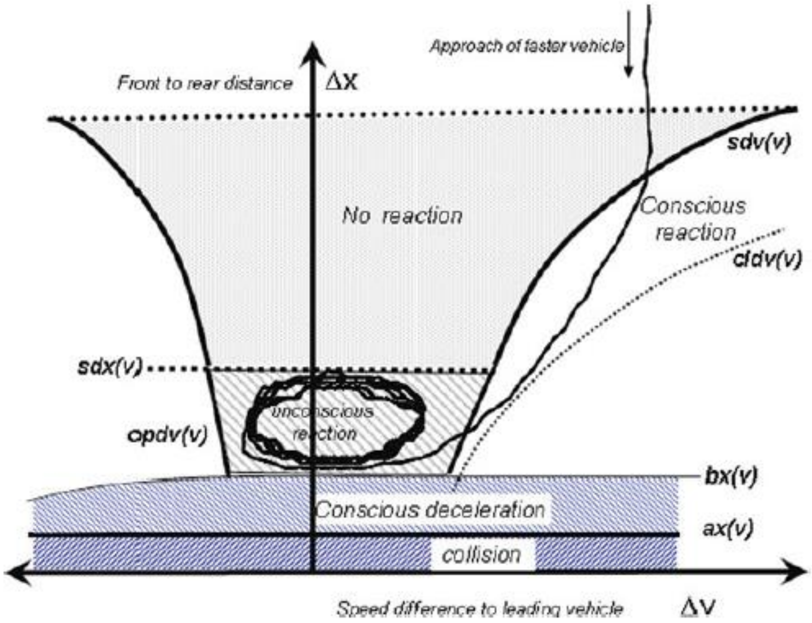
WIEDEMANN ACTION POINT CAR FOLLOWING MODEL

To gain an intuitive understanding of the impact of that car following parameters play in the underlying Wiedemann Action Point car following model (PTV AG 2022), this discussion begins with a brief description of this approach. Car following models define whether a vehicle accelerates, decelerates, or maintains its current speed in the next time step, when the vehicle is in car following mode. VISSIM™ uses the Wiedemann 74 and Wiedeman 99 models as its car following algorithms. The various parameters of the Wiedemann car following models allow simulation developers to calibrate the response (or sensitivity) of the following vehicle's behavior to its lead vehicle within the constraints of the underlying modeling form.

Loosely, given the distance between a lagging (also referred to as following) vehicle and the leading vehicle, and the difference in vehicle speeds, the vehicle will be in one of four driving states. The four states are Free Driving, Approaching, Following, and Braking. Figure 3 illustrates these states.

> “**Free driving**: No influence of preceding vehicles can be observed. In this state, the driver seeks to reach and maintain his desired speed. In reality, the speed in free driving will vary due to imperfect throttle control. It will always oscillate around the desired speed.
>
> **Approaching**: Process of the driver adapting his speed to the lower speed of a preceding vehicle. While approaching, the driver decelerates, so that there is no difference in speed once he reaches the desired safety distance.
>
> **Following**: The driver follows the preceding car without consciously decelerating or accelerating. He keeps the safety distance more or less constant. However, again due to imperfect throttle control, the difference in speed oscillates around zero.
>
> **Braking**: Driver applies medium to high deceleration rates if distance to the preceding vehicle falls below the desired safety distance. This can happen if the driver of the preceding vehicle abruptly changes his speed or the driver of a third vehicle changes lanes to squeeze in between vehicles.”

Source: (PTV AG 2022)

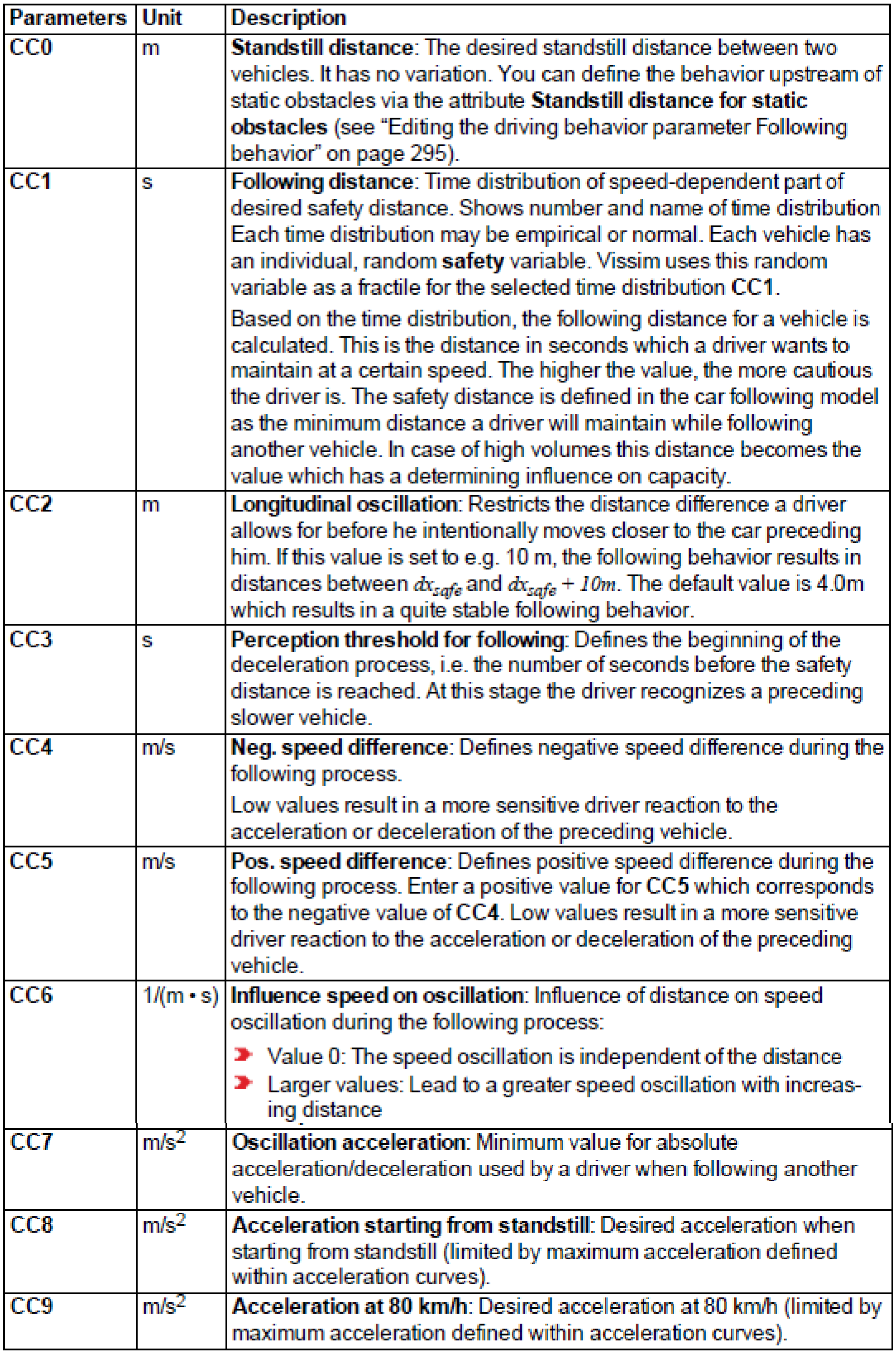


(Source: (Vortisch and Fellendorf 2011))

Figure 3. Graph. Driving state of VISSIM™ Psycho-Physical (Action Point) car following model Wiedemann 99 Parameters.

A simulation modeler may ask the question: How does the Action Point model relate to the model calibration and traffic flow performance? The short answer, the size and location of the zones as seen in Figure 3 are dictated by the car following parameters. Consider the Wiedemann 99 car following CC parameters, seen in Figure 4. (A more detailed discussion is provided in Module 7 on the CC parameters.)

The Module 7 Appendix focuses on CC1, CC2, CC4 and CC5. Based on model testing and review of the literature, it was determined that the remaining parameters had minimal impact on the model execution and are unlikely to be changed during calibration, except under very specific conditions.



Parameters	Unit	Description
CC0	m	**Standstill distance**: The desired standstill distance between two vehicles. It has no variation. You can define the behavior upstream of static obstacles via the attribute **Standstill distance for static obstacles** (see "Editing the driving behavior parameter Following behavior" on page 295).
CC1	s	**Following distance**: Time distribution of speed-dependent part of desired safety distance. Shows number and name of time distribution Each time distribution may be empirical or normal. Each vehicle has an individual, random **safety** variable. Vissim uses this random variable as a fractile for the selected time distribution **CC1**. Based on the time distribution, the following distance for a vehicle is calculated. This is the distance in seconds which a driver wants to maintain at a certain speed. The higher the value, the more cautious the driver is. The safety distance is defined in the car following model as the minimum distance a driver will maintain while following another vehicle. In case of high volumes this distance becomes the value which has a determining influence on capacity.
CC2	m	**Longitudinal oscillation**: Restricts the distance difference a driver allows for before he intentionally moves closer to the car preceding him. If this value is set to e.g. 10 m, the following behavior results in distances between dx_{safe} and $dx_{safe} + 10m$. The default value is 4.0m which results in a quite stable following behavior.
CC3	s	**Perception threshold for following**: Defines the beginning of the deceleration process, i.e. the number of seconds before the safety distance is reached. At this stage the driver recognizes a preceding slower vehicle.
CC4	m/s	**Neg. speed difference**: Defines negative speed difference during the following process. Low values result in a more sensitive driver reaction to the acceleration or deceleration of the preceding vehicle.
CC5	m/s	**Pos. speed difference**: Defines positive speed difference during the following process. Enter a positive value for **CC5** which corresponds to the negative value of **CC4**. Low values result in a more sensitive driver reaction to the acceleration or deceleration of the preceding vehicle.
CC6	1/(m • s)	**Influence speed on oscillation**: Influence of distance on speed oscillation during the following process: ➤ Value 0: The speed oscillation is independent of the distance ➤ Larger values: Lead to a greater speed oscillation with increasing distance
CC7	m/s^2	**Oscillation acceleration**: Minimum value for absolute acceleration/deceleration used by a driver when following another vehicle.
CC8	m/s^2	**Acceleration starting from standstill**: Desired acceleration when starting from standstill (limited by maximum acceleration defined within acceleration curves).
CC9	m/s^2	**Acceleration at 80 km/h**: Desired acceleration at 80 km/h (limited by maximum acceleration defined within acceleration curves).

Source: PTV VISSIM manual, 2019

Figure 4. Table. Wiedemann 99 model parameters and definitions.

.

Wiedemann 99 Parameter: CC1

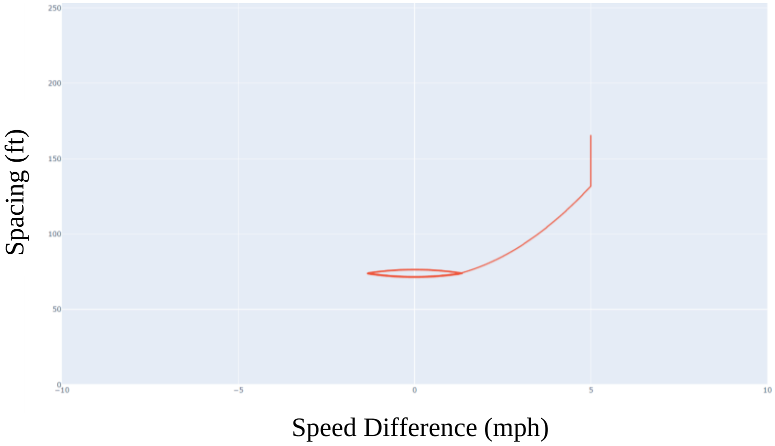
First examined was CC1, the gap time distribution, as this parameter is known to have the most significant impact on capacity, particularly at higher speeds (PTV AG 2022). CC1 directly influences the desired safety distance, which is the minimum distance a vehicle will seek to maintain behind its leading vehicle.

Car-following Behavior

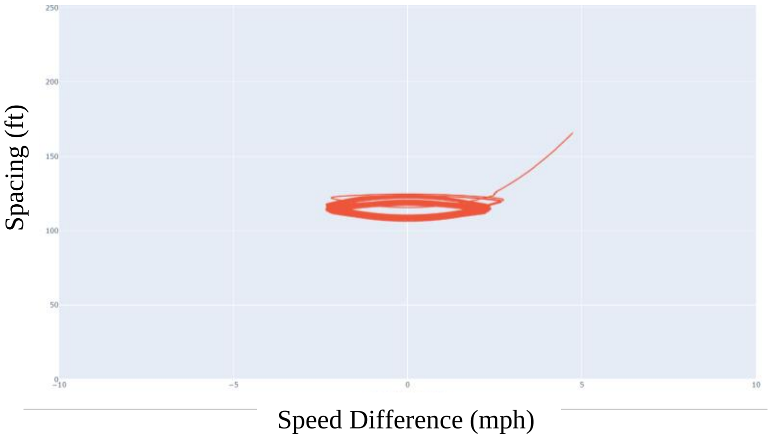
To explore the impact of the CC parameters on car-following behavior a simple single lane model was developed, where a vehicle with a 70-mph desired speed is followed by vehicles with a 75-mph desired speed, forcing car-following. Figure 5a, Figure 5b, and Figure 5c represent the (ΔX, ΔV) path for the 75-mph desired speed vehicle immediately following the 70-mph vehicle, under three different conditions. The vehicle modeled in Figure 5a has a CC1 of 0.5, Figure 5b has a CC1 of 0.9 (default), and Figure 5c has a CC1 of 1.5. All other parameters are set at the default values.

In the appendix it is seen that two trends are observed in Figure 5. First, is that with increasing CC1 the speed range of the following vehicle increases, i.e., the circulating plot is wider along the x-axis. Second, with increasing CC1, the values of ΔX increase, i.e., the median value on the y-axis increases. Consider, at CC1 values of 0.5, 0.9, and 1.5, the median ΔX values are approximately 74 ft, 112 ft, and 175ft and thus increasing CC1 has a dramatic effect on vehicle spacing within platoons.

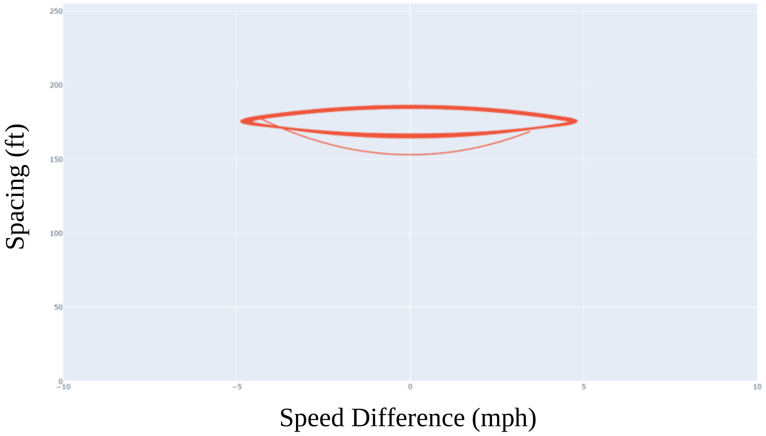
Next, additional vehicles in the platoon were considered. For example, in Figure 6, for the default VISSIM parameter set (i.e., CC1 = 0.9) the progression of vehicle car following behavior for the 2nd (immediate follower of the lead vehicle), 3rd, 4th, 5th, 6th, and 7th vehicles in the platoon is seen. While each subsequent vehicle has a similar median ΔX, the range of ΔX and ΔV values increases. This increasing variability in the platoon results in each added vehicle reducing the platoon density. This would indicate lower capacities than that implied by the more stable spacing of the 1st and 2nd vehicle in the platoon. While not included in this report, the appendix demonstrates similar trends with CC1 values of 0.5 and 1.5.



(a) Wiedemann 99 CC1 of 0.5, all other parameter default

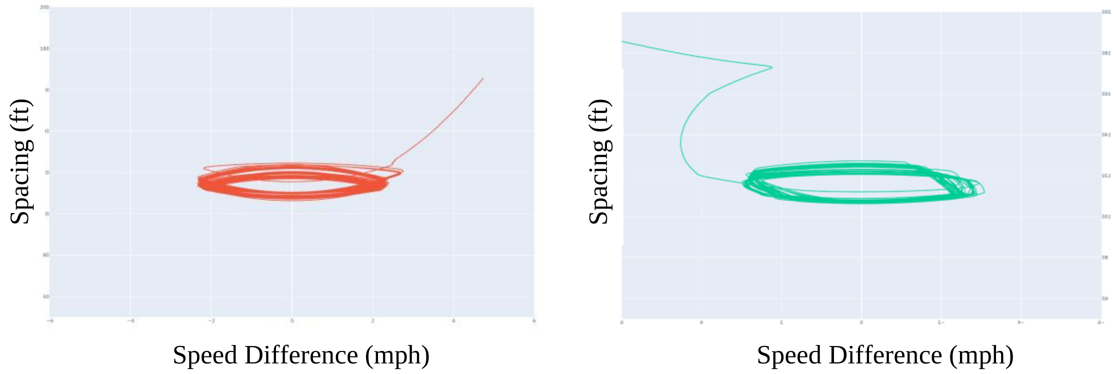


(b) Wiedemann 99 CC1 of 0.9 (default), all other parameter default

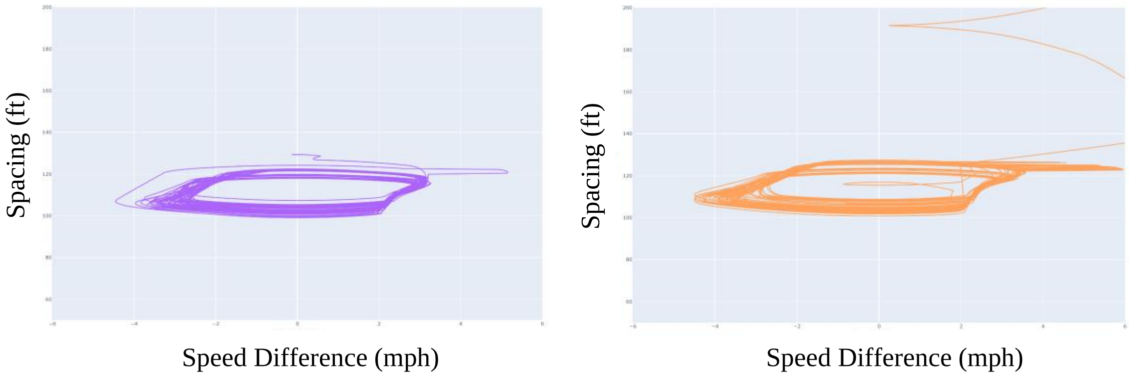


(c) Wiedemann 99 CC1 of 1.5, all other parameter default

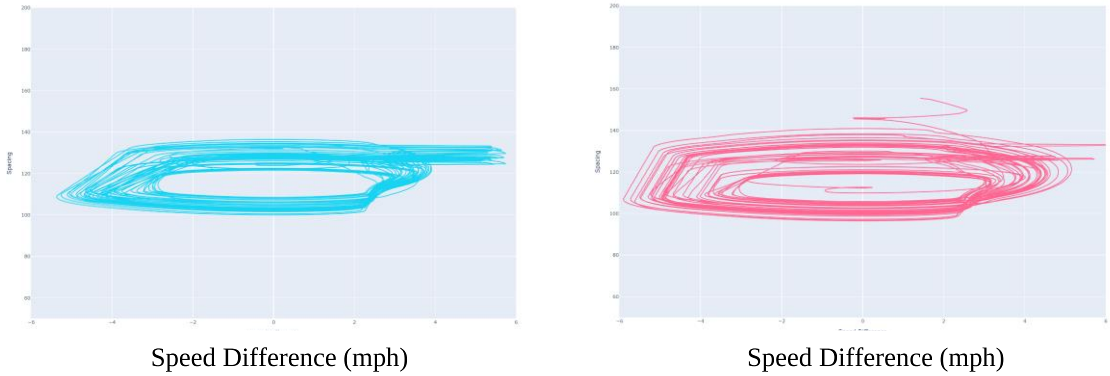
Figure 5. Graph. Influence of CC1 on lagging vehicle car following behavior.



(a) 2nd vehicle (b) 3rd vehicle



(c) 4th vehicle (d) 5th vehicle



(e) 6th vehicle (f) 7th vehicle

Figure 6. Graph. (ΔX, ΔV) behavior by vehicle platoon position for default VISSIM Wiedemann 99 parameters (i.e., CC1 = 0.9). ΔX and ΔV plot ranges of (-6.0, 6.0) and (50, 200), respectively.

From these observations it becomes apparent that determining the capacity associated with a given parameter set is not a simple question of applying the safety distance. The interaction effect among the vehicles when in a platoon reduces the platoon density, thereby reducing capacity. Additionally, the remaining CC parameters can influence this interaction between vehicles. Thus, parameter calibration cannot realistically be accomplished through application of the Wiedemann equations, rather an empirical study of reasonable CC parameters for the model under consideration is required.

Speed-Flow Performance

A primary method to accomplish such a calibration is using speed-flow diagrams. For the examples in the appendix, a four-lane section of a freeway simulation was utilized. Figure 7 displays speed flow data for CC1 values of 0.5 (green), 0.9 (blue), and 1.5 (pink), with all other CC parameters at default values and the desired speed set to a calibrated 80 mph distribution. Each point represents a one-minute interval.

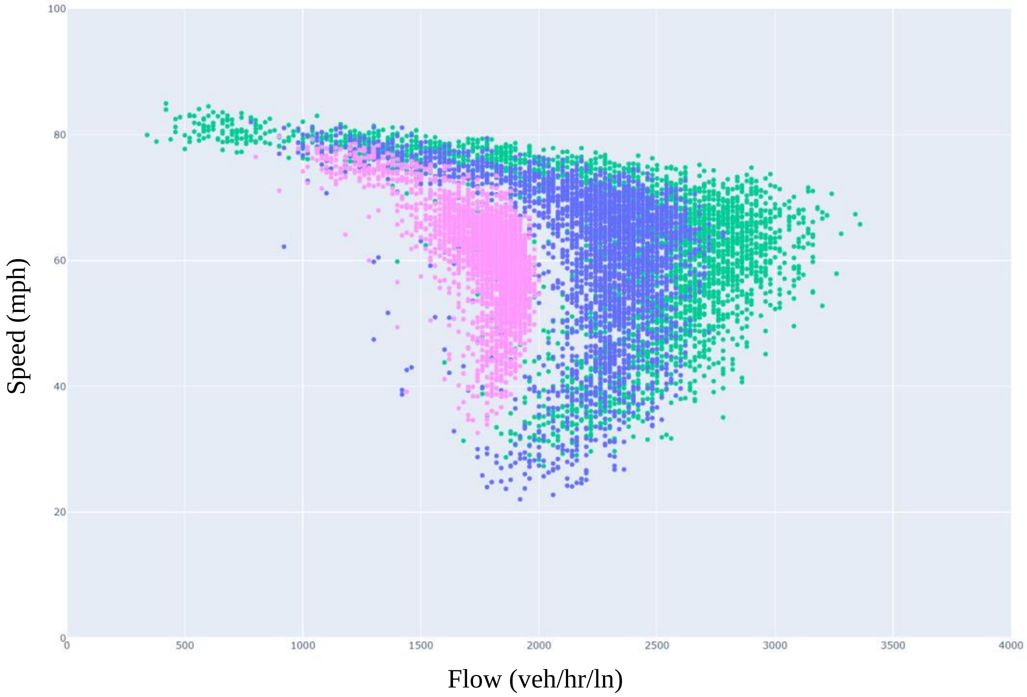


**Figure 7. Graph. Speed Flow Diagram,
Green CC1 = 0.5, Blue CC1 = 0.9, Pink CC1 = 1.5.**

The speed flow diagrams match those expected from typical car-following behavior. It is seen that the CC1 of 0.5 has the highest flow values, followed by the CC1 of 0.9, and CC1 of 1.5. It is also seen that a linear increase in CC1 does not result in a linear increase in flow (i.e., doubling CC1 does not double the maximum flows processed.) Additionally, if all vehicles were in car following and spacing was determined based on the desired speed equation, higher flows would be expected at capacity. However, there are a number of factors that contribute to capacities lower than might be expected based on the desired speed equation, such as platoons becoming less dense as additional vehicles are added, interactions with the other CC1 parameters, etc.

In addition, a significant issue exists that at first may appear non-intuitive. While it would be understandable to expect that most vehicles are in car following when traffic flows reach high values (i.e., approach capacity, lowest vehicle-to-vehicle spacing), in the Action-Point approach of VISSIM™ this is not a correct interpretation. Car following is limited to vehicles with spacings near the safe-following distance, which is a function of CC0, CC1, and CC2. However, when considering the fluctuation of traffic within platoons and the discretionary lane changing occurring as vehicles change lanes in an attempt to achieve their desired speed, many vehicles are not in car-following, but rather free, approaching, or braking, even during the most congested flow periods. For example, Figure 8 shows the percentage of vehicles considered in car following in the Action Point car following model for the freeway scenario with all parameters set at default (i.e., the blue data in Figure 7). Capacity conditions occur at approximately the midpoint along the x-axis. It is seen the under heavy traffic approximately 8 percent to 13 percent of vehicles are categorized as being in car following mode. Thus, while the Wiedemann parameters provide a strong influence over the traffic flow behavior, the underlying action point model form creates significant interaction between states, even in high volume situations where a modeler might expect most vehicles to be in car following. Again, it is seen that calibration is inherently an empirical process.

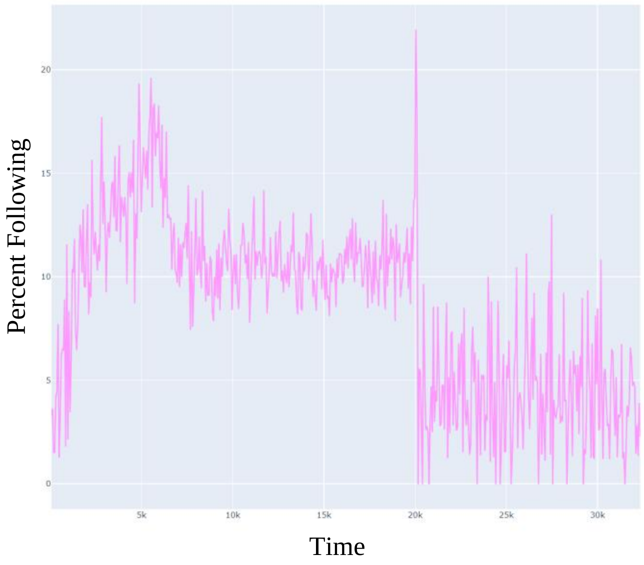


Figure 8. Graph. Percentage of vehicles in car following at simulation times.

Wiedemann 99 Parameter: CC2, CC4, and CC5.

In a similar manner to CC1, parameters CC2 - *following distance oscillation*, CC4 *negative speed difference*, and CC5 - *positive speed difference*, respectively, were explored.

As with the CC1 it is seen that increasing ΔX, ΔV variability is introduced with increasing position in a platoon, for all CC2 cases. Thus, again, platoon density decreases as platoon length increases. This increasing variability mutes the impact of increasing CC2, with similar (ΔX, ΔV) behaviors seen among the CC2 values. Figure 9 is the speed flow diagram for the same four lane section of roadway in the CC1 discussion. In this figure, Pink, Blue, and Green are the CC2 values of 6.56, 13.12, and 19.68. As seen, the impact on the speed flow behavior, in terms of capacity, is much more muted than that seen in CC1. Also observed was a significant interaction effect between CC1 and CC2 and lower CC1 values.

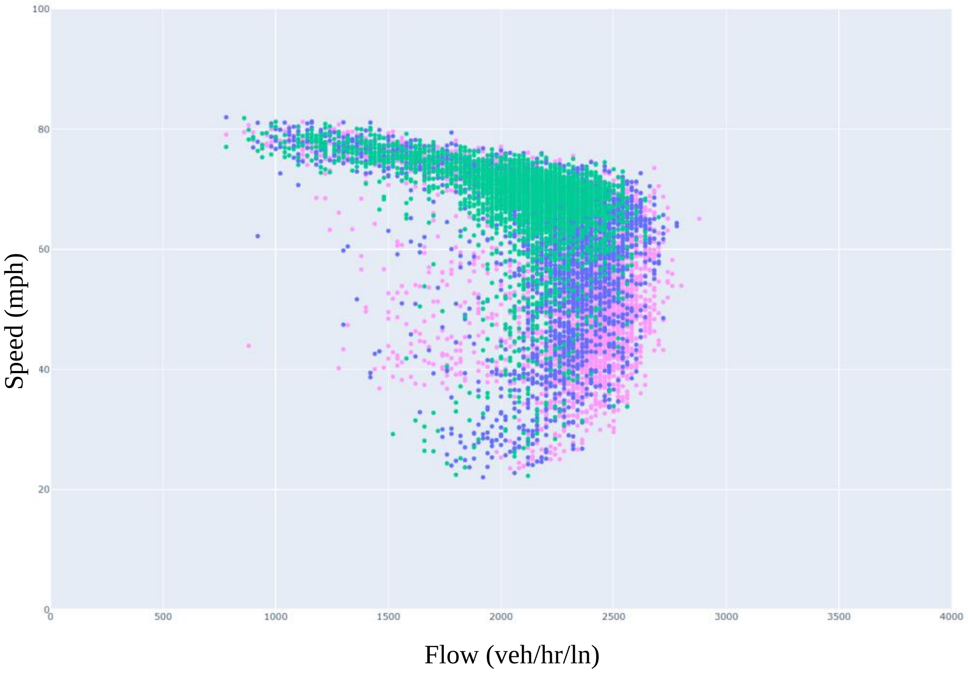


Figure 9. Graph. Speed flow diagram, four lane section of roadway with lane departure. CC1 of 0.9 (default), all other parameters except CC2 at default values. Pink, Red, and Blue are the CC2 values of 6.56, 13.12, and 19.68.

Regarding CC4 and CC5, according to the VISSIM™ manual higher absolute values result in “a more sensitive driver reaction to the acceleration or deceleration of the preceding vehicle.” In this analysis two levels of (CC4, CC5) were considered, (-0.35, 0.35) which is the default, and (-1.05, 1.05). CC4 and CC5 are held at the same value based on the recommendation in the literature and in common practice. In the action point model the effect of the CC4 and CC5 model is to increase the width for the conscious following zone, that is, increase the range of following speed of the lagging vehicle. Also, as the platoon size increases the range in speeds of the following vehicle increases. Similar to CC1 and CC2, this results in lower density platoons as the platoon size increases.

When all values are at default, i.e., CC1 is 0.9 and CC2 is 13.12, the impact of CC4 and CC5 is minimal, resulting in a potentially slight shift to lower flows with higher CC4 and CC5 values. This trend remains true for higher CC1 values as well as the range of CC2 values tested for the CC1 of 0.9 and 1.5. However, at lower CC1 values, an interaction with CC1 is witnessed, with significantly lower capacity as CC4 and CC5 increase. This trend holds for the CC2 levels tested (i.e., CC2 of 6.56, and 19.68) at CC1 of 0.5.

SUMMARY

In summary, several key features have arisen as part of this exploration. First, calibration is an empirical exercise. With the given interactions between CC levels and the application of the Action Point model, it is not realistic to directly calculate CC values. Additionally, the Action Point model does not result in a high percentage of vehicles in car following (as defined by the desired safety distance), even under congested conditions. This implies that the acceleration value determination for a given vehicle across all four Action Point zones significantly influences individual vehicle behavior as well as overall link speed, flow, and density. As the length of platoon formation increases, the density of the platoons tends to decrease. Finally, near the default values the interactions tend to be less, as CC parameters diverge from the defaults increasing interactions may be seen, requiring additional testing and significant caution by the modeler.

CHAPTER 4. CALIBRATION METHOD GUIDANCE

The following provides suggested steps for inclusion in a VISSIM™ model calibration. The intent of these steps is to not to be overly prescriptive. It is recognized that calibration must be reflective of the model intent, objectives, components, size, etc. Each modeling effort is unique, and calibration should account for these unique aspects. The calibration focuses on the car following model parameters (Wiedemann 74 and Wiedemann 99), as well as the desired speed distribution. It is assumed that the given model has undergone a thorough verification check.

GENERAL APPROACH

Key concepts for the suggested calibration steps presented in the appendix include:

- Car following calibration is performed at the link level.
- Evaluation metrics include speed-flow diagrams and headway distribution rather than travel time and delay, as commonly found in the literature.
- Calibrated parameter sets for critical or typical links may be applied to links throughout the model.
- Setting of the desired speed distribution.
- The method seeks to limit deviations from defaults parameters, focusing calibration on CC1 and CC2 in most cases.
- The approach is flexible, leveraging expert judgement of model developer and design team.
- Calibration is an iterative process:

  - Check field conditions against selected default values
  - Calibrate Desired Speed
  - Calibrate CC1
  - Calibrate CC2 (as necessary)

Except in limited circumstances addition CC parameter calibration should not be needed.

Link based calibration

While the entire network is calibrated, in the context of the car-following, calibration occurs at the point or link level. That is, within VISSIM™ the Wiedemann parameters are assigned according to a given link and may change from link to link. Thus, it is suggested to focus calibration efforts on critical or typical links, with the determined parameter sets applied to other similar links throughout the network.

Evaluation metrics

In Module 7 and numerous other documents, the common convention is to utilize travel time (e.g., 85% of links within some range of the field travel), delay, queue length, or other metrics. However, for this calibration, these metrics are considered part of the verification and validation steps. Such metrics are not used for the car following model calibration, except for final model validation after calibration. Rather, link or point measures, such as speed-flow diagrams and headway distributions, are used.

Application of critical or typical link car following parameter sets.

A key question is which links should be selected for development of car following parameter sets. First, the general objective is to have as few calibrated car following parameter sets as possible, while still providing reasonable model performance. It may be expected, with some caveats to be discussed, that within a given geographic region or area that a driver has similar car-following characteristics, when traveling on similar facilities. Additionally, within a region, similar facilities will encounter similar driving populations. For example, within Atlanta, drivers on I-85 are similar to those driving on I-75. Thus, it should hold that the same car following parameter set can be used across similar links in a network.

However, it is recognized that situations will arise where additional parameter sets may be needed. For example, when considering geometry, sharper curvatures can influence car following and speed behavior. Thus, it may be necessary to develop unique parameters sets where the geometry has a significant influence on driver behavior. Similarly, when studying barrier separated HOT facilities or work zones, the barrier separated lane (or narrowed work zone lanes) may have different car following characteristics than the general-purpose lanes. Operations during inclement weather, nighttime, etc. may justify individualized parameter sets, should these conditions be included in the project objectives.

The appendix provides detailed discussion and examples for selection of the critical or typical link.

Demand volume considerations

For the Wiedemann 99 calibration this procedure recommends considering at least two scenarios as part of a full calibration process. The first is the time period under consideration. For instance, during the PM peak with the field measured traffic demands. For this scenario field data is used for the existing time period of interest and the simulation is developed for the equivalent time period (accounting for warm-up time, etc., as discussed in Module 7).

The second scenario of the model is to ensure that a range of demands are captured, from low flow to demand exceeding capacity. This scenario is used to ensure the overall speed-flow relationship is reasonable. For the field, this data is ideally obtained for the location of interest over an extended period, ideally on the order of multiple days or months. It is important that these data capture a range of flow from stable flow through capacity conditions. Where such data are not available, the simulation team may seek data for a site with expected similar performance or find other means to estimate a reasonable speed flow diagram.

To obtain the data for a similar speed-flow diagram in VISSIM™, scenario demands may be placed similar to those seen in Figure 10. The volume (i.e., demand) is increased from a low value until the demand exceeds capacity, then the demand is dropped to the original low value.

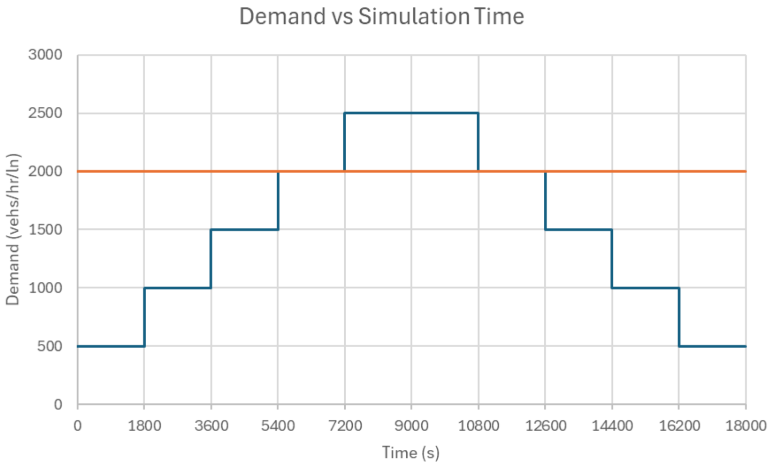


Figure 10. Graph. Demand vs Simulation Time for Car Following Model Calibration.

EXAMPLE CALIBRATION STEPS: WIEDEMANN 99

The calibration steps discussed are intended to be straightforward, without relying on any "black box" algorithms. The steps are to: 1) Check the results of the default parameter set versus the field observation, 2) Calibrate the Desired Speed distribution, 3) Calibrate CC1 parameter for platoon headways, 4) Calibrate the CC parameters to replicate expected field speed-flow diagram, 5) Verify the desired speed calibration, and 6) Validation. In most circumstances additional CC parameter calibration should not be necessary.

For the Wiedemann 99 example within the appendix, the initial data source was two hours of video recording during the afternoon peak for I-85 S before Buffington Rd at Mile Marker 67.6, with flow levels generally ranging between 1400 and 1800 veh/h/ln. This freeway segment has 4 lanes in the direction of travel considered, and a posted speed limit of 65 miles-per-hour. From these trajectory data individual vehicle headways and speed distributions were obtained for a screen line across the roadway. Additionally, speed flow data in 1-, 5-, 15-, and 30-minute bins were processed for the same screen line. The second data set used here was speed - flow data from the GDOT VDS system over a several month period. These data were obtained as 30-second bins and thus individual vehicle speeds and headways were not available from these data.

Step 1: Default Parameters and Desired Speed Distribution

Prior to any calibration, it is first necessary to determine how well the verified model with default parameters reflects the field observations. As stated, it is recommended to consider the speed-flow relationship, headways distribution, and speed distribution. Data collection points will need to be placed at the appropriate location in your model to collect the model results. Guidance on how to set up data collection points may be found in Module 6. It was seen in the appendix that the simulation run with default parameters did not match the field observations within acceptable limits.

Step 2: Desired Speed Distribution Calibration

The second step is the calibration of the desired speed distribution. The following procedure is recommended:

1. Take a reasonable sample of field data (e.g., 1 hour), at a medium/high flow rate (1500-1800 veh/h/ln), if available. Speed data should also be representative of speed occurrence. Data should also be held in reserve for validation. Generally, at least 20% of the data.

2. Fit a CDF distribution to the measured field speeds entered in PTV-VISSIM™ (see Figure 11). As discussed, while traffic is heavy it should not be in breakdown, with most measured speeds under stable conditions (i.e., the top half of the speed-flow diagram).

3. Run the simulation with the field volumes, vehicle compositions and desired speed distribution from step 2.

4. Conduct ten or more replicate runs of the model.

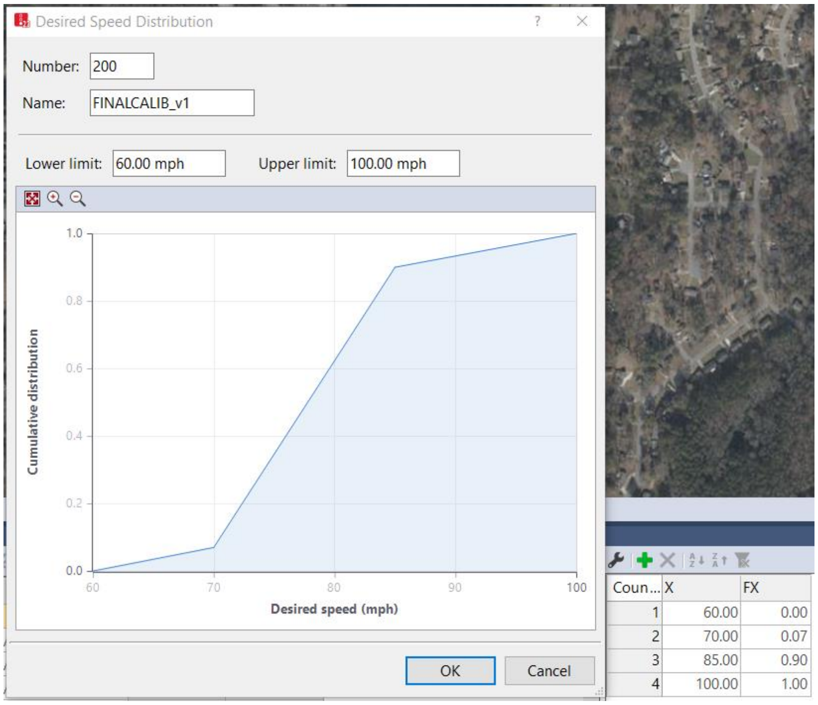
5. Shift the desired speed by some small percentage, keeping the minimum speed fixed to the observed low value.

6. Iterate Step 5 until the simulated speeds sufficiently match the field observations.

The resulting simulated speeds (plotted alongside the field-collected and the desired speed distributions) after Step 4 can be seen in Figure 12. The simulated data is labeled “0.9, 13.12”, which are the default CC1 and CC2 parameters. It is seen that when the entered desired speed distribution matches the field, the simulation results in speeds lower than the field measured. Why? This is due to a significant subset of vehicles likely in car-following (or other Action Point model states) and thus unable to travel at their desired speed.

However, the objective of setting the desired speed distribution is that when the model is run the simulated speeds match the field observations. Thus, slightly shift the desired speed distribution and rerun the model. Iteratively continue slight shifts until a sufficient match is accomplished, for example as seen in Figure 13.

In summary, the process is to start with a desired speed distribution based on the measured field data. Then iteratively adjust the desired speed distribution until the simulated speeds match the field. A reasonable question is why not measure the desired speed distribution when the traffic volume is very low and most vehicles would be traveling at their “desired speed”. The underlying reason for not doing this is that the desired speed has significant interaction with the car following CC parameters and the PTV VISSIM™ Action Point model. In addition, in the field, drivers do not necessarily have a fixed desired speed, with the speed selected (i.e., “desired”) changing with conditions. Thus, it is recommended to set the desired speed distribution such the simulated speeds reflect actual field conditions for demands approaching, but prior to reaching capacity and breakdown.



Number: 200

Name: FINALCALIB_v1

Lower limit: 60.00 mph

Upper limit: 100.00 mph

Coun...	X	FX
1	60.00	0.00
2	70.00	0.07
3	85.00	0.90
4	100.00	1.00

Figure 11. Image. Version 1 of calibrated desired speed distribution.

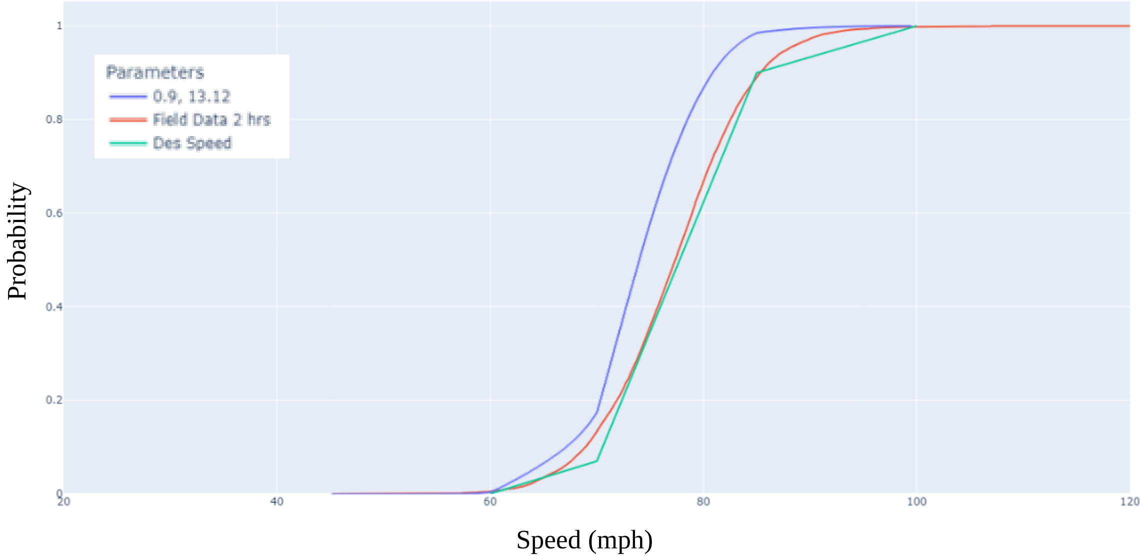


Figure 12. Graph. Plot of the speed distribution
(simulated in blue, field-collected in red, desired in green).

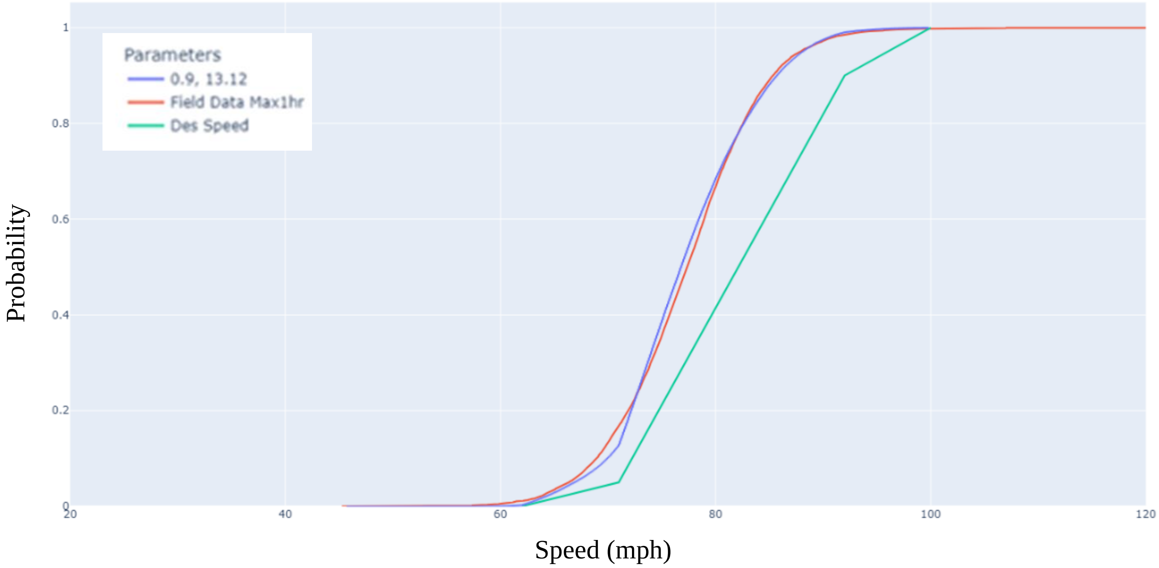
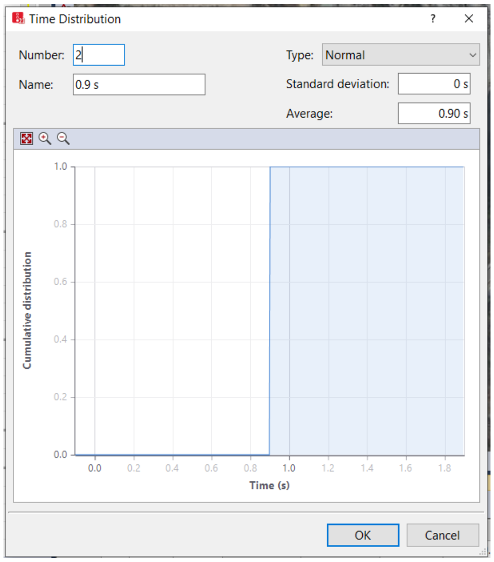


Figure 13. Graph. Final iteration of desired speed distribution calibration.

Step 3: CC1 Parameter Editing for Platoon Calibration

The next step in the process, after desired speed distribution calibration, is the calibration of the car following model parameters. Overall, the parameter whose adjustment was shown to be most impactful and relevant to both individual-vehicle and overall flow behavior was CC1 (Gap Time Distribution), whose default settings are shown in Figure 14. VISSIM's default Gap Time Distribution is a normal distribution $(\mu = 0.9; \sigma = 0)$, which means all vehicle have the same CC1, i.e., 0.9. However, for calibration purposes it is recommended to define an empirical distribution in the "Time Distribution" pane and assign it to the Driving Behavior used in the model. This allows for more control and flexibility during the calibration process.



Time Distribution

Number: 2

Name: 0.9 s

Type: Normal

Standard deviation: 0 s

Average: 0.90 s

Figure 14. Image. CC1 (Gap Time Distribution) default distribution.
$(\boldsymbol{\mu} = \mathbf{0.9}; \boldsymbol{\sigma} = \mathbf{0})$.

At a microscopic level, the constant value of CC1 is the main driver of the difference in platooning behavior observed in Figure 14. At a macroscopic level, CC1 was found to have a clear effect on capacity and breakdown behavior. As seen in Figure 15, from a probability of approximately 0.05 to 0.3, the spacing is on the order of 1 second. This is slightly higher than the CC1 value of 0.9, due to CC0 and CC2. This implies that for this demand, approximately 25% of the vehicles are in car-following (platooned) as defined in the Action Point model (Figure 3). These vehicles are following their respective lead vehicles at their desired safety distance.

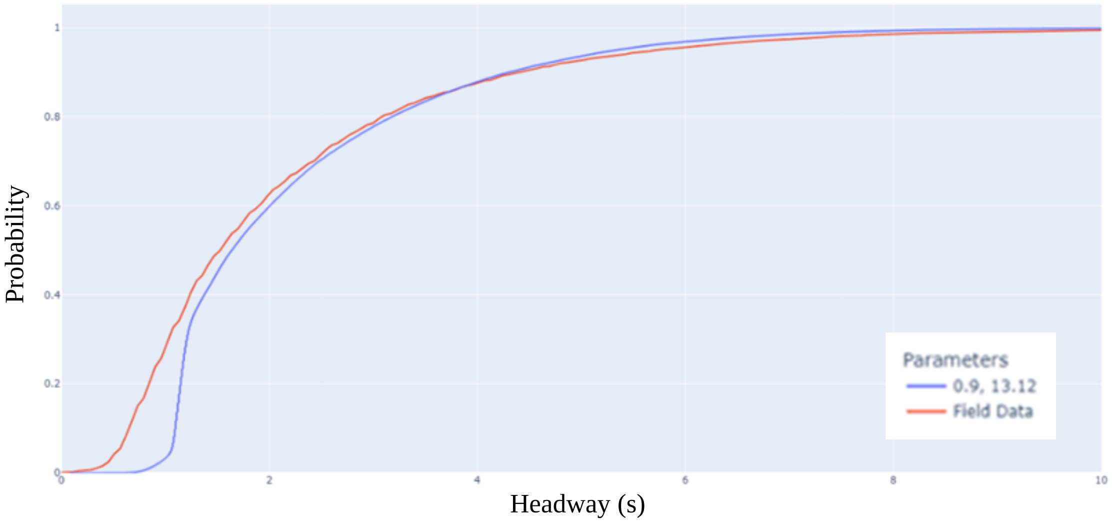
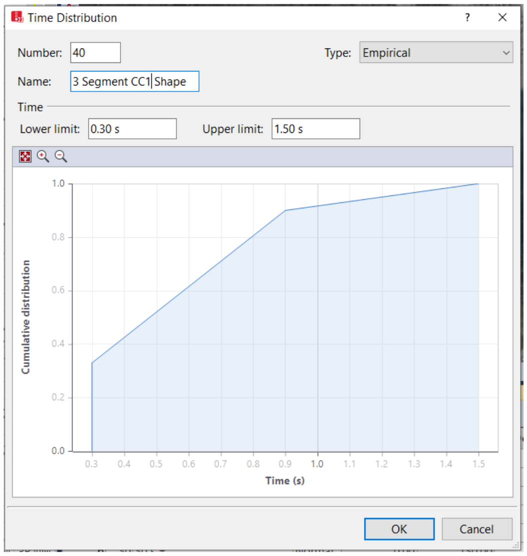


Figure 15. Graph. Headway CDF after Desired Speed Distribution calibration.

The vehicles with spacing under one second covers a range of conditions, such as vehicles temporarily violating the desired safety distance or in lane changing, or an error in the automated video data collection (for example, a vehicle pulling a trailer being identified as two vehicles with a less than 0.1 second headway). However, most of the measured lower field headways were correct. A detailed visual review of hundreds of the field data measurements was performed, using the skip lines for distance approximation. Vehicles were observed with 0.3 second and higher spacing. A majority of the field measured headways under one second appear to be correct. However, other vehicles do clearly maintain higher headways. Thus, it was deemed that rather than a fixed CC1 value, a distribution of values should be used.

Within the “Time Distributions” pane, a new Time Distribution can be created and assigned either a Normal or an Empirical distribution, Figure 16. Based on the field observations conducted, a subset of highly aggressive drivers (i.e., drivers willing to follow preceding vehicles at time headways of around 0.5 seconds) were observed. To better match these very low headways observed in the field, the shape of the CC1 distribution should be edited accordingly, by introducing a percentage of drivers with a very low CC1 values.



Number: 40

Type: Empirical

Name: 3 Segment CC1 Shape

Lower limit: 0.30 s

Upper limit: 1.50 s

Figure 16. Image. CC1 editing example.

The recommended CC1 calibration involves iterative parameter editing, model running, and plotting of headway distributions to achieve a good fit at the low end of the headway CDF, as shown in Figure 17. For the freeway field data in this example the lowest CC1 value was set at 0.3 seconds at 33%, 0.9 seconds at 90% and 1.5 seconds at 100%. The main objective in this phase of the calibration is to match the shape of the curve at the "bottom" of the CDF, seeking to better capture the observed platooning behavior, while still maintaining a distribution of longer headways.

The calibration of platooning behavior achieved in this step can be verified at a microscopic level using the proposed comparison to the headway distribution. When traffic flow conditions are below capacity, only a small portion of vehicles are in car following and subject to the calibration of CC parameters, thus the focus in this step on the lower portion of the Headway CDF (headways under approximately 1.5 seconds). Higher headway values are associated with vehicles which are not in car following.

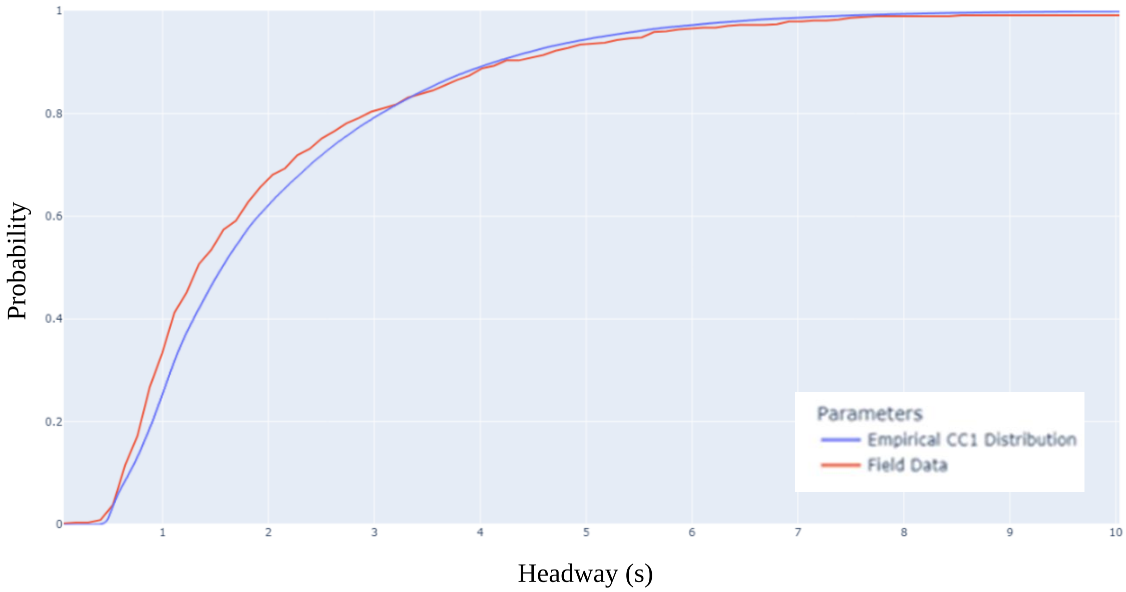
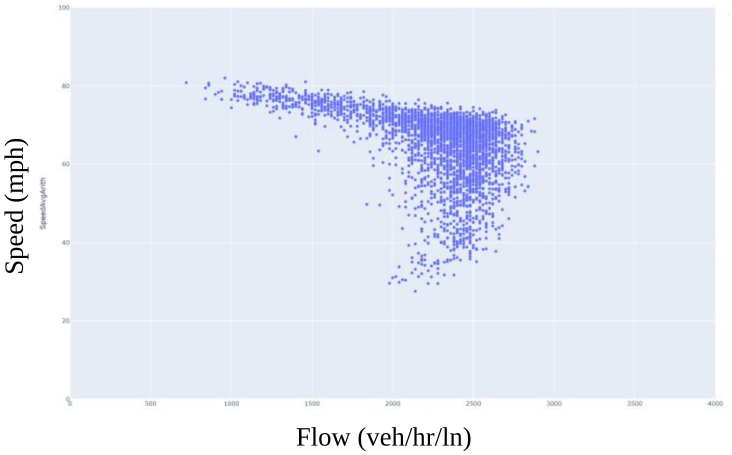


Figure 17. Graph. Headway CDF for field data (red) and simulated data with calibrated CC1 empirical distribution (blue).

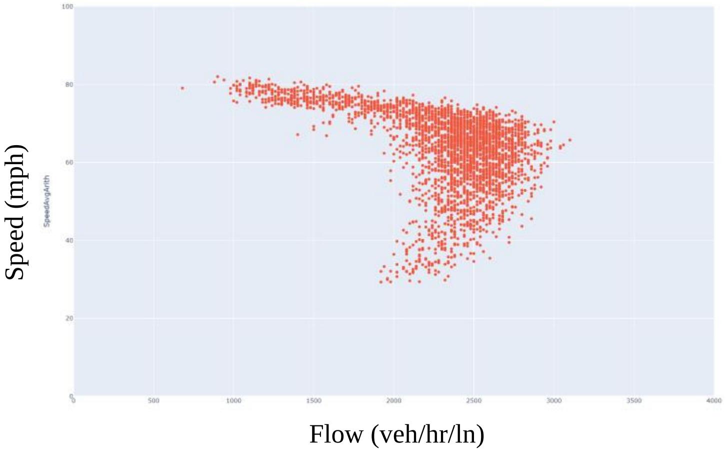
It is readily recognized that the sample calibration demonstrated is for an urban area (Atlanta) with what may be termed “aggressive” driving behaviors. Similar low headways may not be seen in other areas. This calibration should be completed for each area, reflecting the local driving population.

Step 4: Speed – Flow Diagram Calibration

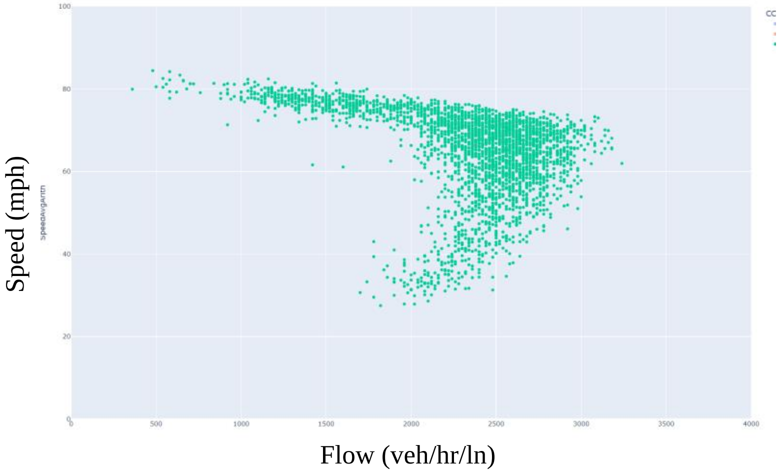
In this step of the calibration, the focus is shifted to a more macroscopic perspective, for the given link. Though the parameter editing still affects vehicle-to-vehicle behavior, the effects of these changes are measured (and calibration is performed) at a macroscopic level, which involves a higher degree of data aggregation. Binning speed (averaged across each bin) and flow values (to obtain flow rates) into 1- or 5-minute intervals yields speed – flow diagrams such as that shown in Figure 18. These point clouds are based on the modified CC1 parameter with the calibrated desired speed. For this experiment, all CC1 distributions have a lowest value of 0.3 and a highest value of 1.9. The selection of the minimum value endpoint is based on matching the lower values headways distribution as described previously and the higher value is based on a reasonable maximum for car following. The midpoint values are set at 0.5, 0.7, or 0.9. As the midpoint value increases the percentage of lower CC1 values increases and the capacity should increase (i.e., the maximum observed points in the speed flow diagram shift to the higher flow values.). As seen in Figure 18, these minor adjustments in the midpoint of the distribution allow slight shifting of the speed flow diagram, from lower to higher values. For more significant shifts in the speed flow diagram the end points would also need to be adjusted. However, if desired speed distribution and headway distribution in the prior steps have been reasonably matched, significant edits to the CC1 distribution should not be required. Additionally, as seen earlier, smaller shifts in the speed flow diagram may be achieved by editing CC2. However, it is recommended to first finalize CC1, then move on to CC2 edits, only if necessary.



(a) CC1 Dist: 0.4 seconds @ .33%, 0.9 seconds @ 50%, 1.5 seconds @ 100%



(b) CC1 Dist: 0.4 seconds @ .33%, 0.9 seconds @ 50%, 1.5 seconds @ 100%



(c) CC1 Dist: 0.4 seconds @ .33%, 0.9 seconds @ 50%, 1.5 seconds @ 100%

Figure 18. Graph. Speed flow distribution, with adjusted desired speed distribution, for three CC1 distributions.

Step 5: Check Desired Speed Distribution

Once the CC parameters have been calibrated, modelers should check the effects that the parameter calibration has had on the accuracy of the desired speed distribution. After an extensive CC calibration process, the desired speed distribution may need adjusted to generate simulated speeds that match field data. Generally, if changes to the CC parameters are minimal (in number and magnitude) then no significant changes in the simulated speed distribution should be observed, but this step should always be performed to check.

Step 6: Calibration Validation

After the calibration process is complete, the calibration model should be validated using the field collected data set aside early in the process. It is important that the data (speeds, headways, flow rates) reserved for validation be collected in the same manner (and with the same precision) as the data used during calibration. The calibrated model should thus be run using the characteristics (traffic volumes, vehicle compositions, etc.) as the validation dataset and simulated results should lie within the acceptability criteria.

EXAMPLE CALIBRATION STEPS: WIEDEMANN 74

Thus far this calibration document has focused on the calibration of the Wiedemann 99 model. With the nine CC parameters Wiedemann 99 is a more complex calibration compared to Wiedemann 74, which has three parameters. The complete Wiedemann 74 safety distance model, as reported in the VISSIM™ manual, is as follows:

$$d = ax + (bx_{Add} + bx_{Mult} \cdot z) \cdot \sqrt{v}$$

Where:

ax: is the speed independent parameter, representing the distance between vehicles while stopped.

bxAdd: is the additive part of the safety distance.

bxMult: is the multiplicative part of the safety distance.

The calibration follows the same general guidance as the Wiedemann 99 calibration.

1) Checking default setting against existing conditions
2) Calibrating desired speed distribution
3) Calibrating car following parameters, ax, bxAdd, and bxMult.

As with the Wiedemann 99 model, the calibration is link based. However, recalling that Wiedemann 74 is generally used for interrupted flow facilities (e.g., arterials, intersections, etc.) simplifies the task of identifying the calibration location in the model. For the intersections the critical component relative to the car following parameters is the distribution of departure headways from the stop. Desired speeds may be calibrated at a mid-block location. The steps are described below, the appendix includes examples.

Step 1 – Default Parameters and Desired Speed Distribution

The first step is to check how well the model with default calibration reflects speeds and stop bar departure headways. This can be done by running the model for at least one hour (plus network loading time, see Module 7), for a total of 10 replicate runs. Results can then be aggregated and averaged across all 10 hours. (Should the model not be reaching a steady state during the network loading time see discussion in Module 7.)

Step 2: Desired Speed Distribution Calibration

This component of the calibration is to calibrate desired speed distribution. The procedure is similar to that for the Wiedemann 99 model and is summarized here (see the Wiedemann 99 discussion for an example execution of the method):

1. Take a reasonable sample of field data (e.g., 1 hour), holding 20% of the sample for validation.
2. Fit a CDF distribution to the measured field speeds.
3. Run the simulation with the field volumes, vehicle compositions and desired speed distribution from step 2.
4. Conduct 10 replicate runs of the model.
5. Shift the desired speed by some small percentage, keeping the minimum speed fixed to the observed low value.
6. Iterate Steps 4 & 5 until the simulated speeds sufficiently match the field observations.

Step 3: Wiedemann 74 ax parameter calibration

The next step in the process, after desired speed distribution calibration, is the calibration of the car following model parameters. Extensive testing was conducted to evaluate and understand the effects of changes to the speed dependent and speed independent components of the Wiedemann 74 car following model on the headway distribution at the stop bar. As a result of this analysis, a few key results were found:

- All three model parameters (ax, bxAdd, and bxMult) have a clear, measurable, and consistent effect on the headway distribution of vehicles in queue at the stop bar.
- The value of ax (the speed independent parameter) influences the width (Interquartile Range, or IQR) of the headway distribution.
- The value of bxAdd and bxMult (the speed dependent components) influence the headway value of the median of the headway distribution.

After having compared the field-collected headway distribution with the uncalibrated model, modelers should edit the ax parameter following this rule:

- An increase in ax value leads to an increase in the IQR of the headway distribution, coupled with a slight increase in the median.
- A decrease in ax value leads to a decrease in the IQR of the headway distribution, coupled with a slight decrease in the median.

Step 4: Wiedemann 74 bx parameter calibration

After having calibrated ax, modelers should turn their focus on bxAdd and bxMult. The two terms serve to increase headway as speed increases, with headway increasing with the square root of speed. The bxAdd term's contribution to headway is consistent across vehicles, while the introduction of the *z* term with bxMult introduces variability in headways maintained by different vehicles at the same speed. Most recommendations in the literature recommend calibration of bxAdd and bxMult together, typically fixing bxAdd = bxMult +1. While there is not a strict theoretical justification for fixing this relationship the presented calibration method in this document maintains this relationship for simplicity in calibration.

Step 5: Check Desired Speed Distribution

Once the Wiedemann 74 parameters have been calibrated, the modeler should check the effects that the parameter calibration has had on the accuracy of the desired speed distribution, as in the Wiedemann 99 calibration. Generally, if changes to ax and bx parameters are minimal (in number and magnitude) then no significant changes in the simulated speed distribution should be observed, but this step should always be performed as a check.

Step 6: Model Validation

After the calibration process is complete, the model should be validated using field collected data. It is important that the data (speeds, headways, flow rates) that was stored for validation be collected in the same manner (and with the same precision) as the data used during calibration. The calibrated model should thus be run using the characteristics (traffic volumes, vehicle compositions, etc.) as the validation dataset and simulated results should lie within the acceptability criteria.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

Nearly all modeling efforts include three distinct, but related, processes: verification, validation, and calibration. This project focuses on calibration, the adjustment of the underlying model parameters of a verified model to achieve a valid model.

Underlying most VISSIM™ calibration is the adjustment of the Wiedemann car following parameters used to simulate vehicle behavior within the model. VISSIM™ utilizes an Action Point model (Wiedemann 74 and Wiedemann 99) to approximate actual car-following behavior. The Wiedemann models categorize the car-following behavior of a vehicle into different states: free driving, approaching, following, and braking (PTV AG, 2019). In practice, Wiedemann 74 is typically applied to signalized and low speed corridors, while Wiedemann 99 is utilized for freeways. The Wiedemann models directly influence a roadway segment's capacity, saturation flow, density, etc. Thus, it may be necessary to calibrate the model parameters to reflect field conditions.

Several key features were identified as part of this study. First, calibration is an empirical exercise. With the given interactions between CC levels and the application of the Action Point model, it is not realistic to directly calculate CC values. Additionally, as seen, the Action Point model does not result in a high percentage of vehicles in car following (as defined by the desired safety distance), even under congested conditions. This implies that the acceleration value determination for a given vehicle across all four Action Point zones significantly influences individual vehicle behavior as well as overall link speed, flow, and density. As the length of platoon formation increases, the density of the platoons tends to decrease. Finally, near the default values the interactions tend to be less, as CC parameters diverge from the defaults increasing interactions may be seen, requiring additional testing and caution by the modeler.

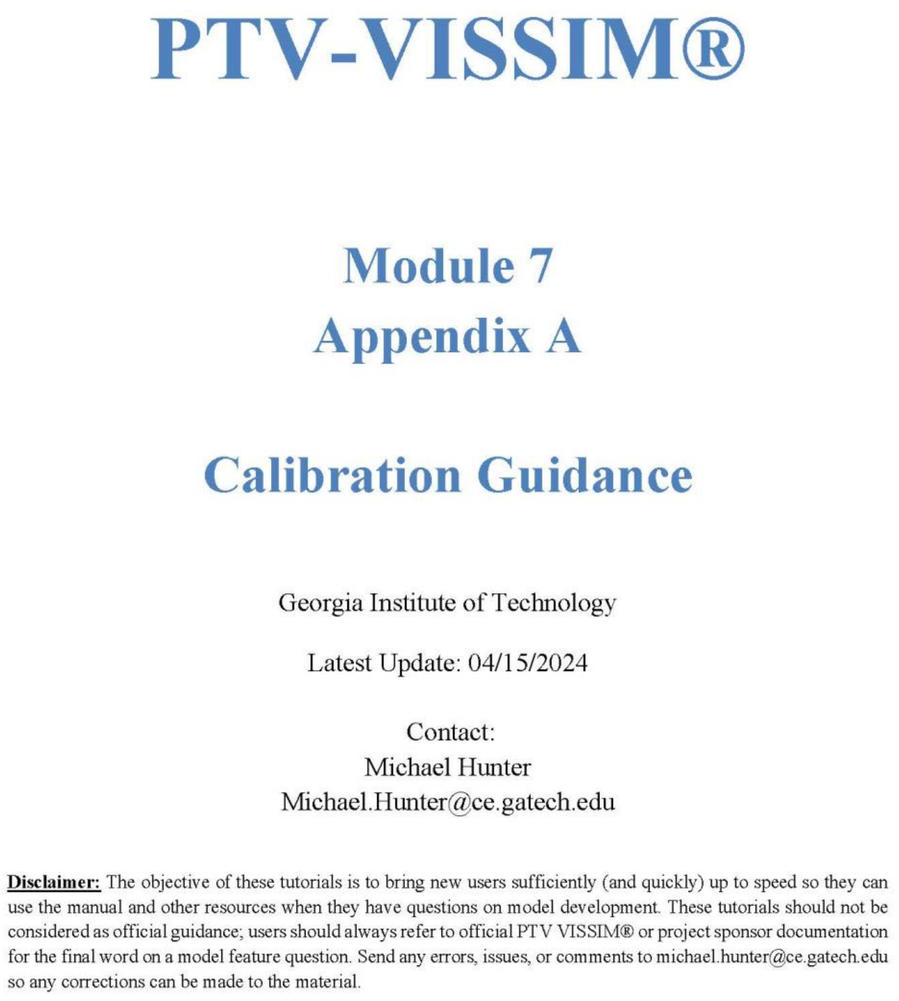
Through the project a preferred calibration approach has been developed that seeks the fewest parameter adjustments, by the smallest increments, that provides a reasonable reflection of field conditions. The developed method focuses on desired speed distribution and several key parameters of both Wiedemann 99 and Wiedemann 74 models. Key concepts for the suggested calibration steps presented in the appendix include:

- Car following calibration is performed at the link level.
- Evaluation metrics include speed-flow diagrams and headway distribution.
- Calibrated parameter sets for critical or typical links may be applied to links throughout the model.
- Calibration includes setting of the desired speed distribution.
- The method seeks to limit deviations from default parameters, focusing calibration on CC1 and CC2 in most cases for Wiedemann 99; and ax and bxAdd = bxMult +1 for Wiedemann 74.
- The approach is flexible, leveraging expert judgement of model developer and design team.

The final calibration is an iterative process including: 1) checking field conditions against selected default values; 2) calibrating desired speed; 3) calibrating key Wiedemann parameters; and 4) validation. Through this focused approach the method reduces the likelihood of unrealistic parameter interaction effects and allows the simulation modeler to understand the potential impact of any calibration adjustments. While the proposed method may be applied to additional car following parameters the discussed select parameters and calibration approach should be sufficient for most modeling efforts.

APPENDIX A. CALIBRATION GUIDANCE

The following images provide a copy of Module 7, Appendix A, Calibration Guidance.



PTV-VISSIM®

Module 7
Appendix A

Calibration Guidance

Georgia Institute of Technology

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Disclaimer: The objective of these tutorials is to bring new users sufficiently (and quickly) up to speed so they can use the manual and other resources when they have questions on model development. These tutorials should not be considered as official guidance; users should always refer to official PTV VISSIM® or project sponsor documentation for the final word on a model feature question. Send any errors, issues, or comments to michael.hunter@ce.gatech.edu so any corrections can be made to the material.

Introduction

Module 7, Appendix A, provides additional guidance and insights on the calibration of the underling Wiedemann car-following models. As a reminder from Module 7, there are three separate, but related, processes that should be undertaken for each model: verification, validation, and calibration.

> **Verification** is the confirmation that a model has been constructed and operates as intended. Verification requires carefully stepping through a model to confirm each modeling element operates as intended. It is critical to maintain the understanding that many verification errors (e.g., two lanes where there should be three) will not be indicated as a PTV-VISSIM® warning or error. PTV-VISSIM® warnings contribute to the verification process, but *they do not replace a deliberate, detailed review of the model!*
>
> **Validation** confirms that the performance of the model satisfies expectations (e.g., the model approximately matches field conditions). Validation seeks to confirm that a model matches approximately the real world (or expected performance), often in terms of some performance measure, such as speed, delay, travel time, etc.
>
> **Calibration** is the adjustment of the underlying parameters of a **verified** model to achieve a valid model. In PTV-VISSIM® this is often taken to be a calibration of the underlying Wiedemann car following parameters, although other parameters, such as lane changing parameters may be considered as well.

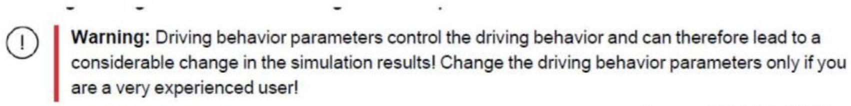
The importance of a detailed and thorough verification process prior to any calibration of the Wiedemann car-following parameters cannot be understated. Any model calibration effort where underlying issues exist within the model may result in a poorly calibrated model yielding unreliable results when subsequent scenarios are constructed building on the base simulation. For example, consider the alternative left turn bay design in Module 5 that utilized a single link to represent both the through lanes and the left turn bay. If left turning vehicles unrealistically block the through traffic by being too aggressive in seeking a downstream lane change point (e.g., very close to the stop bar), travel times and thus delays may be significantly impacted. While certain adjustments to the Wiedemann parameters might result in travel times matching the field observations under these conditions, it is likely that these parameter values will be too aggressive given the need to adjust for the erroneous delay occurring at the left turn. Prior to calibration, the model developer must address any such blockages or other unrealistic behaviors. Many other similar examples may be considered, such as lane change settings, link-connector structure at on-ramp merging, routes through weaving zones or closely spaced intersections, to name a few. Modifications necessary to address any identified issues with routing, link-connector, conflict zone, etc. must be made before calibrating any Wiedemann-type car-following models. Likewise, any local calibrations, such as Lane Change Distance and Emergency Stop Distance, should be adjusted prior to Wiedemann parameter calibration.

Only when such adjustments have been completed should the modeler consider car-following parameter adjustment. The modeler must be aware that the calibration process itself may uncover additional verification issues that need to be addressed, requiring that the calibration be revisited after any necessary model modifications.

As part of the verification checks, the model developer is encouraged to utilize the power of sensitivity analysis. For instance, many potential model issues may not be obvious under conditions well below capacity. Therefore, it is often useful to load the model with high volumes as part of the verification process, even if those volumes are not expected in the later analysis. Reviewing the model under these conditions can often highlight potential underlying issues with the model.

Calibration Philosophy

Any model calibration effort should consider the following guidance, repeated several times throughout the PTV-VISSIM manual:



Warning: Driving behavior parameters control the driving behavior and can therefore lead to a considerable change in the simulation results! Change the driving behavior parameters only if you are a very experienced user!

Source: (PTV_AG, 2024)

Thus, as a general calibration philosophy, this guidance recommends a “less in more” approach. The calibration with the fewest parameters adjustments, by the smallest increments, that provides a reasonable reflection of field conditions (not necessarily the “best”) is considered the preferred solution. As will be seen in the following discussion, car following parameters can have interactive effects that make the prediction of the impact of changing a parameter difficult to predict. Additionally, these interactions can change depending on the parameter values, underlying model construction, speeds, and demands. Recall, the objective of many modeling and calibration efforts is to create a model that represents field conditions **AND** provides reasonably accurate performance when the model is altered to build or future conditions.

Unfortunately, there is no guarantee in simulation that a model’s outcome will be accurate when demands and designs change from calibrated conditions. The advantage of default, or commonly used parameter sets, is that they have passed the test of time, i.e., many different successful use cases. While significant parameter values ranges may be found in the literature, values closer to the default have the benefit of demonstrated reliability under many differing situations. The greater the number of parameters changed, or the degree of such changes, the greater the requirement that the model developer ensures reasonable performance under alternative conditions. This discussion is not intended to prohibit a model developer from changing parameter values, in fact there are many situations where such changes may be warranted. However, one should heed the PTV-VISSIM® warning and **PROCEED WITH CAUTION!**

Wiedemann Car Following Model

Action Point Model

Car following models define whether a vehicle accelerates, decelerates, or maintains its current speed in the next time step, when the vehicle is in car following mode. PTV-VISSIM® uses the Wiedemann 74 and Wiedman 99 models as its car following algorithms. The various parameters of the Wiedemann car following models allow simulation developers to calibrate the response (or sensitivity) of the following vehicle's behavior to its lead vehicle within the constraints of the underlying modeling form.

Before exploring how these parameters impact aggregate or macroscopic traffic flow metrics, we will examine how these parameters the impact behavior of individual vehicles following a lead vehicle. Better understanding an individual vehicle's behavior can often lead to an improved intuitive sense of how the variability of a parameter is likely to influence this aggregate traffic flow.

The Wiedemann models follow an "Action Point" car-following model also referred to as a Psycho-physical car following model (Vortisch & Fellendorf, 2011). Loosely, given the distance between a lagging (also referred to as following) vehicle and the leading vehicle, and the difference in vehicle speeds, the vehicle will be in one of four driving states. The four states are Free Driving, Approaching, Following, and Braking. Figure 1 illustrates these states.

- "Free driving: No influence of preceding vehicles can be observed. In this state, the driver seeks to reach and maintain his desired speed. In reality, the speed in free driving will vary due to imperfect throttle control. It will always oscillate around the desired speed.
- Approaching: Process of the driver adapting his speed to the lower speed of a preceding vehicle. While approaching, the driver decelerates, so that there is no difference in speed once he reaches the desired safety distance.
- Following: The driver follows the preceding car without consciously decelerating or accelerating. He keeps the safety distance more or less constant. However, again due to imperfect throttle control, the difference in speed oscillates around zero.
- Braking: Driver applies medium to high deceleration rates if distance to the preceding vehicle falls below the desired safety distance. This can happen if the driver of the preceding vehicle abruptly changes his speed or the driver of a third vehicle changes lanes to squeeze in between vehicles."

(PTV_AG, 2024)

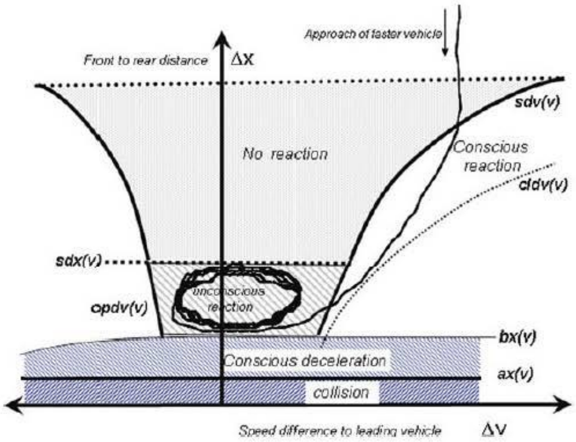


Figure 1. Graph. Driving state of PTV-VISSIM Psycho-Physical (Action Point) car following model (Vortisch & Fellendorf, 2011).

The axes on Figure 1 are ΔX on the y-axis representing the distance between the lead and lag vehicles, and ΔV on the x-axis which is the speed difference between the lead and lag vehicles. The figure represents the "action points" for the lag vehicle, where a vehicle changes from one state to another. The "No reaction" zone represents the range of ΔX and ΔV values where the vehicle is in free driving. That is, the vehicle behavior is unaffected by the presence of the leading vehicle. The "Conscious reaction" zone is the ΔX and ΔV zone where a faster lagging vehicle is approaching a slower leading vehicle and has determined that it needs to brake as it is approaching. The objective of the lagging vehicle is to slow to the leading vehicle's speed by the time it reaches its "safe following distance" (safe following distance will be further described in subsequent text). The "Unconscious reaction" represents the ΔX and ΔV range of the lagging vehicle in car-following. The underlying assumption is that the lagging vehicle does not perfectly match the speed of the leading vehicle. The lagging vehicle will tend to decelerate and accelerate within a few mile-per-hour range of the leading vehicle, resulting in varying of the following distance and speed. The "Conscious deceleration" zone is where the lagging vehicle's distance to the leading vehicle is less than the desired safety distance, thus the lagging vehicle will more aggressively brake to achieve a safe following distance.

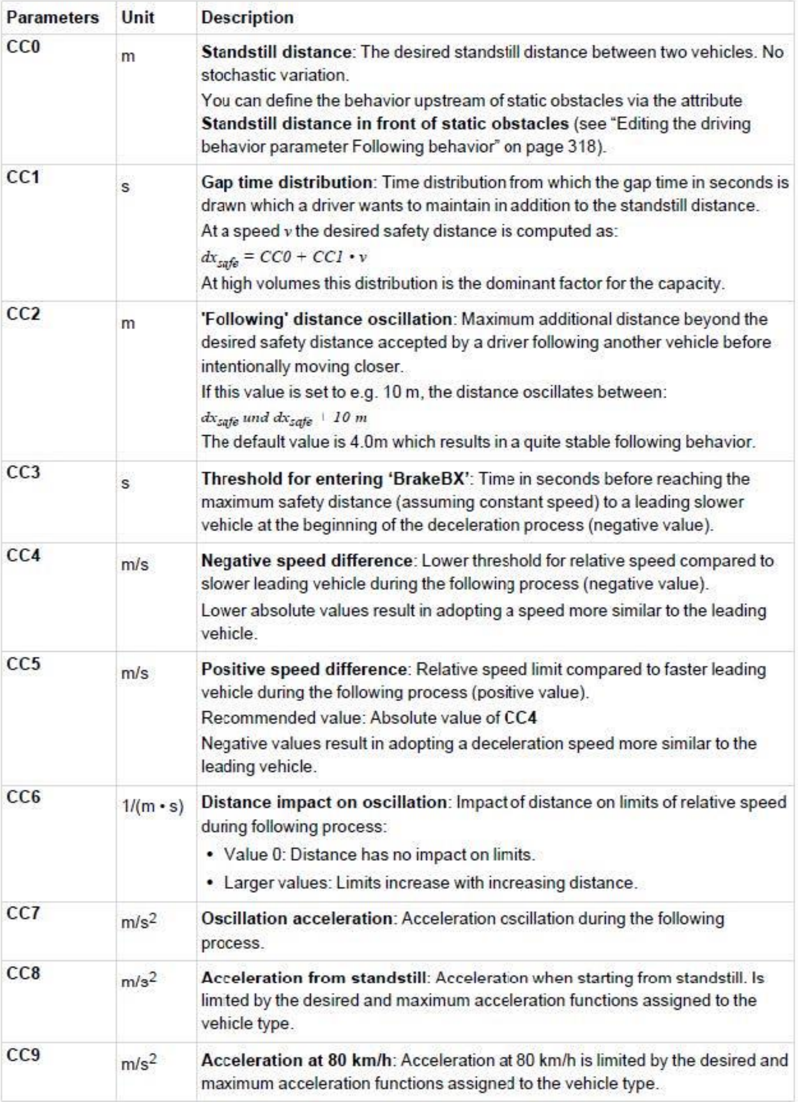
Figure 1 includes an example (ΔX, ΔV) path for a lagging vehicle, labeled "Approach of faster vehicle." In the example the lagging vehicle initially has a speed greater than the leading vehicle. This may be a result of the lagging vehicle having a higher desired speed than the leading vehicle, or the leading vehicle itself being behind another slower vehicle.

While at sufficiently large ΔX and ΔV values, the lagging vehicle remains in the "Free driving" zone traveling at its desired speed, uninfluenced by the leading vehicle. Eventually, the ΔX will sufficiently reduce such the lagging vehicle will enter the "Conscious reaction" zone. In this zone the lagging vehicle will begin to slow, which is represented by the reducing ΔV. Finally, the lagging vehicle enters car following with ΔX and ΔV varying over a small interval. This can be seen by the repeating circle in the "Unconscious reaction" zone.

Wiedmann 99 Parameters

A simulation modeler may ask the question: How does the Action Point model relate to the model calibration and traffic flow performance? The short answer, the size and location of the zones as seen in Figure 1 are dictated by the car following parameters. Consider the Wiedemann 99 car following CC parameters, seen in Figure 2. (A more detailed discussion is provided in Module 7 on the CC parameters.)

This discussion will focus on CC1, CC2, CC4 and CC5. Based on model testing as part of this effort and review of the literature it was determined that the remaining parameters had minimal impact on the model execution and are unlikely to be changed during calibration, except under very specific conditions. One parameter often considered in the literature is CC0, the standstill distance. However, the effect is minimal compared to CC2, thus the focus is placed on CC2 in this effort. In addition, CC0 may be field measured in stopped traffic. Where there is a desire to calibrate CC0 it should be field measured, and that field-observed value used. This should be done prior to the calibration of other parameters.



Parameters	Unit	Description
CC0	m	**Standstill distance**: The desired standstill distance between two vehicles. No stochastic variation. You can define the behavior upstream of static obstacles via the attribute **Standstill distance in front of static obstacles** (see "Editing the driving behavior parameter Following behavior" on page 318).
CC1	s	**Gap time distribution**: Time distribution from which the gap time in seconds is drawn which a driver wants to maintain in addition to the standstill distance. At a speed v the desired safety distance is computed as: $dx_{safe} = CC0 + CC1 \cdot v$ At high volumes this distribution is the dominant factor for the capacity.
CC2	m	**'Following' distance oscillation**: Maximum additional distance beyond the desired safety distance accepted by a driver following another vehicle before intentionally moving closer. If this value is set to e.g. 10 m, the distance oscillates between: dx_{safe} und $dx_{safe} + 10\ m$ The default value is 4.0m which results in a quite stable following behavior.
CC3	s	**Threshold for entering 'BrakeBX'**: Time in seconds before reaching the maximum safety distance (assuming constant speed) to a leading slower vehicle at the beginning of the deceleration process (negative value).
CC4	m/s	**Negative speed difference**: Lower threshold for relative speed compared to slower leading vehicle during the following process (negative value). Lower absolute values result in adopting a speed more similar to the leading vehicle.
CC5	m/s	**Positive speed difference**: Relative speed limit compared to faster leading vehicle during the following process (positive value). Recommended value: Absolute value of **CC4** Negative values result in adopting a deceleration speed more similar to the leading vehicle.
CC6	1/(m • s)	**Distance impact on oscillation**: Impact of distance on limits of relative speed during following process: • Value 0: Distance has no impact on limits. • Larger values: Limits increase with increasing distance.
CC7	m/s^2	**Oscillation acceleration**: Acceleration oscillation during the following process.
CC8	m/s^2	**Acceleration from standstill**: Acceleration when starting from standstill. Is limited by the desired and maximum acceleration functions assigned to the vehicle type.
CC9	m/s^2	**Acceleration at 80 km/h**: Acceleration at 80 km/h is limited by the desired and maximum acceleration functions assigned to the vehicle type.

Figure 2. Table. Wiedemann 99 model parameters and definitions. Source: (PTV _AG, 2024)

Wiedemann 99 Parameter: CC1

First examining CC1, the gap time distribution, as this parameter is known to have the most significant impact on capacity, particularly at higher speeds (PTV_AG, 2024). (May, 1990) CC1 directly influences the desired safety distance, which is the minimum distance a vehicle will seek to maintain behind its leading vehicle.

$$\textit{desired safety distance} = CC0 + CC1 * v \qquad [1]$$

where: CCO is Standstill Distance
CC1 is Gap Time Distribution
v is lagging vehicle speed

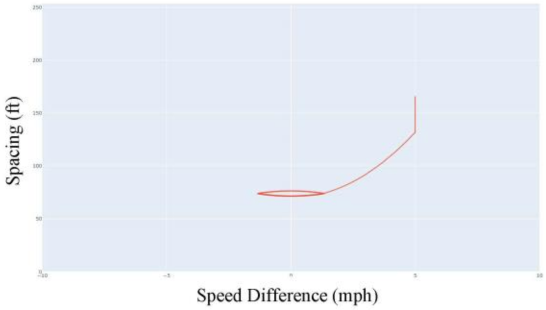
From Equation 1 it is seen that with increasing CC1 the desired safety distance will increase. As desired safety distance increases the density of vehicles in car following decreases and thus the capacity or total possible flow decreases. While an over-simplification, for visualization the reader may consider a platoon of vehicles traveling down a roadway. Increasing the CC1 parameter will increase the headway between vehicles and the total space on the roadway occupied by the platoon.

Car-following Behavior

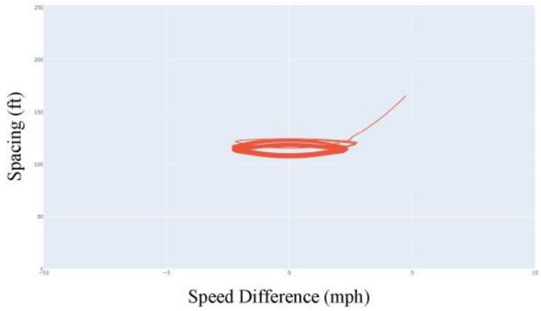
To explore the impact of the CC parameters on car-following behavior a simple single lane model was developed, where a vehicle with a 70-mph desired speed is followed by vehicles with a 75-mph desired speed, forcing car-following. Figure 3a, Figure 3b, and Figure 3c represent the (ΔX, ΔV) path for the 75-mph desired speed vehicle immediately following the 70-mph vehicle, under three different conditions. The vehicle modeled in Figure 3a has a CC1 of 0.5, Figure 3b has a CC1 of 13.12 (default), and Figure 3c has a CC1 of 19.68. All other parameters are set at the default values.

Two trends may be witnessed in Figure 3. First, is that with increasing CC1 the speed range of the following vehicle increases, i.e., the circulating plot is wider along the x-axis. Second, with increasing CC1, the values of ΔX increase, i.e., the median value on the y-axis increases. Consider, at CC1 values of 0.5, 0.9, and 1.5 the median ΔX values are approximately 74 ft, 112 ft, and 175ft and thus increasing CC1 has a dramatic effect on vehicle spacing within platoons.

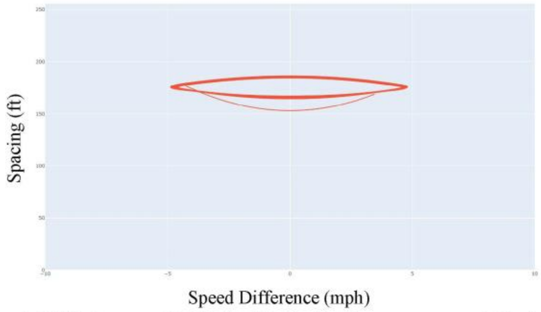
Next, consider additional vehicles in the platoon. In Figure 4, for the default VISSIM parameter set (i.e., CC1 = 0.9) the progression of vehicle car following behavior for the 2nd (immediate follower of the lead vehicle), 3rd, 4th, 5th, 6th, and 7th vehicles in the platoon is seen. While each subsequent vehicle has a similar median ΔX, the range of ΔX and ΔV values increases. This increasing variability in the platoon results in each added vehicle reducing the platoon density. This would indicate lower capacities than that implied by the more stable spacing of the 1st and 2nd vehicle in the platoon. Similar trends are seen with the CC1 values of 0.5 (Figure 5) and 1.5 (Figure 6). However, for CC1 of 0.5 the increasing instability in the platoon is more muted.



(a) Wiedemann 99 CC1 of 0.5, all other parameter default

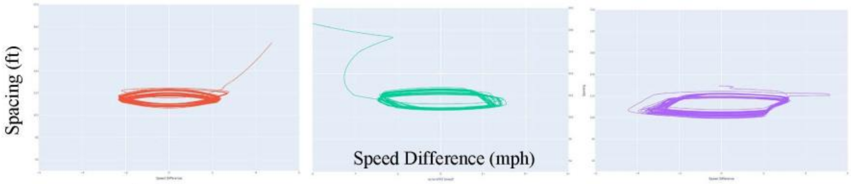


(b) Wiedemann 99 CC1 of 0.9 (default), all other parameter default

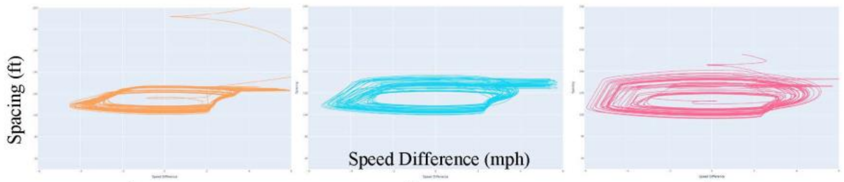


(c) Wiedemann 99 CC1 of 1.5, all other parameter default

Figure 3. Graph. Influence of CC1 on lagging vehicle car following behavior.

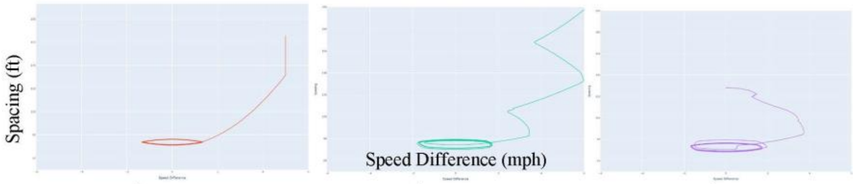


(a) 2nd vehicle (b) 3rd vehicle (c) 4th vehicle

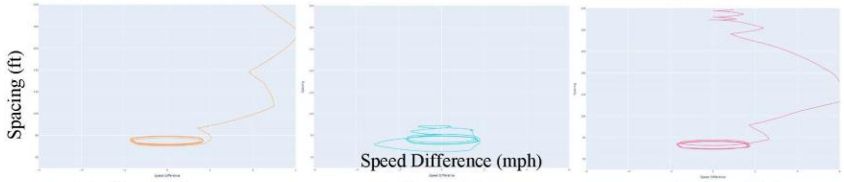


(d) 5th vehicle (e) 6th vehicle (f) 7th vehicle

Figure 4. Graph. (ΔX, ΔV) behavior by vehicle platoon position for default VISSIM Wiedemann 99 parameters (i.e., CC1 = 0.9). ΔX and ΔV plot ranges of (-6.0, 6.0) and (50, 200), respectively.



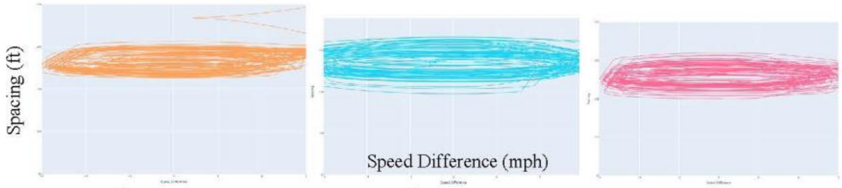
(a) 2nd vehicle (b) 3rd vehicle (c) 4th vehicle



(d) 5th vehicle (e) 6th vehicle (f) 7th vehicle

Figure 5. Graph. (ΔX, ΔV) behavior by vehicle platoon position for Wiedemann 99 parameter CC1 = 0.5, other parameters at default. ΔX and ΔV plot ranges of (-6.0, 6.0) and (50, 200), respectively.

(a) 2nd vehicle (b) 3rd vehicle (c) 4th vehicle



(d) 5th vehicle (e) 6th vehicle (f) 7th vehicle

Figure 6. Graph. (ΔX, ΔV) behavior by vehicle platoon position for VISSIM® Wiedemann 99 parameter CC1 = 1.5, other parameters at default. ΔX and ΔV plot ranges of (-6.0, 6.0) and (50, 200), respectively.

From these observations it becomes apparent that determining the capacity associated with a given parameter set is not a simple question of applying the safety distance as would be calculated using the CC0 and CC1 values (even when accounting for variability due to CC2, which will be discussed subsequently). The interaction effect among the vehicles when in a platoon reduces the platoon density, thereby reducing capacity. Additionally, the remaining CC parameters can influence this interaction between vehicles. Thus, parameter calibration cannot realistically be accomplished through application of the Wiedemann equations, rather an empirical study of reasonable CC parameters for the model under consideration is required.

Speed-Flow Performance

A primary method to accomplish such a calibration is using speed-flow diagrams. For the examples in this section of the Appendix a four-lane section of a freeway simulation was utilized, with the right most lane exiting, see Figure 7. The exiting lane was included to allow various overcapacity conditions to be simulated as this cannot be easily accomplished otherwise due to the impact of the vehicle entry model on the simulation. Traffic volumes were increased from under capacity to overcapacity, then return to under capacity, allowing for a full range of demands through the section. Additionally, data is collected on the mainline lanes at the diverge point. Figure 8 displays speed flow data for CC1 values of 0.5 (green), 0.9 (blue), and 1.5 (pink), with all other CC parameters at default values and the desired speed set to the default 70 mph distribution. Each point represents a one-minute interval.

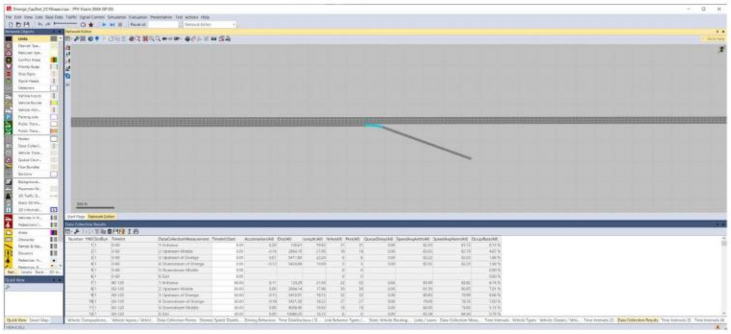


Figure 7. Image. Freeway segment utilized for Speed-Flow graph examples.

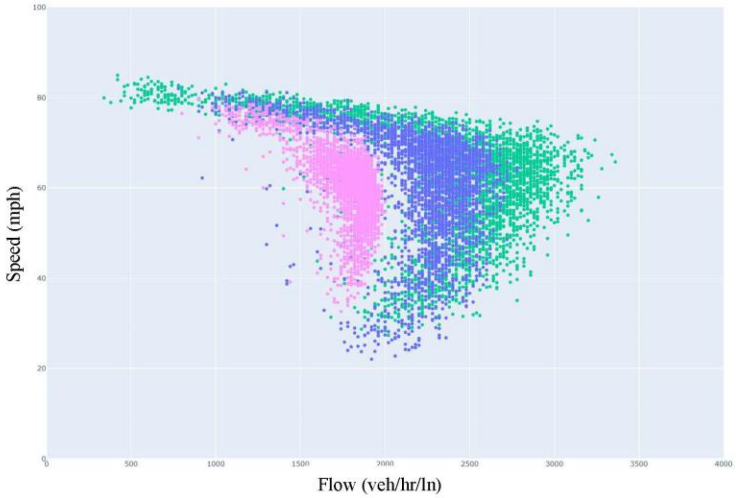


Figure 8. Graph. Speed Flow Diagram, Green CC1 = 0.5, Blue CC1 = 0.9, Pink CC1 = 1.5.

The speed flow diagrams match those expected from typical car-following behavior. It is seen that the CC1 of 0.5 has the highest flow values, followed by the CC1 of 0.9, and CC1 of 1.5. It is also seen that a linear increase in CC1 does not result in a linear increase in flow (i.e., doubling CC1 does not double the maximum flows processed.) Additionally, if all vehicles were in car following and spacing was determined based on the desired speed equation, higher flows would be expected at capacity. However, there are a number of factors that contribute to capacities lower than might be expected based on the desired speed equation, such as platoons becoming less dense as additional vehicles are added, interactions with the other CC1 parameters, etc. However, a significant issue exists that at first may appear non-intuitive. While it would be understandable to expect that most vehicles are in car following when traffic flows reach high values (i.e., approach capacity, lowest vehicle-to-vehicle spacing), in the Action-Point approach of PTV-VISSIM® this is not a correct interpretation. Car following is limited to vehicles with spacings near the safe-following distance, which is a function of CC0, CC1, and CC2 (see *Car Following Intuition* below for example spacing calculation). However, when considering the fluctuation of traffic within platoons and the discretionary lane changing occurring as vehicles change lanes in an attempt to achieve their desired speed, many vehicles are not in car-following, but rather free, approaching, or braking, even during the most congested flow periods. For example, Figure 9 shows the percentage of vehicles considered in car following in the Action Point car following model for the freeway scenario with all parameters set at default (i.e., the blue data in Figure 8). Capacity conditions occur at approximately the midpoint along the x-axis. It is seen the under heavy traffic approximately 8 percent to 13 percent of vehicles are categorized as in car following mode. Thus, while the Wiedemann parameters provide a strong influence over the traffic flow behavior, the underlying action point model form creates significant interaction between states, even in high volume situations where a modeler might expect most vehicles to be in car following. Again, it is seen that calibration must be an empirical process.

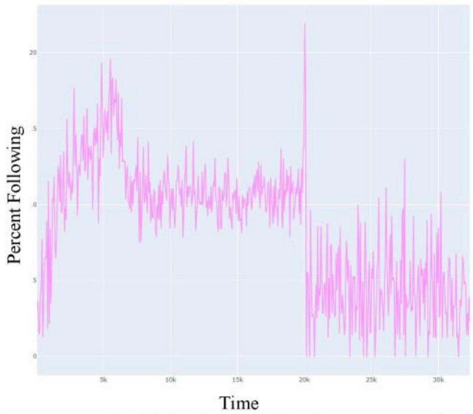


Figure 9. Graph. Percentage of vehicles in car following at respective simulation times.

Helpful Hints
Car Following Intuition in VISSIM

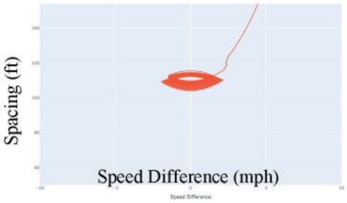
Consider a vehicle traveling a 70 mph. The maximum distance that vehicle could be from a downstream vehicle and still be considered in car-following (under the VISSIM Action Point definition) is:

CCO + CC1*v + CC2

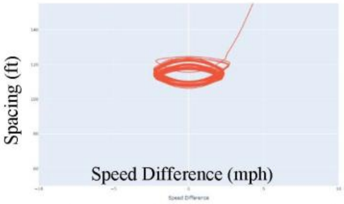
Using a 70-mph speed and the default CC values this would be 4.92 + 0.9*70*1.47 + 13.12, or 111 ft. For context, at 70 mph this would be 1.1 seconds or less, or less than three skip lines, from the leading vehicle. This does not necessarily imply the lagging vehicle is uninfluenced by the downstream vehicle at spacings greater than 1.1 seconds, as it may be braking in the "approaching" zone. If in "free" it will likely be accelerating, seeking to reach its desired speed. Clearly, the vehicle behavior is not solely governed by the Weidmann parameters.

Wiedemann 99 Parameter: CC2

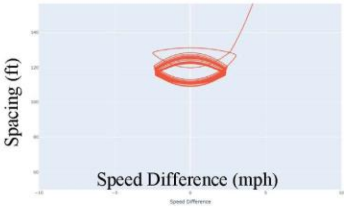
The next parameter considered is CC2, *Following distance oscillation.* This parameter directly influences the range over which a vehicle will remain in car following, with the ΔX ranging from desired safety distance to desired safety distance + CC2. In Figure 10, increasing CC2 would be associated with an increasing ΔX range in the unconscious reaction zone. Intuitively, increasing CC2 should have the effect of increasing the median headway within a platoon, as the range of car-following headways increases with increasing CC2. This would result in lower capacities at higher CC2 values. Figure 10 demonstrates this behavior. Using the same model discussed in the CC1 section above, the (ΔX, ΔV) car following path for the second vehicle in the platoon (i.e., the vehicle following the platoon leader) is shown for CC2 values or 6.56, 13.12 (VISSIM® default), and 19.68. As expected, an increase is seen in the range of ΔX values as CC2 increases. However, Figures Figure 11, Figure 12, and Figure 13 show the following behavior for the 2nd, 3rd, 4th, 5th, 6th, and 7th vehicle in the queue, for CC2 values of 6.56, 13.12, and 16.68, respectively.



(a) CC2 of 6.56, all other parameters default

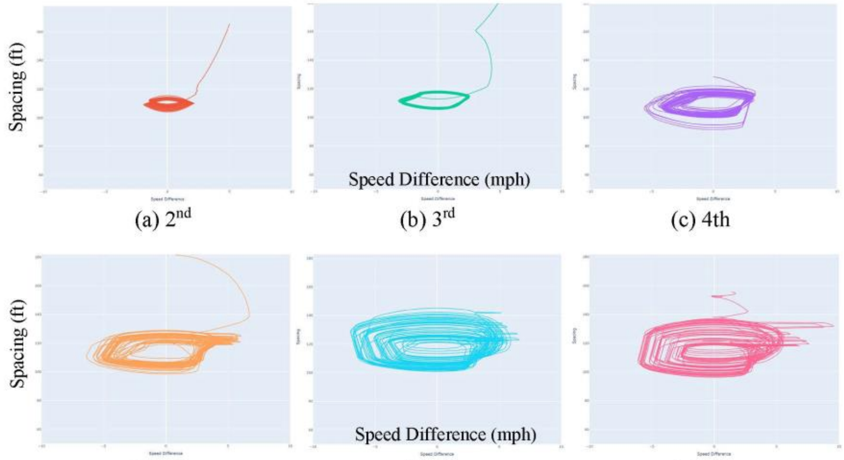


(b) CC2 of 13.12, all other parameters default



(c) CC2 of 19.68, all other parameters default

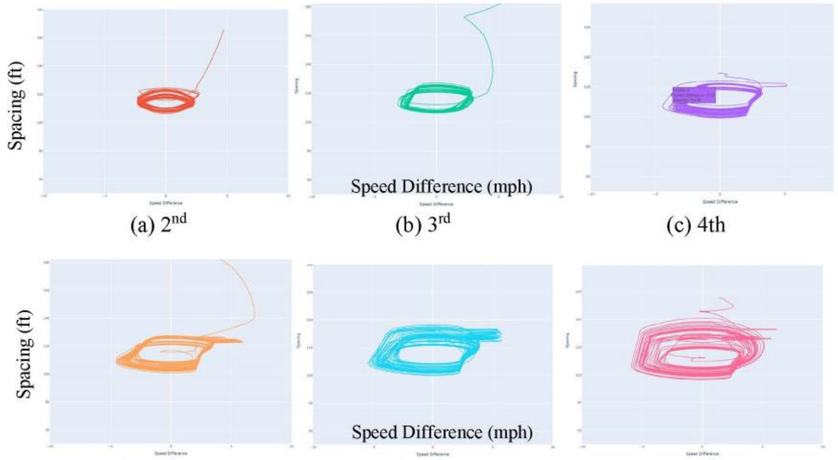
Figure 10. Graph. Second platoon vehicle in car following.



(a) 2nd (b) 3rd (c) 4th

(d) 5th (e) 6th (c) 7th

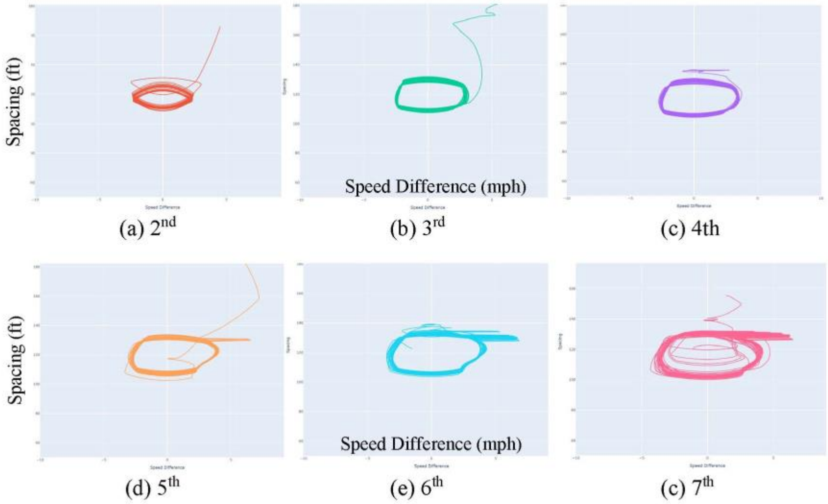
Figure 11. Graph. (ΔX, ΔV) car following path for the 2nd, 3rd, 4th, 5th, and 6th vehicle in the platoon for CC2 of 6.56, all other CC parameters at default.



(a) 2nd (b) 3rd (c) 4th

(d) 5th (e) 6th (c) 7th

Figure 12. Graph. (ΔX, ΔV) car following path for the 2nd, 3rd, 4th, 5th, and 6th vehicle in the platoon for CC2 of 13.12, all other CC parameters at default.



(a) 2nd (b) 3rd (c) 4th

(d) 5th (e) 6th (c) 7th

Figure 13. Graph. (ΔX, ΔV) car following path for the 2nd, 3rd, 4th, 5th, and 6th vehicle in the platoon for CC2 of 19.68, all other CC parameters at default.

As with the CC1 exploration Figure 11, Figure 12, and Figure 13 show that increasing ΔX, ΔV varibility is introduced with increasing position, for all CC2 cases. Thus, again, platoon density decreases as platoon length increases. This increasing variability mutes the impact of increasing CC2, with similar (ΔX, ΔV) behaviors seen among the CC2 values. Figure 14 is the speed flow diagram for the same four lane section of roadway in the CC1 discussion. In this figure, Pink, Blue, and Green are the CC2 values of 6.56, 13.12, and 19.68. As seen, the impact on the speed flow behavior, in terms of capacity, is much more muted than that seen in CC1. Although interesting, it is seen that decreasing CC2 results in a higher likelihood traffic slowing, that is, more high flows are found at lower speeds. This is likely a result of the interaction between Action Point zones, with the smaller CC2 values potentially resulting in a higher likelihood of entering the conscious breaking zone, resulting in additional deceleration. An interesting outcome of this finding is that where speed heat maps are used for calibration it may be useful to consider further calibration of CC2, while the capacity impact is somewhat muted the speed impact may be more dramatic.

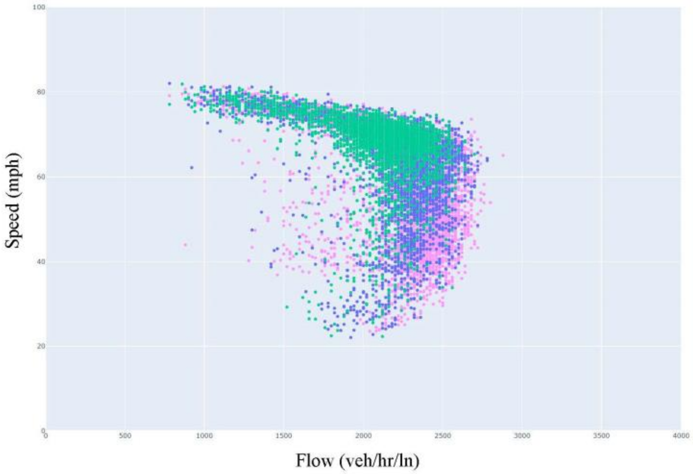


Figure 14. Graph. Speed flow diagram, four lane section of roadway with lane departure. CC1 of 0.9 (default), all other parameters except CC2 at default values. Pink, Red, and Blue are the CC2 values of 6.56, 13.12, and 19.68.

The results presented in detail for CC2 are based on other parameters being at VISSIM default values. Other parameters sets may give different interactions, with different behaviors. For example, for a CC1 value of 1.5 and all other parameters at defaults, the speed flow graphs in Figure 15 are obtained for the four-lane freeway section. In this result it is seen that the maximum flow processed is relatively consistent between the CC2 values, with almost no change in capacity. However, again, a higher likelihood of lower speed values under high flow conditions is seen with lower CC2 values. Recalling the earlier discussion, this impact of CC2 values is witnessed at the bottleneck. Further downstream the flows have had an ability to recover, with minimal difference in the speed flow graphs, see Figure 16. Again, this highlights the importance of location selection for calibration.

For a CC1 value of 0.5 and all other vehicles at default, a trend of decreasing capacity is seen with increasing CC2; however, the impact on the presence of lower speeds is more muted. As with the prior results, the number of observations of lower speeds dissipates with distance downstream from the bottleneck. These results again demonstrate the interactions effects of the parameters and the action point car following model. This highlights the importance of understanding that Wiedemann car following parameters do not operate in isolation with significant potential for interactive effects.

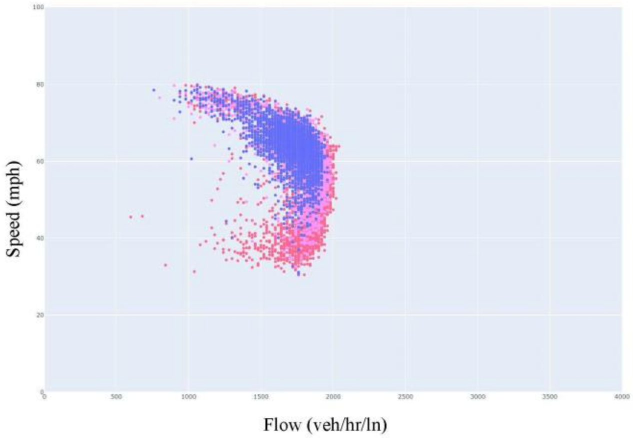


Figure 15. Graph. Speed-Flow diagram, four lane section of roadway with lane departure, data at bottleneck. CC1 of 1.5, all other parameters except CC2 at default values. Red, Pink, and Blue are the CC2 values of 6.56, 13.12, and 19.68.

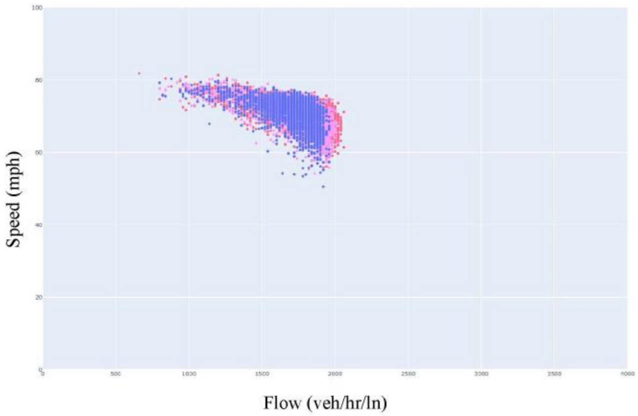


Figure 16. Graph. Speed-Flow diagram, four lane section of roadway with lane departure, data downstream of bottleneck. CC1 of 1.5, all other parameters except CC2 at default values. Red, Pink, and Blue are the CC2 values of 6.56, 13.12, and 19.68.

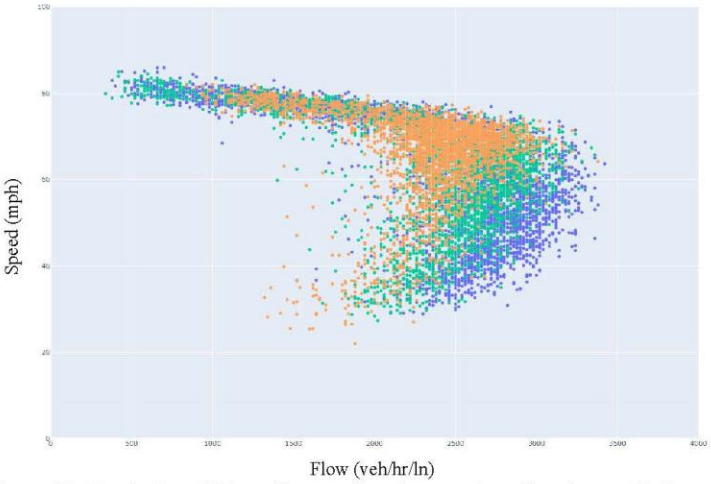


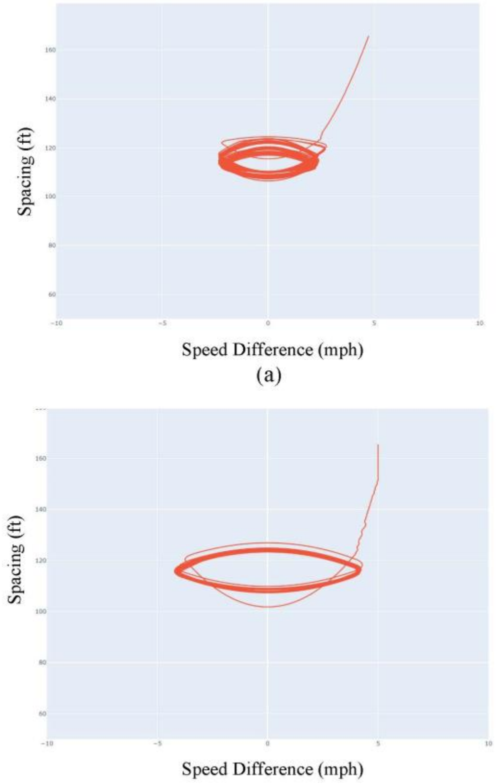
Figure 17. Graph. Speed-Flow diagram, four lane section of roadway with lane departure, data at start of bottleneck. CC1 of 0.5, all other parameters at default values. Blue, Green, and Orange are the CC2 values of 6.56, 13.12, and 19.68.

Wiedemann 99 Parameter: CC4 and CC5

The last parameters to be considered in detail are CC4 and CC5, negative speed difference and positive speed difference, respectively. According to the PTV-VISSIM® manual higher absolute values result in "a more sensitive driver reaction to the acceleration or deceleration of the preceding vehicle." In this analysis two levels of (CC4, CC5) were considered, (-0.35, 0.35) which is the default, and (-1.05, 1.05). CC4 and CC5 are held at the same value based on the recommendation in the literature and in common practice.

In the action point model the effect of the CC4 and CC5 model is to increase the width for the conscious following zone, that is, increase the range of following speed of the lagging vehicle, see Figure 18. While not shown, as the platoon size increases the range in speeds of the following vehicle increases. Similar to CC1 and CC2, this results in lower density platoons as the platoon size increases.

When all values are at default, i.e., CC1 is 0.9 and CC2 is 13.12, the impact of CC4 and CC5 is minimal, resulting in a potentially slight shift to lower flows with higher CC4 and CC5 values, see Figure 19. This trend remains true for higher CC1 values as well as the range of CC2 values tested for the CC1 of 0.9 and 1.5, for an example see Figure 21. However, at lower CC1 values an interaction with CC1 is witnessed, with significantly lower capacity as CC4 and CC5 increase, Figure 20. This trend holds for the CC2 levels tested (i.e., CC2 of 6.56, and 19.68) at CC1 of 0.5.



(a)

(b)

Figure 18. Graph. CC4/CC5 (a) 0.35 and (b) 1.05, all other parameters are set to their defaults.

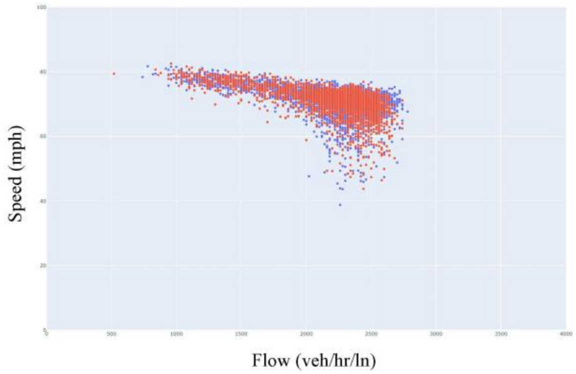


Figure 19. Graph. Speed-Flow diagram, four lane section of roadway with lane departure, bottleneck location. All parameters at default values, CC1 is 0.9, CC2 is 13.12. Blue and Red are the CC4/CC5 values of +/- 0.35 and of +/- 1.05, respectively.

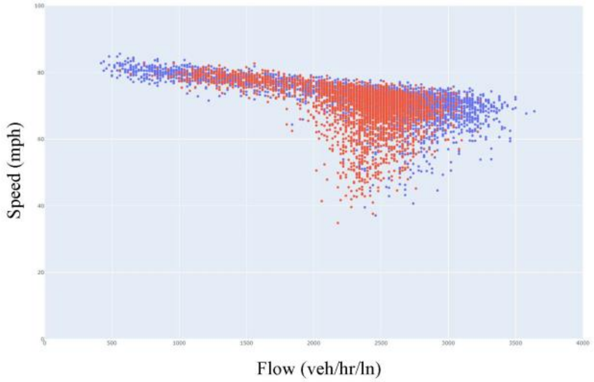


Figure 20. Graph. Speed-Flow diagram, four lane section of roadway with lane departure, bottleneck location. All parameters at default values, CC1 is 0.5, CC2 is 13.12. Blue and Red are the CC4/CC5 values of +/- 0.35 and of +/- 1.05, respectively.

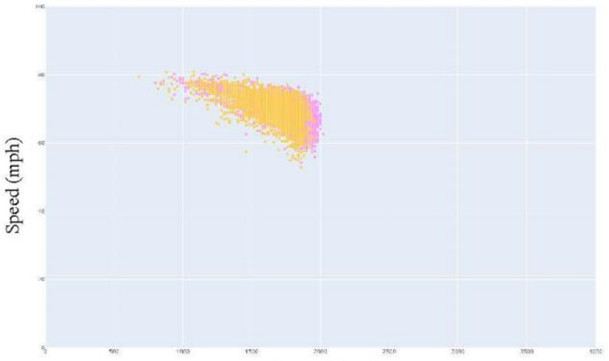


Figure 21. Graph. Speed-Flow diagram, four lane section of roadway with lane departure, bottleneck location. All parameters at default values, CC1 is 1.5, CC2 is 13.12. Blue and Red are the CC4/CC5 values of +/- 0.35 and of +/- 1.05, respectively.

Summary

In summary, several key features have arisen as part of this exploration. First, it is clear that calibration is an empirical exercise. With the given interactions between CC levels and the application of the Action Point model, it is not realistic to directly calculate CC values. Additionally, as seen, the Action Point model does not result in a high percentage of vehicles in car following (as defined by the desired safety distance), even under congested conditions. This implies that the acceleration value determination for a given vehicle across all four Action Point zones significantly influences individual vehicle behavior as well as overall link speed, flow, and density. As the length of platoon formation increases, the density of the platoons tends to decrease. Finally, near the default values the interactions tend to be less, as CC parameters diverge from the defaults increasing interactions may be seen, requiring additional testing and caution by the modeler.

Calibration Method Guidance

The following provides suggested steps for inclusion in a PTV VISSIM® model calibration. The intent of these steps is to not to be overly prescriptive. It is recognized that calibration must be reflective of the model intent, objectives, components, size, etc. Each modeling effort is unique, and calibration should account for these unique aspects. Additionally, while at a general level these steps may help inform the calibration of other simulation platforms, they are tailored to the underlying PTV VISSIM® car-following model and parameter sets. Thus, transferring this approach to other simulation environments is not straightforward, requiring significant understanding of the other simulation environment's car-following and modeling approach.

The calibration focuses on the car following model parameters (Wiedemann 74 and Wiedemann 99), as well as the desired speed distribution. It is assumed that the given model has undergone a thorough verification check. This includes confirming geometry and signal settings, placing appropriate reduced speed zones, route placement, fine tuning emergency stop distance, setting conflict zones, etc. Further discussion may be found in Module 7 and detailed checklists for potential sources of modeling error may be found in Module 8. **These items must be addressed *prior* to car following model calibration**. Traffic flow parameter calibration must not be used to address errors in the base model! In many instances it may be found that car-following parameter calibration is not necessary, with default parameters providing adequate model performance.

Finally, calibration (as well as all simulation modeling) relies on sound engineering judgement. Suggested steps in the discussion (or any of the Modules) should not override sound judgment based on experience. In addition, reviewers with PTV VISSIM® experience models should be reviewed by individuals with a deep understanding of reasonable and expected traffic flow behaviors.

General Approach

Key concepts for the suggested calibration steps that will be presented throughout the following text include:

- Car following calibration is performed at the link level.
- Evaluation metrics include speed-flow diagrams and headway distribution rather than travel time and delay, as commonly found in the literature.
- Calibrated parameter sets for critical or typical links may be applied to links throughout the model.
- Calibration includes setting of the desired speed distribution.
- The method seeks to limit deviations from defaults parameters, focusing calibration on CC1 and CC2 in most cases.
- The approach is flexible, leveraging expert judgement of model developer and design team.
- Calibration is an iterative process:
    - Check field conditions against selected default values
    - Calibrate Desired Speed
    - Calibrate CC1
    - Calibrate CC2 (as necessary)

Except in limited circumstances addition CC parameter calibration should not be needed.

Link based calibration

While the entire network is calibrated, in the context of the car-following, calibration occurs at the point or link level. That is, within PTV VISSIM® the Wiedemann parameters are assigned according to a given link and may change from link to link. (This is somewhat simplified, PTV VISSIM® allows calibration per vehicle class, based on leading vehicle, etc.; however, for this discussion calibration is considered at the link level.) Thus, it is suggested to focus calibration efforts on critical or typical links, with the determined parameter sets applied to other similar links throughout the network.

Evaluation metrics

In Module 7 and numerous other documents, the common convention is to utilize travel time (e.g., 85% of links within some range of the field travel), delay, queue length, or other metrics (add citations). However, for this calibration, these metrics are considered part of the verification and validation steps. Such metrics are not utilized for the car following model calibration, except for final model validation after calibration. Rather, link or point measures, such as speed-flow diagrams and headway distributions, are used. From a practical perspective, it is difficult to determine the accuracy of a link level calibration when considering network wide metrics. Calibration parameter set selection based on network performance metrics is more likely to become confounded with the many other model aspects (and is more likely to be subject to model errors), whereas focusing on a specific link allows for a clearer evaluation of the calibration impact.

Application of critical or typical link car following parameter sets.

A key question is which links should be selected for development of car following parameter sets. First, the general objective is to have as few calibrated car following parameter sets as possible, while still providing reasonable model performance. It may be expected, with some caveats to be discussed, that within a given geographic region or area that a driver has similar car-following characteristics, when traveling on similar facilities. Additionally, within a region, similar facilities will encounter similar driving populations. For example, within Atlanta, drivers on I-85 are similar to those on I-75. Thus, it should hold that the same car following parameter set can be used across similar links in a network.

The preceding is a generic discussion, arguing for a common set of car following parameter values throughout a model. In many cases, a single parameter set should be sufficient. However, situations will arise where additional parameter sets may be needed. For example, when considering geometry, sharper curvatures can influence car following and speed behavior. Thus, it may be necessary to develop unique parameters sets where the geometry has a significant influence on driver behavior. Similarly, when studying barrier separated HOT facilities or work zones, the barrier separated lane (or narrowed work zone lanes) may have different car following characteristics than the general-purpose lanes. Operations during inclement weather, nighttime, etc. may justify individualized parameter sets, should these conditions be included in the project objectives. Models specific to special events (e.g., large sporting events) may require separate calibration as the driving population is not the typical population for that area. There are numerous other potential situations where unique calibration sets may be justified. As a rule of thumb, for facilities with the same speed limit (this assumes desired speed is highly correlated with speed limit), compare the field data generated speed flow diagrams on different segments, if the diagrams are similar under similar flow conditions than the same parameter set should be acceptable. Also, it is critical to consider in project planning that when incorporating calibration for different underlying conditions, e.g., weather, special event, etc., it is necessary to have the data applicable to these conditions.

An additional simplification for the following calibration is that a signal parameter set is developed for a link. This means that all vehicle types will use this calibration. However, it is possible to utilize the given methods and provide a calibration parameter set for different vehicle types. For example, heavy vehicles may have a different calibration than passenger cars. While such individual vehicle type calibration may be accomplished it should generally not be necessary, although it may sometimes be desirable (e.g., along a long grade or where heavy trucks may have a different speed limit). As long as the ratios of vehicle types are relatively stable the single calibration should be sufficient. However, if the simulation objective is to explore specific vehicle type impacts, then vehicle type classification may prove useful. For instance, exploring the impact of a large increase or decrease in the heavy vehicle percentage, such as the development of truck only lanes. PTV VISSIM® will allow even more detailed calibration, where the behavior of a vehicle is a function of the vehicle it is following. For example, is the car following behavior of a passenger car following another passenger car different than a passenger car following a tractor trailer? Often yes, although, this level of detail in the calibration is not typically necessary, with minimal impact on overall model performance. However, for example, when considering the impact of connected and autonomous vehicles, such lead-lag vehicle type pair specific car following calibration may be necessary, as such technologies directly seek to enable tight platoon and alter underlying car following models.

As stated, the below calibration provides a suggested series of steps for model calibration. However, as discussed there are many potential situations where additional or a higher resolution calibration may be justified. Such additional calibration is dependent on the objectives of the model and the expert judgement of the modeling team.

Link Selection for Calibration

It is critical that the links utilized for calibration are able to receive a full range of demands, i.e., demands that exceed the capacity of that roadway section. The challenge in selecting appropriate links is described in Traffic Flow Fundamentals by Adolf May (May, 1990) and summarized in the following. Consider Figure 22 below from May (May, 1990).

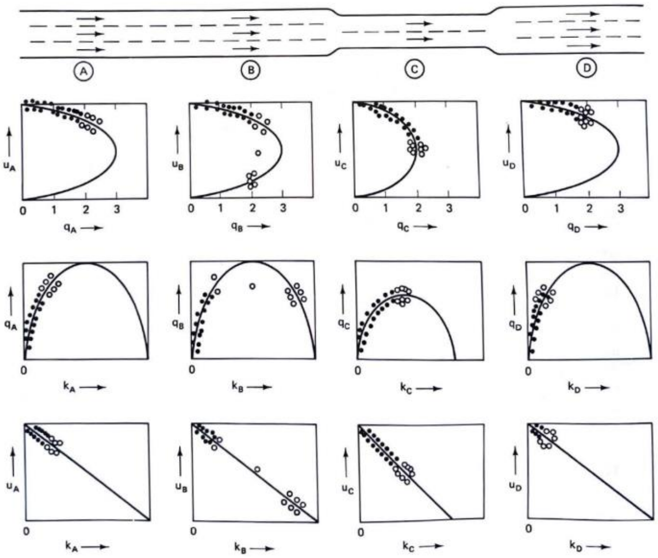


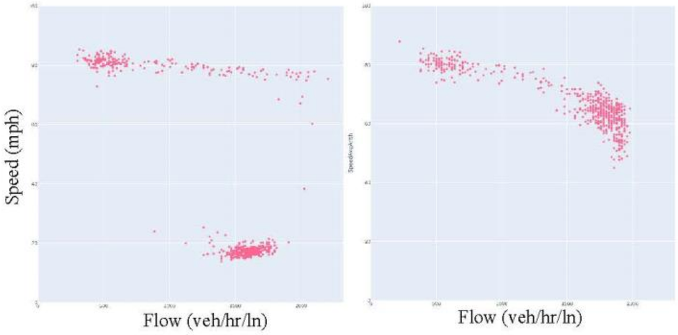
Figure 22. Graph. Importance of location (Source: (May, 1990), Figure 10.2.).

In Figure 22 a bottleneck is present at location C, where the roadway drops from three lanes to two lanes. The circles represent a measurement, where for a solid circle the flow is less than the capacity of the bottleneck (i.e. two lanes) and the hollow circles are flows ranging from 2 to 2.5 times single lane capacity. The first row of figures is the speed-flow (u, q) relationship for each segment, the second row is the flow-density (q, k) relationships, and the third row is the speed-density (u, k) relationships. In the speed-flow figures it is seen that only at the bottleneck location are flows equal to the section capacity. Thus, this section may be used to determine a per-lane capacity. In section B, measurements are seen in the unstable flow regime; however, capacity is never reached. This is because the downstream bottleneck only processes two lanes of equivalent capacity. This results in a breakdown at the start of the bottleneck when the demand exceeds two lanes of capacity. The breakdown spills back through Section B, resulting in unstable flow at low speeds, processing only the equivalent of two lanes of traffic. Section A never experiences capacity constraints as the total demand never exceeds 2.5 lanes of capacity and the spillback does not reach this section. Section D does not experience capacity conditions (or breakdown) as the bottleneck only allows two lanes of capacity flow to enter the three-lane section. The second and third rows of figures show the flow-density and speed-density relationships as well. More detailed discussion may be found in the May text (May, 1990).

While a relatively simple example, this demonstrates a critical concept. For car following parameter calibration, where data over the range of flows from low demands to capacity demands is necessary, the simulation and field data location must be carefully selected. For instance, if a location in Section D was selected it would not be possible to develop a parameter set that reflects capacity with any reasonable assurance. Section B would also fail to reflect capacity, and thus not be appropriate for calibration of parameter sets. A parameter set developed based on data from these sections may significantly over or underestimate capacity as capacity was not considered in the calibration. The beginning of a bottleneck, i.e., start of Section C, will often provide a useful location for calibration.

PTV-VISSIM example for link selection

Figure 23 provides speed-flow data drawn from a developed PTV-VISSIM® simulation. This example is for a four-lane freeway segment as discussed. An exit ramp location is modeled with a lane drop at the exit. Vehicles not exiting must merge into the through lanes, resulting in a bottleneck. Traffic demand gradually increases from below capacity to above capacity, returning to below capacity, until all congestion clears. Figure 23(a) data is recorded upstream of the bottleneck while Figure 23(b) data is recorded for the through lanes at the exit point (i.e., location of the bottleneck). It is seen that the upstream position, Figure 23(a), does not clearly show the link capacity or full speed flow diagram. In this section traffic maintains a high speed until the spillback from the bottleneck related breakdown results in a significant drop in speed. Whereas at the exit location, Figure 23(b), the speed flow diagram demonstrates a clear indication of the capacity conditions. Figure 23(b) does not contain data in the unstable flow regime as there is no location further downstream resulting in spillback to the exit location. In this instance, field data from the bottleneck location should be used to calibrate the model at the exit location. Unless there is a geometric or other reason to expect different car following behavior at the upstream location the same parameter set would be used.



(a) (b)

Figure 23. Graph. Speed flow: (a) upstream of exit bottleneck, (b) at exit bottleneck.

Helpful Hints

As discussed, the calibration will occur at a link level. For large models with long run times it may prove efficient to break out a small section of the model with the critical links for calibration, or not load portions of the model with traffic. While the full, loaded model may be utilized, depending on model size this could result in excessive time for calibration runs. Once the calibrated parameter sets have been determined they may be applied to the full model. Engineering judgement should be utilized to decide if using only a subsection of the model for calibration efforts is reasonable, considering in part the time required to develop the sub network model vs the runtime required for the potential numerous replications of the full network as part of the calibration process.

Demand volume considerations

For the Wiedemann 99 calibration this procedure recommends considering at least two scenarios as part of a full calibration process. The first is for the time period under consideration. For instance, during the PM peak with the field measured traffic demands (see time period discussion). For this scenario field data is used for the existing time period of interest and the simulation is developed for the equivalent time period (accounting for warm-up time, etc., as discussed in Module 7).

The second scenario of the model is to ensure that a range of demands are captured, from low flow to demand in excess of capacity. This scenario it used to ensure the overall speed-flow relationship is reasonable. For the field, this data is ideally obtained for the location of interest over an extended period, on the order of multiple days or months. It is important that these data capture a range of flow from stable flow through capacity conditions. Where such data are not available the simulation team may seek data for a site with expected similar performance or find other means to estimate a reasonable speed flow diagram. For example, Figure 24 is the speed data for two months of data from the GDOT VDS system at a site on I-85 before Pleasantdale Road.

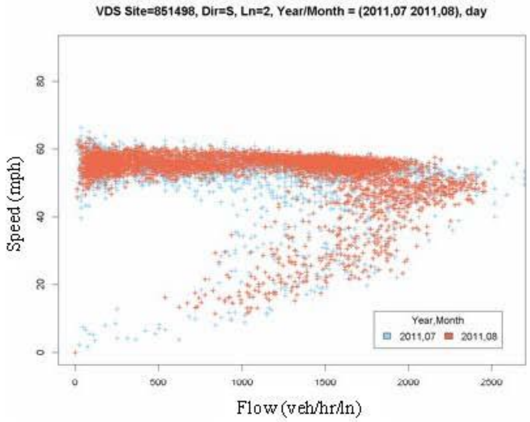


Figure 24. Graph. Speed flow diagram for two months of data at I-85 before Pleasantdale Rd.

To obtain the data for a similar speed-flow diagram in VISSIM®, scenario demands may be placed similar to those seen in Figure 25. The volume (i.e., demand) is increased from a low value until the demand exceeds capacity, then the demand is dropped to the original low value. The simulation should be run until the congestion clears. By covering the range of demands the speed-flow relationship for the link may be determined. As an important caution, Figure 25 is for the demand on the link being calibrated, not necessarily the overall model. Where the full model is being utilized for calibration the model developer will need to ensure that the desired flows are able to reach the link under consideration. The images in Figure 23 utilized a demand scenario similar to that in Figure 25.

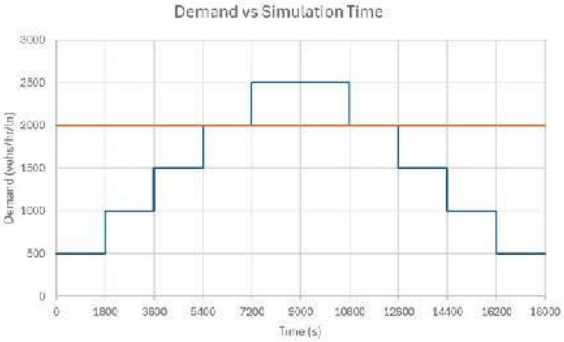


Figure 25. Graph. Demand vs Simulation Time for Car Following Model Calibration.

Existing Scenario Clarification

In the time period discussion, the PM peak was mentioned as an example. Other time periods, e.g., PM, noon, off-peak, etc. can be used as well. It is recommended for model calibration to use a time period with heavy traffic, although not in breakdown throughout the model period. Breakdown conditions are considered in the second scenario where a much longer timeframe is considered, as well as in potential subsequent checks of the overall model. Also, while the developed calibration set should be tested across all time periods of interest, it is typically not recommended to develop time period specific parameter sets. This is likely over specifying the model parameters. A challenge of using different parameter sets for different time periods is that significant uncertainty exists when determining the appropriate parameter set for build or future conditions. It is best to select a parameter set that is robust across time periods, although may not be optimal in any individual case.

Example calibration steps - Wiedemann 99

The calibration steps discussed are intended to be straightforward, without relying on any "black box" algorithms. The steps are to: 1) Check the results of the default parameter set versus the field observation, 2) Calibrate the Desired Speed distribution, 3) Calibrate the CC1 parameter, and 4) Calibrate CC2 (only if needed). In most circumstances additional CC parameter calibration should not be necessary.

To calibrate the car following models it is necessary to have the appropriate data. As discussed, for the approach described here, it is assumed that speed, flow, and headway distribution data are available. Depending on the data source, vehicle speed and flow data may be available in various forms. For this example, the initial data source was two hours of video recording during the afternoon peak for I-85 S before Buffington Rd at MM 67.6, with flow levels generally between 1400 and 1800 veh/h/ln. This freeway segment has 4 lanes in the direction of travel considered, and a posted speed limit of 65. These video data were processed using the Data-from-the-Sky™ application, allowing for the generation of trajectory data for all vehicles through the video zone. Other commercial video processing services are also available as well as from a range of both proprietary and open-source software.

From these trajectory data individual vehicle headways and speed distributions were obtained for a screen line across the roadway. Additionally, speed flow data in 1-, 5-, 15-, and 30-minute bins were processed for the same screen line. The second data set used here was speed - flow data from the GDOT VDS system over a several month period. These data were obtained as 30 second bins and thus individual vehicle speeds and headways were not available from these data.

Step 1 – Default Parameters and Desired Speed Distribution

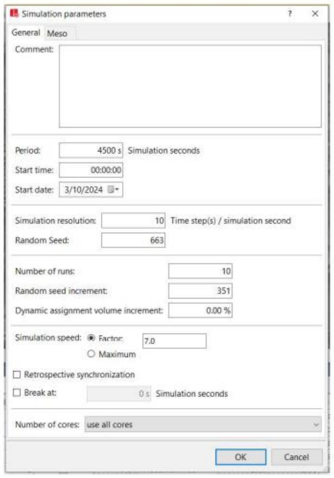
Prior to any calibration, it is first necessary to determine how well the verified model with default parameters reflects the field observations. As stated, it is recommended to consider the speed-flow relationship, headways distribution, and speed distribution. Data collection points will need to be placed at the appropriate location in your model to collect the model results. Guidance on how to set up data collection points may be found in Module 6. To obtain this data run the model, model run parameters are shown in Figure 26. In this example, results from ten replicate runs were aggregated and averaged. While ten replicates will typically prove to be sufficient, additional detail on replicate trials may be found in Module 7.

When running this initial scenario, there are two result files that should be examined for each run:

- Data Collection Point (DCP) files, which can be found under the "Direct Output" tab of the Evaluation Configuration pane (Figure 27)
- Data Collection Results (DCR) files, which can be saved from the Data Collection Results pane (accessible through Evaluation -> Result Lists -> Data Collection Results (Figure 28)

Helpful Hints

It is vital for a clear data management system to be in place, as all files will be output to the same evaluation output directory (specified at the top of Figure 2). As many sets of replicate runs may be performed during the calibration process, if the output is not filed correctly, it will become difficult to differentiate which files belong to which set of runs. For this reason, it is highly recommended that a file management protocol/standard be developed before calibration begins.


Simulation parameters

Comment:

Period: 4500 s Simulation seconds
Start time: 00:00:00
Start date: 3/10/2024

Simulation resolution: 10 Time step(s) / simulation second
Random Seed: 663

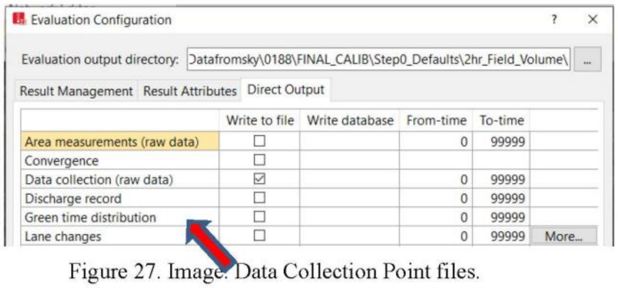
Number of runs: 10
Random seed increment: 351
Dynamic assignment volume increment: 0.00 %

Simulation speed: ● Factor: 7.0
○ Maximum

☐ Retrospective synchronization
☐ Break at: 0 s Simulation seconds

Number of cores: use all cores

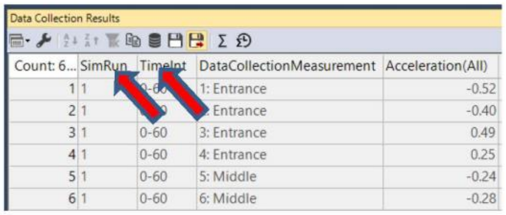
Figure 26. Image. Simulation Parameters for Default Runs.


Evaluation Configuration

Evaluation output directory: Datafromsky\0188\FINAL_CALIB\Step0_Defaults\2hr_Field_Volume\

	Write to file	Write database	From-time	To-time	
Area measurements (raw data)	☐		0	99999	
Convergence	☐				
Data collection (raw data)	☑		0	99999	
Discharge record	☐		0	99999	
Green time distribution	☐		0	99999	
Lane changes	☐		0	99999	More...

Figure 27. Image. Data Collection Point files.


Data Collection Results

Count: 6...	SimRun	TimeInt	DataCollectionMeasurement	Acceleration(All)
1	1	0-60	1: Entrance	-0.52
2	1	0-60	: Entrance	-0.40
3	1	0-60	3: Entrance	0.49
4	1	0-60	4: Entrance	0.25
5	1	0-60	5: Middle	-0.24
6	1	0-60	6: Middle	-0.28

Figure 28. Image. Data Collection Results list, notice that the autosave function should be toggled and the summary statistics not selected).

Using the DCP files, plot the CDF (Cumulative Distribution Function) plots of the headways across all lanes. Overlay this plot with the field-collected data. Figure 29 is an example plot containing the field and simulated data, with all default CC parameter settings in the simulation. When processing the simulated data, filter the DCP files according to t(Entry) (or t(Exit)). This will ensure that the simulated headways are front-to-front (see caution below). As seen in Figure 29, with the default parameters there are differences in the headway distribution, particularly at the lower headway values, under two seconds duration.

Caution: Be sure the vehicle data collection method from the field and your PTV-VISSIM® model match. That is, make sure you are measuring from the same points on the vehicles in both the field and simulated data. For example, from the *front* of lagging vehicle to the *front* of leading vehicle OR from the *front* of lagging vehicle to the *back* of the leading vehicle. If the points of vehicle measurement are not the same in both the field and simulation the calibrated headways will be either long or short, depending on the error type.

Similarly, from the DCP files the simulated speed distribution can be extracted and plotted alongside the CDF of the field speeds and the desired speed distribution (Figure 30). The default speed distribution utilized was 65 mph, as this was reflective of the speed limit, which is typically utilized. In this example, the use of default distributions for a specific speed limit is not reflective of field conditions, as can be clearly seen in the difference between the blue and red lines in Figure 30.

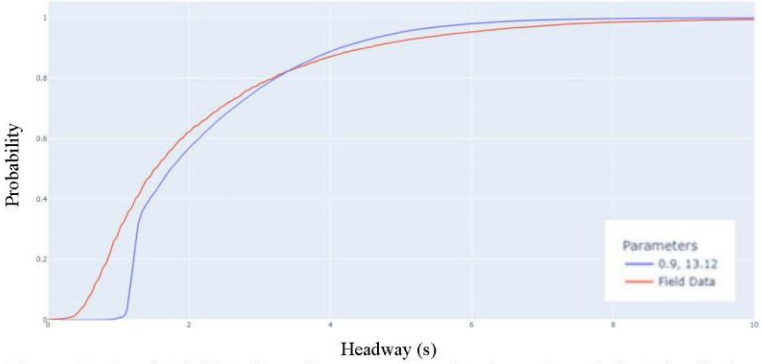


Figure 29. Graph. Field (red) vs simulated (blue) headway Cumulative Distribution Functions (CDFs).

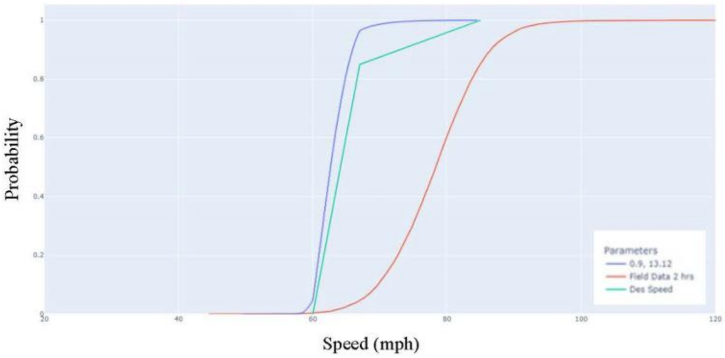


Figure 30. Graph. Desired Speed Distribution Calibration. Simulated speed distribution is in blue, default desired speed distribution is green, and field data are in red.

The Speed – Flow diagram can be obtained through the DCR files, as shown in Figure 31. This plot helps to visualize the differences between the field collected data and the simulated results. As seen, even within this relatively small range of field data the simulation does not match the field observations. The more complete speed-flow diagram will be discussed after calibration of the desired speed distribution.

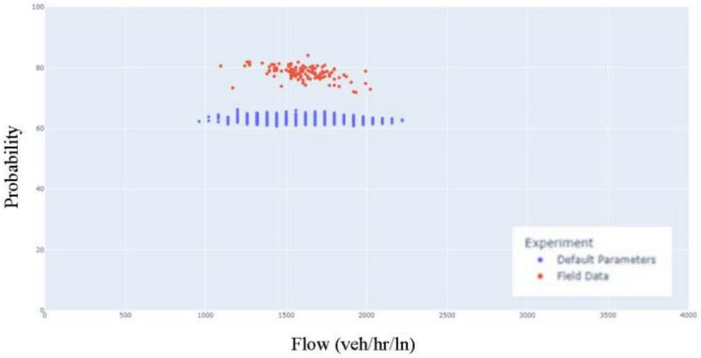


Figure 31. Graph. Speed Flow Diagram.

From this brief overview and through a rapid analysis of the three plots shown above, it is clear that a calibration of multiple model parameters is needed to achieve a reasonable simulation of field conditions.

Step 2: Desired Speed Distribution Calibration

The second step is the calibration of the desired speed distribution. The following procedure is recommended:

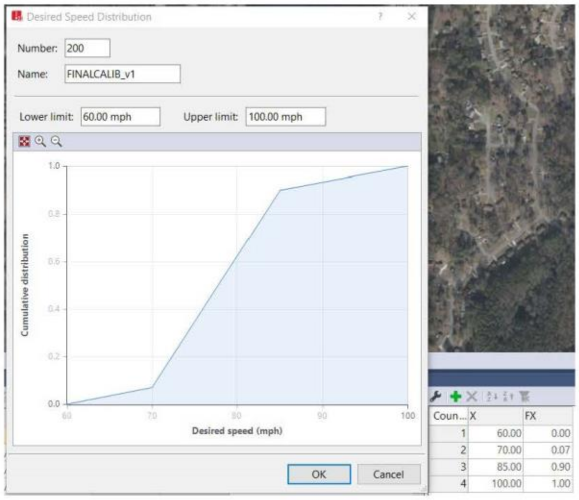
1. Take a reasonable sample of field data (e.g., 1 hour), at a medium/high flow rate (1500-1800 veh/h/ln), if available. "Reasonable sample" is left for some interpretation and understood to often be constrained by data availability; however, for a distribution estimation at least several hundred individual speed data points should be included. Speed data should also be representative of speed occurrence, that is, caution should be exercised to avoid a sampling method that is biased to high or low speeds. Data should also be held in reserve for validation. Generally, at least 20% of the data. In this example speed calibration is based on one hour of observations, with one hour of data held for validation of the desired speed distribution.
2. Fit a CDF distribution to the measured field speeds. This can be a relatively simple distribution, consisting of linear segments. Such a distribution is relatively simple to enter in PTV-VISSIM® (see Figure 32). As discussed, while traffic is heavy it should not be in breakdown, with most measured speeds under stable conditions (i.e., the top half of the speed-flow diagram). As seen in Figure 32, the first attempt at a calibration of the desired speed distribution involved a three-segment fit for the example data. (In the following test it will be discussed why the desired speed distribution is not being set according to very light or "free flow" traffic conditions.)
3. Run the simulation with the field volumes, vehicle compositions and desired speed distribution from Step 2.
4. Conduct ten or more replicate runs of the model.
5. Shift the desired speed by some small percentage, keeping the minimum speed fixed to the observed low value.
6. Iterate Step 5 until the simulated speeds sufficiently match the field observations.

These steps assume a general understanding of sampling statics and distribution fitting that is beyond the scope of this document. If the modeler is not comfortable with the concepts, they are encouraged to review some of the many available texts or online resources.

The resulting simulated speeds (plotted alongside the field-collected and the desired speed distributions) after Step 4 can be seen in Figure 33. The simulated data is labeled "0.9, 13.12", which are the default CC1 and CC2 parameters. It is seen that when the entered desired speed distribution matches the field, the simulation results in speeds lower than the field measured. Why? This is due to a significant subset of vehicles likely in car-following (or other Action Point model states) and thus unable to travel at their desired speed.

However, the objective of setting the desired speed distribution is that when the model is run the simulated speeds match the field observations. Thus, slightly shift the desired speed distribution and rerun the model. The results of shifting by 10 % (shift applied in Step 5) may be seen in Figure 33. While this is likely sufficient, in the example a few additional small "tweaks" to the desired speed distribution were made, resulting in the results shown in Figure 34 and Figure 35.

In summary, the process is to start with a desired speed distribution based on the measured field data. Then iteratively adjust the desired speed distribution until the simulated speeds match the field. A reasonable question is why not measure the desired speed distribution when the traffic volume is very low and most vehicles would be traveling at their "desired speed". The underlying reason for not doing this is that the desired speed has significant interaction with the car following CC parameters and the PTV VISSIM® Action Point model. In addition, in the field, drivers do not necessarily have a fixed desired speed, with the speed selected (i.e., "desired") changing with conditions. For example, a driver having a "free flow" speed of 70 mph when there are no other cars on the road does not mean that the driver will aggressively seek 70 mph in dense traffic. They may be content to stay in a platoon traveling at 67 mph rather than seek lane changes, or they may choose to maintain pace with a platoon traveling at 72 mph. While this is a notional example, the intent is to highlight that "desired speed" and "free flow speed" are not interchangeable terms when considering the interaction with the car following model. Further, drivers do not likely have a fixed desired speed, but rather an adaptive desired speed that changes with conditions. Thus, it is recommended to set the desired speed distribution such the simulated speeds reflects actual field conditions for demands approaching, but prior to reaching capacity and breakdown. This likely means the desired speed distribution may be slightly shifted from actual in low volume conditions; however, this is a result of it not being possible to set a single desired speed that fits all demands. The recommendation for this calibration procedure is to fit the most critical demands for the model.



Number: 200

Name: FINALCALIB_v1

Lower limit: 60.00 mph

Upper limit: 100.00 mph

Coun...	X	FX
1	60.00	0.00
2	70.00	0.07
3	85.00	0.90
4	100.00	1.00

Figure 32. Graph. Version 1 of calibrated desired speed distribution.

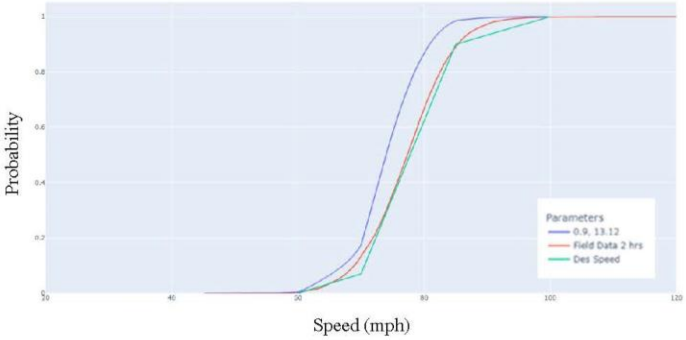


Figure 33. Graph. Plot of the speed distribution (simulated in blue, field-collected in red, desired in green).

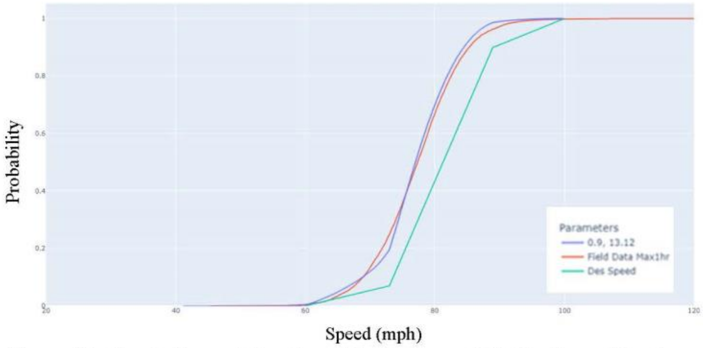


Figure 34. Graph. Second iteration of desired speed distribution calibration.

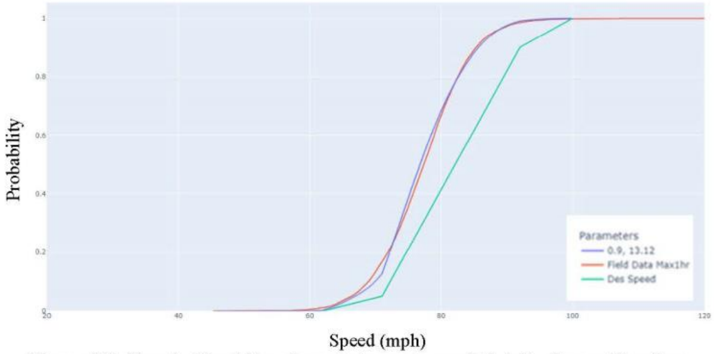


Figure 35. Graph. Final iteration of desired speed distribution calibration.

The calibration of the desired speed distribution has little to no effect on the platooning behavior, as can be seen in Figure 36, the headway distribution with the final desired speed distribution. Though the error at the top end of the distribution (> 0.9 probability) has decreased, there is still a significant gap between field and simulated headways for < 0.2 probability (i.e., platooning vehicles).

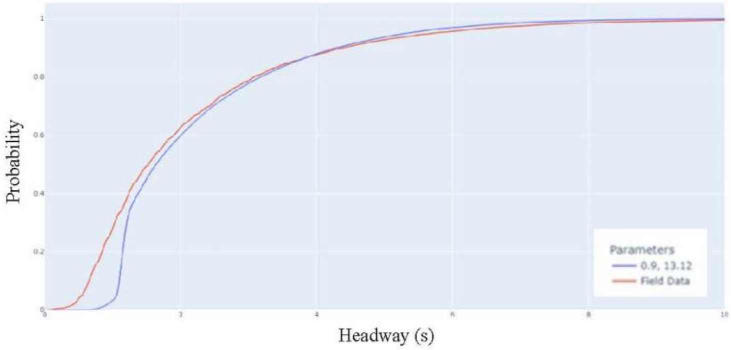


Figure 36. Graph. Headway CDF after Desired Speed Distribution calibration.

The change in desired speed distribution has, however, had the desired effect on the speed – flow diagram for the measured PM peak, as can be seen in Figure 37: by increasing both the desired speeds and, as a consequence, the simulated speeds of all vehicle, the speed – flow diagram of the simulated speeds now matches the field data reasonably well.

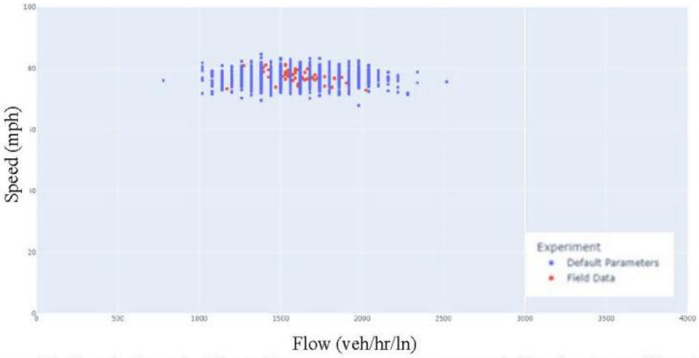


Figure 37. Graph. Speed - Flow diagram after desired speed distribution calibration.

Step 3: CC1 Parameter Editing for Platoon Calibration

The next step in the process, after desired speed distribution calibration, is the calibration of the car following model parameters. Extensive testing was conducted on different geometrical and functional types of facilities: all CC parameters were analyzed and varied to understand their effects on car following behavior. As a result of this analysis and findings from the literature, a few key results were found:

- Only a small subset of CC parameters has a clear and measurable effects on both microscopic (individual-vehicle car following) and macroscopic (overall flow and density) traffic characteristics.
- CC parameter editing should only be carried out if necessary, and any changes to the parameters should be well documented.
- Changes to CC parameters should be minimal, and modelers should avoid large departures from the default values to avoid introducing instability into the model.

Overall, the parameter whose adjustment was shown to be most impactful and relevant to both individual-vehicle and overall flow behavior was CC1 (Gap Time Distribution), whose default setting is shown in Figure 38. VISSIM's default Gap Time Distribution is a normal distribution $(\mu = 0.9; \sigma = 0)$, which means all vehicle have the same CC1, i.e., 0.9. However, for calibration purposes it is recommended to define an empirical distribution in the "Time Distribution" pane and assign it to the Driving Behavior used in the model. This allows for more control and flexibility during the calibration process.

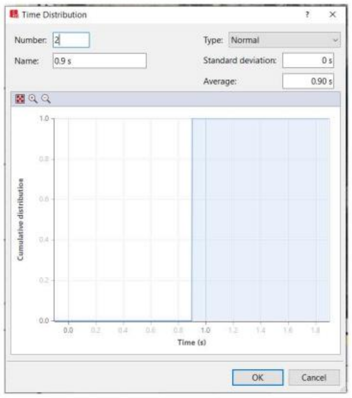
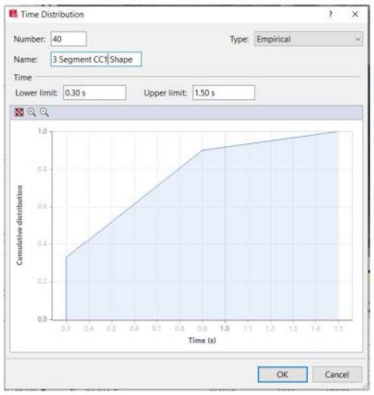

Number: 2
Name: 0.9 s
Type: Normal
Standard deviation: 0 s
Average: 0.90 s

Figure 38. Image. CC1 (Gap Time Distribution) default distribution. $(\mu = 0.9; \sigma = 0)$.

At a microscopic level, the constant value of CC1 is the main driver of the difference in platooning behavior observed in Figure 36. At a macroscopic level, CC1 was found to have a clear effect on capacity and breakdown behavior (this will be explored in Step 3). As seen in Figure 36, from a probability of approximately 0.05 to 0.3, the spacing is on the order of 1 second. This is slightly higher than the CC1 value of 0.9, due to CC0 and CC2. This implies that for this demand, approximately 25% of the vehicles are in car-following (platooned) as defined in the Action Point model (Figure 1). These vehicles are following their respective lead vehicles at their desired safety distance.

The vehicles with spacing under one second covers a range of conditions, such as vehicles temporarily violating the desired safety distance or in lane changing, or an error in the automated video data collection (for example, a vehicle pulling a trailer being identified as two vehicles with a less than 0.1 second headway). However, many of the measured lower field headways were correct. A detailed visual review of hundreds of the field data measurements was performed, using the skip lines for distance approximation. Vehicles were observed with 0.3 second and higher spacing. A majority of the field measured headways under one second appear to be correct. However, other vehicles do clearly maintain higher headways. Thus, it was deemed that rather than a fixed CC1 value a distribution of values should be used.

Within the "Time Distributions" pane, a new Time Distribution can be created and assigned either a Normal or an Empirical type distribution. Based on the field observations conducted, a subset of highly-aggressive drivers (i.e., drivers willing to follow preceding vehicles at time headways of around 0.5 seconds) were observed. To better match these very low headways observed in the field, the shape of the CC1 distribution should be edited accordingly, by introducing a percentage of drivers with a very low CC1 values.



Number: 40

Type: Empirical

Name: 3 Segment CC1 Shape

Time

Lower limit: 0.30 s

Upper limit: 1.50 s

Figure 39. Image. CC1 editing example.

The recommended CC1 calibration involves iterative parameter editing, model running, and plotting of headway distributions to achieve a good fit at the low end of the headway CDF, as shown in Figure 40. For the freeway field data in this example the lowest CC1 value was set at 0.3 seconds at 33%, 0.9 seconds at 90% and 1.5 seconds at 100% (Figure 39). The main objective in this phase of the calibration is to match the shape of the curve at the "bottom" of the CDF, seeking to better capture the observed platooning behavior, while still maintaining a distribution of longer headways.

The calibration of platooning behavior achieved in this step can be verified at a microscopic level using the proposed comparison to the headway distribution. When traffic flow conditions are below capacity, only a small portion of vehicles are in car following and subject to the calibration of CC parameters, thus the focus in this step on the lower portion of the Headway CDF (headways under approximately 1.5 seconds). Higher headway values are associated with vehicles which are not in car following.

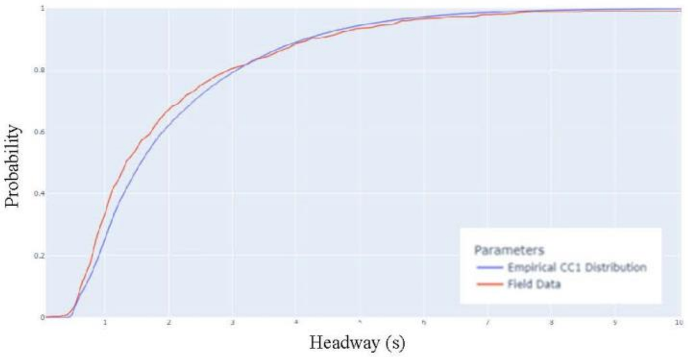


Figure 40. Graph. Headway CDF for field data (red) and simulated data with calibrated CC1 empirical distribution (blue).

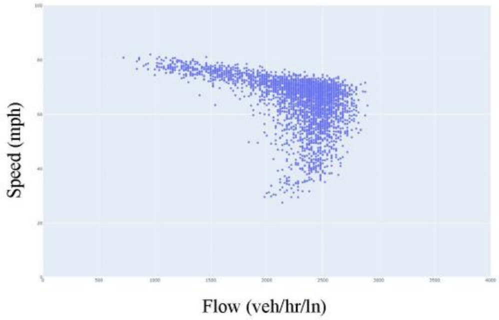
It is readily recognized that the sample calibration demonstrated is for an urban area (Atlanta) with what may be termed "aggressive" driving behaviors. Similar low headways may not be seen in other areas. This calibration should be completed for each area, reflecting the local driving population.

Step 4: Speed – Flow Diagram Calibration

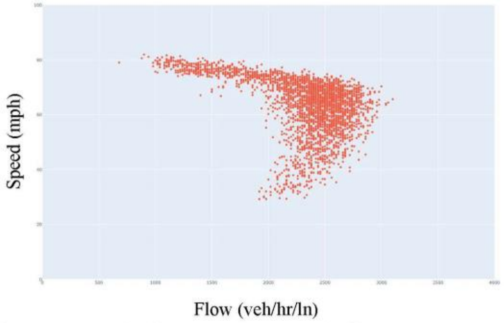
In this step of the calibration, the focus is shifted to a more macroscopic perspective, for the given link. Though the parameter editing still affects vehicle-to-vehicle behavior, the effects of these changes are measured (and calibration is performed) at a macroscopic level, which involves a higher degree of data aggregation. Binning speed (averaged across each bin) and flow values (to obtain flow rates) into 1- or 5-minute intervals yields speed – flow diagrams such as that shown in Figure 41. These point clouds are based on the modified CC1 parameter with the calibrated desired speed. For this experiment all CC1 distributions have a lowest value of 0.4 and a highest value of 1.9. The selection of the minimum value endpoint is based on matching the lower values headways distribution as described previously and the higher value is based on a reasonable maximum for car following. The midpoint values are set at 0.5, 0.7, or 0.9. As the midpoint value increases the percentage of lower CC1 values increases and the capacity should increase (i.e., the maximum observed points in the speed flow diagram shift to the higher flow values.). As seen in

Figure 41, these minor adjustments in the midpoint of the distribution allow slight shifting of the speed flow diagram, from lower to higher values. For more significant shifts in the speed flow diagram the end points would also need to be adjusted. However, if desired speed distribution and headway distribution in the prior steps have been reasonably matched, significant edits to the CC1 distribution should not be required. Additionally, as seen earlier, smaller shifts in the speed flow diagram may be achieved by editing CC2. However, it is recommended to first finalize CC1, then move on to CC2 edits, only if necessary.

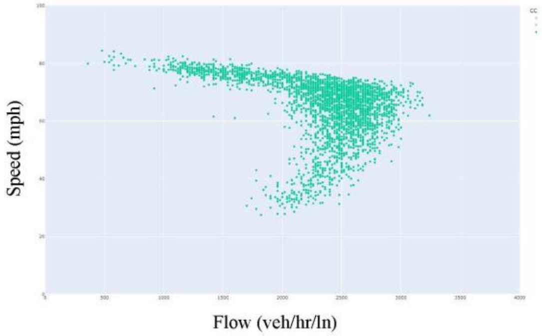
The selection of the final CC1 parameter set should be based on comparison with extensive field speed-flow data. Where such field data are unavailable, selection will need to be based on data from similar sites or expert experience on the expected behavior for the area. If at all possible, it is critical that field data be obtained for the given model. As seen, within much of the stable flow regime, the operations are robust to the parameter CC selection. That is, for demands under capacity the CC parameters do not have significant influence over the model. However, as the demands increase, capacity and breakdown are both highly influenced by the CC parameter selection. Thus, calibration for these conditions will be critical, particularly when existing conditions may not reach capacity but future or build conditions have the potential for capacity demands.



(a) CC1 Dist: 0.4 seconds @ .33%, 0.9 seconds @ 50%, 1.5 seconds @ 100%



(b) CC1 Dist: 0.4 seconds @ .33%, 0.9 seconds @ 50%, 1.5 seconds @ 100%



(c) CC1 Dist: 0.4 seconds @ .33%, 0.9 seconds @ 50%, 1.5 seconds @ 100%

Figure 41. Graph. Speed flow distribution, with adjusted desired speed distribution, for three CC1 distributions.

Step 5: Check Desired Speed Distribution

Once the CC parameters have been calibrated, modelers should check the effects that the parameter calibration has had on the accuracy of the desired speed distribution. For example, Figure 42 shows how, after an extensive CC calibration process, the desired speed distribution must be adjusted so as to generate simulated speeds that match field data. Generally, if changes to CC parameters are minimal (in number and magnitude) then no significant changes in the simulated speed distribution should be observed, but this step should always be performed to check.

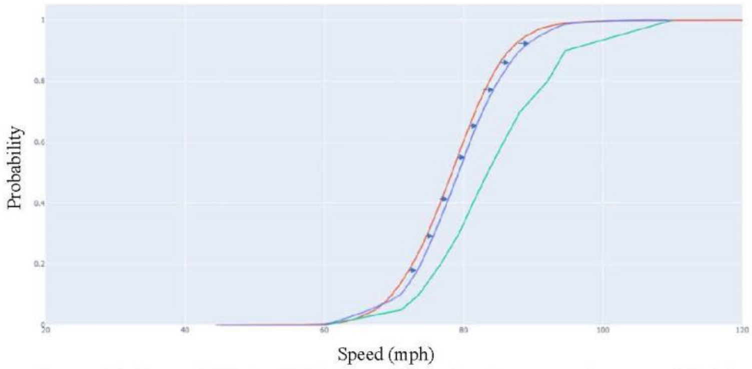


Figure 42. Graph. Effects of CC parameter calibration on desired speed distribution accuracy: as a result of changes to CC0, CC1, and CC2 the simulated speeds no longer match (see blue arrows) the field data.

Step 6: Calibration Validation

After the calibration process is complete, the calibration model should be validated using the field collected data set aside early in the process. It is important that the data (speeds, headways, flow rates) reserved for validation be collected in the same manner (and with the same precision) as the data used during calibration. The calibrated model should thus be run using the characteristics (traffic volumes, vehicle compositions, etc.) as the validation dataset and simulated results should lie within the acceptability criteria.

Summary

In summary, a six-step calibration process is recommended for the Wiedemann 99 model.

Step 1) Check the results of the default parameter set versus the field observation: Determine if it is necessary to modify the car following parameters based on a comparison of the model to existing conditions and expected operations under over-capacity demand.

Step 2) Calibrate the desired speed distribution: Set the underlying desired speed distribution form to that of the field conditions under moderate to high flow conditions. Iterate small adjustments to desired speed distribution until simulated conditions match the field.

Step 3) Calibrate CC1 for field platoon data: Calibration CC1 to replicate headway distribution for platooned vehicle.

Step 4) Calibrate Wiedemann parameters to replicate field Speed - Flow diagram: With a primary focus on CC1 the model should be calibrated to match the expected speed-flow diagram at bottleneck or critical locations. Additional CC parameters may be calibrated sequentially; however, this should typically be unnecessary.

Step 5) Verify the desired speed calibration: Confirm and update the calibrated speed distribution.

Step 6) Validation: Validate the model using the field collected data.

Example calibration steps – Wiedemann 74

Thus far this calibration document has focused on the calibration of the Wiedemann 99 model. With the nine CC parameters Wiedemann 99 is a more complex calibration compared to Wiedemann 74, which has three parameters. The complete Wiedemann 74 safety distance model, as reported in the VISSIM® manual, is as follows:

$$d = ax + (bx_{Add} + bx_{Mult} \cdot z) \cdot \sqrt{v}$$

Where:

ax: is the speed independent parameter, representing the distance between vehicles while stopped

bxAdd: is the additive part of the safety distance

bxMult: is the multiplicative part of the safety distance

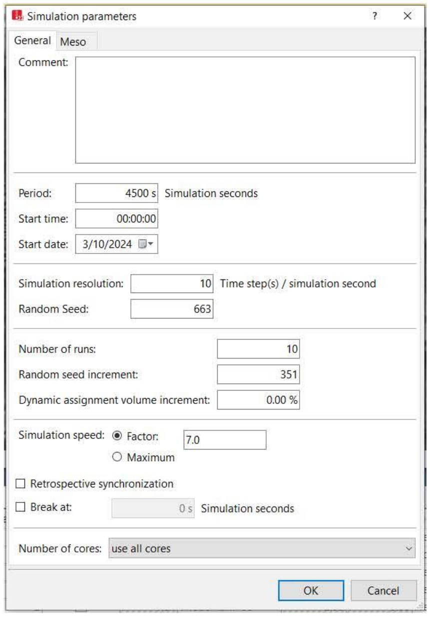
The calibration follows the same general guidance as the Wiedemann 99 calibration, begining with a comparison to field conditions, followed by the calibration of the desired speed distribution, then the calibration for the Wiedemann 74 parameters (ax, bxAdd, and bxMult), and lastly rechecking the desired speed distribution and model validation.

As with the Wiedemann 99 model the calibration is link based. However, recalling that Wiedemann 74 is generally utilized for interrupted flow facilities (e.g., arterials, intersections, etc.) simplifies the task of identifying the calibration location in the model. For the intersections the critical component relative to the car following parameters is the distribution of departure headways from the stop. Desired speeds may be calibrated at a mid-block locations.

Also, as with the Wiedemann 99 procedure, it cannot be overly stated that the model must be thoroughly checked prior to calibration. Model calibration must not be utilized to account for errors in signal timings, detector placement, conflict zones, etc.

Step 1 – Default Parameters and Desired Speed Distribution

The first step is to check how well the model with default calibration reflects speeds and stop bar departure headways. This can be done by running the model for at least one hour (plus network loading time, see Module 7), for a total of 10 replicate runs, as shown in Figure 43. Results can then be aggregated and averaged across all 10 hours. (Should the model not be reaching a steady state during the network loading time see discussion in Module 7.)



Comment:

Period: 4500 s Simulation seconds

Start time: 00:00:00

Start date: 3/10/2024

Simulation resolution: 10 Time step(s) / simulation second

Random Seed: 663

Number of runs: 10

Random seed increment: 351

Dynamic assignment volume increment: 0.00 %

Simulation speed: ● Factor: 7.0

○ Maximum

☐ Retrospective synchronization

☐ Break at: 0 s Simulation seconds

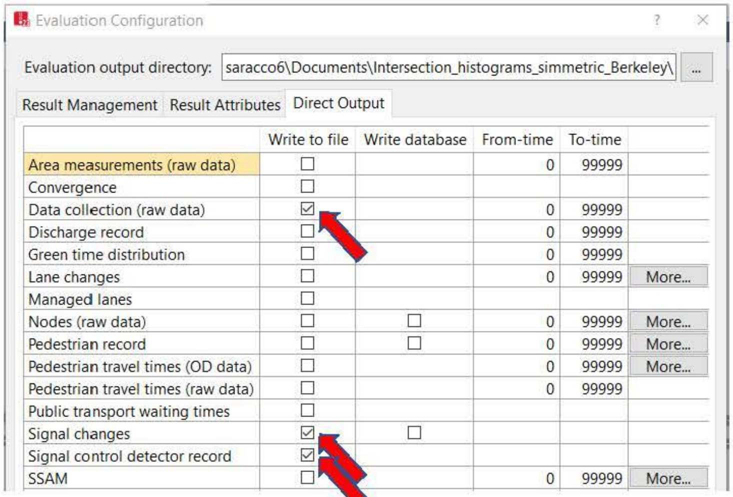
Number of cores: use all cores

Figure 43. Image. Simulation Parameters for Default Runs.

When running this initial scenario, there are four result files that should be output for each run:

- Data Collection Point (DCP) files for the detectors at the stop bar, which can be found under the “Direct Output” tab of the Evaluation Configuration pane (Figure 44).
- Trajectory files, which can be found under the “Direct Output” tab of the Evaluation Configuration pane (Figure 44).
- Signal Control Protocol (SCP) files, which can be found under the “Direct Output” tab of the Evaluation Configuration pane (Figure 44).
- Data Collection Results (DCR) files, which can be saved from the Data Collection Results pane (accessible through Evaluation -> Result Lists -> Data Collection Results) (Figure 45).

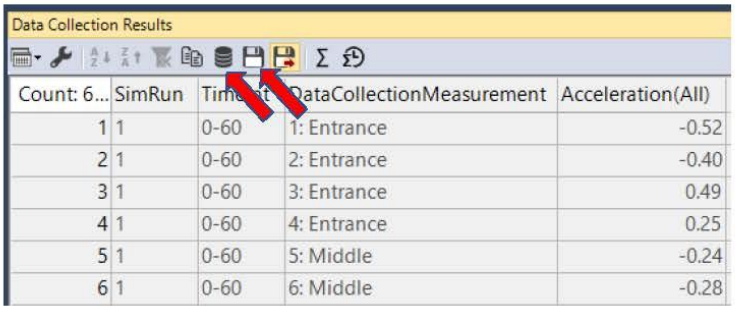
Additional guidance on data collection may be found in Module 6. Also, as noted previously, it is critical a clear data management plan be in place.



Evaluation output directory: saracco6\Documents\Intersection_histograms_simmetric_Berkeley\

	Write to file	Write database	From-time	To-time	
Area measurements (raw data)	☐		0	99999	
Convergence	☐				
Data collection (raw data)	☑		0	99999	
Discharge record	☐		0	99999	
Green time distribution	☐		0	99999	
Lane changes	☐		0	99999	More...
Managed lanes	☐				
Nodes (raw data)	☐	☐	0	99999	More...
Pedestrian record	☐	☐	0	99999	More...
Pedestrian travel times (OD data)	☐		0	99999	More...
Pedestrian travel times (raw data)	☐		0	99999	
Public transport waiting times	☐				
Signal changes	☑	☐			
Signal control detector record	☑				
SSAM	☐		0	99999	More...

Figure 44. Image. Data Collection Point files, Trajectory files and Signal Control Protocol files.



Count: 6...	SimRun	Tim nt	DataCollectionMeasurement	Acceleration(All)
1	1	0-60	1: Entrance	-0.52
2	1	0-60	2: Entrance	-0.40
3	1	0-60	3: Entrance	0.49
4	1	0-60	4: Entrance	0.25
5	1	0-60	5: Middle	-0.24
6	1	0-60	6: Middle	-0.28

Figure 45. Image. Data Collection Results list, notice that the autosave function should be toggled and the summary statistics not selected).

Using the DCP files, plot the CDF (Cumulative Distribution Function) plots of the headways departing from the stop bar, across all lanes of the movement being calibrated (though, left, right). Overlay this plot with the field-collected data, ensuring it is properly filtered to include only records of vehicles present in the queue at the time of green onset (Figure 46, this effort used data from Peachtree Industrial Boulevard in metro Atlanta Ga for the example). When processing the simulated data, filter the DCP files according to t(Entry) (or t(Exit)). This will ensure that the simulated headways are front-to-front (or rear-to-rear). Of course, if the available field data is not front-to-front or rear-to-rear, but rear-to-front this process should be modified, as noted in the Wiedemann 99 discussion.

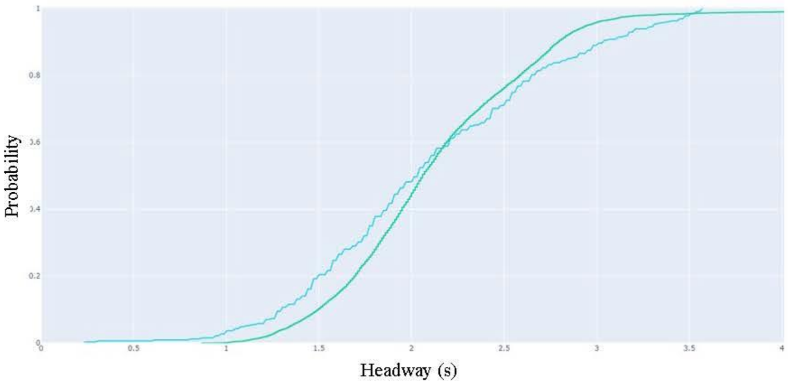
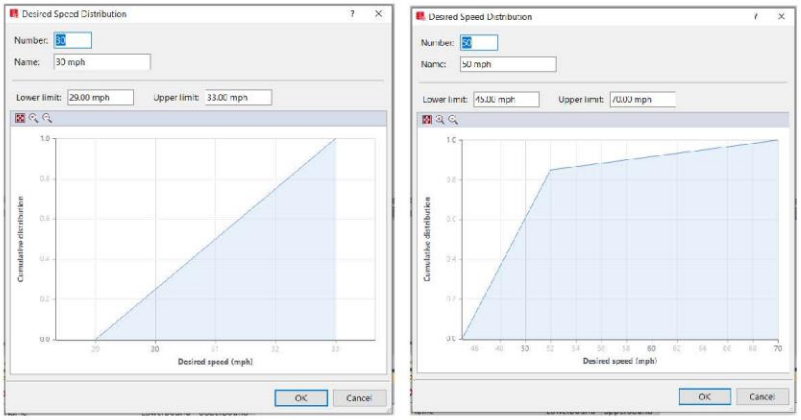


Figure 46. Graph. Field (blue) vs simulated (green) headway Cumulative Distribution Functions (CDFs).

Similarly, from the DCP files the simulated speed distribution can be extracted and plotted alongside the CDF of the field speeds at a midblock location. Additionally, the desired speed distribution should be included in the plot. In selecting a mid-block location seek a point or time where the downstream intersection queue is not backing up over the mid-block location and any accelerations have been completed from the upstream intersections. As with the Wiedemann 99 discussion, the default distribution for a specific speed limit (examples shown in Figure 47) may not be reflective of field conditions. Generally, measured speeds are higher than the speed limit and do not follow a linear (or two-segment) shape. The use of a desired speed distribution that does not conform with the field will lead to discrepancies between field-collected speeds and simulated speeds along the modeled corridor. This will impact the accuracy of travel time (and other MoEs) at a corridor level. For this reason, modelers should generally build a custom desired speed distribution based on collected field data.



Number: 30
Name: 30 mph
Lower limit: 29.00 mph Upper limit: 33.00 mph

Number: 50
Name: 50 mph
Lower limit: 45.00 mph Upper limit: 70.00 mph

Figure 47. Image. Default desired speed distributions for 30 mph (left) and 50 mph (right).

If the given utilized default speed distribution and the default Wiedemann 74 parameters do not reasonably match the field, calibration should proceed as in the following steps.

Step 2: Desired Speed Distribution Calibration

The component of the calibration is to calibrate desired speed distribution. The procedure is similar to that for the Wiedemann 99 model and is summarized here (see the Wiedemann 99 discussion for an example execution of the method):

1. Take a reasonable sample of field data (e.g., 1 hour), holding 20% of the sample for validation.
2. Fit a CDF distribution to the measured field speeds.
3. Run the simulation with the field volumes, vehicle compositions and desired speed distribution from step 2.
4. Conduct 10 replicate runs of the model.
5. Shift the desired speed by some small percentage, keeping the minimum speed fixed to the observed low value.
6. Iterate Steps 4 & 5 until the simulated speeds sufficiently match the field observations.

The calibration of the desired speed distribution has minimal effect on the behavior of the vehicles at the stop bar at the beginning of the green phase. This is because, when departing from a standing queue at a traffic signal, most vehicles do not reach their desired speed before crossing the stop bar (unless the queue is very long). This can be seen in Figure 48, where most vehicles that where in queue at the start of the phase green indication (red points in the Figure 48) reach speeds at the stop bar well below the speed limit (here 40 mph). Thus, for the calibration of the car following parameters using headways at the stop bar, the influence of the speed limit (and the desired speed distribution) is limited.

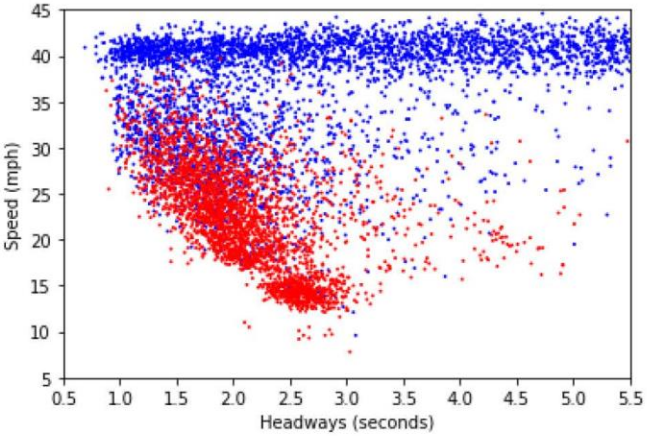


Figure 48. Graph. Simulated speed (mph) and time headway (seconds) of vehicles at stop bar. Vehicles in queue at the onset of green phase are shown in red, while all other vehicles are shown in blue.

Step 3: Wiedemann 74 ax parameter calibration

The next step in the process, after desired speed distribution calibration, is the calibration of the car following model parameters. Extensive testing was conducted to evaluate and understand the effects of changes to the speed dependent and speed independent components of the Wiedemann 74 car following model on the headway distribution at the stop bar. As a result of this analysis, a few key results were found:

- All three model parameters (ax, bxAdd, and bxMult) have a clear, measurable, and consistent effect on the headway distribution of vehicles in queue at the stop bar.
- The value of ax (the speed independent parameter) influences the width (Interquartile Range, or IQR) of the headway distribution
- The value of bxAdd and bxMult (the speed dependent components) influence the headway value of the median of the headway distribution

After having compared the field-collected headway distribution with the uncalibrated model, modelers should edit the ax parameter following this rule:

- An increase in ax value leads to an increase in the IQR of the headway distribution, coupled with a slight increase in the median.
- A decrease in ax value leads to a decrease in the IQR of the headway distribution, coupled with a slight decrease in the median.

This effect can be seen in Figure 48.

Table 1, and Figure 49. Modelers should iteratively vary ax values until the correct shape of the headway distribution is achieved. The objective in this phase is not necessarily to match the median value of the simulated headway distribution with the field-collected data, as that issue is addressed in Step 2.2.

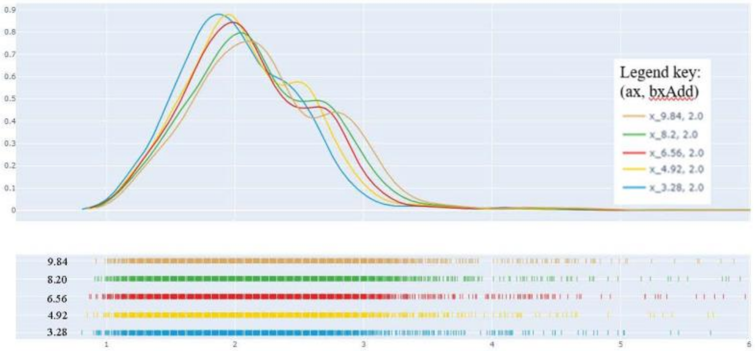


Figure 49. Graph. Effect of ax on the headway distribution of vehicles in queue at onset of green, all with default bxAdd and bxMult. Top: probability density function of headway distributions for 5 different ax values. Bottom: rugplot of headway distributions for 5 different ax values.

Table 1. Median, first & third quartiles, and IQR for different ax values.

ax Value	Median	First Quartile	Third Quartile	IQR
9.84	2.18	1.84	2.63	0.79
8.2	2.13	1.81	2.56	0.75
6.56	2.06	1.76	2.47	0.71
4.92	2.04	1.76	2.44	0.68
3.28	1.98	1.7	2.35	0.65

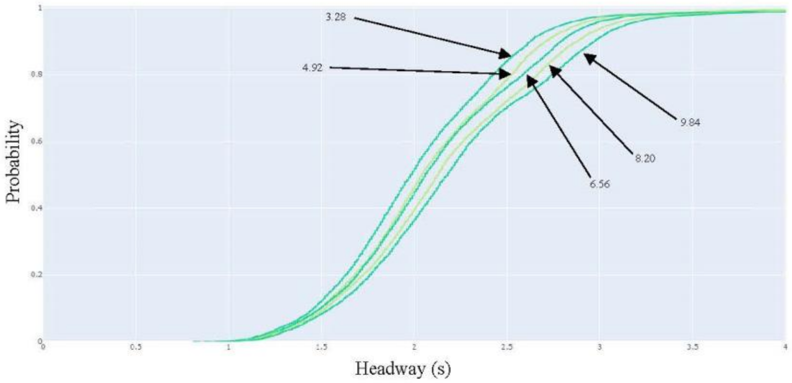


Figure 50. Graph. Simulated headway distribution for varying ax values (bxAdd and bxMult default).

Step 4: Wiedemann 74 bx parameter calibration

After having calibrated ax, modelers should turn their focus on bx. Recall, the Wiedemann 74 Model is:

$$d = ax + (bx_{Add} + bx_{Mult} \cdot z) \cdot \sqrt{v}$$

Where bxAdd is the additive part of the safety distance and bxMult is the multiplicative part of the safety distance. As for the effect on the headway distribution, both bxAdd and bxMult can be modified according to the following rule:

- An increase in bxAdd (or bxMult) leads to an increase in the median of the headway distribution.
- A decrease in bxAdd (or bxMult) leads to a decrease in the median of the headway distribution.

As seen, the two terms serve to increase headway as speed increases, with headway increasing with the square root of speed. The bxAdd term's contribution to headway is consistent across vehicles, while the introduction of the *z* term with bxMult introduces variability in headways maintained by different vehicles at the same speed. Most recommendations in the literature recommend calibration of bxAdd and bxMult together, typically fixing bxAdd = bxMult +1. While there is not a strict theoretical justification for fixing this relationship the presented calibration method in this document maintains this relationship for simplicity in calibration. However, this is not a hard rule and separate calibration may be undertaken. For instance, calibration for AV car following behavior would likely justify separate calibration, with a significant reduction in the bxMult contribution as reduced variably would be expected. Such independent calibration should not be done in a “black box” manner as it is easily possible to select differing bxAdd and bxMult parameter sets that result in very similar headway distributions. Separate calibration for the two parameters should be supported with field measurement of the variability in headways at given speeds.

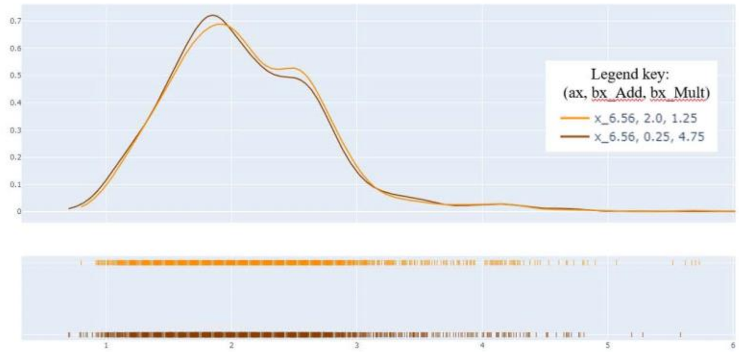


Figure 51. Graph. Example bxAdd and bxMult parameter sets with similar headway distributions.

With this additional constraint, modelers can focus on editing bxAdd, as shown in Figure 52, Table 2, and Figure 53. The modeler should select the bxAdd parameter that best match the field data distribution. An example of a completed calibration, before fine tuning is carried out, follows in Figure 52, Figure 53, Figure 54, and Table 2.

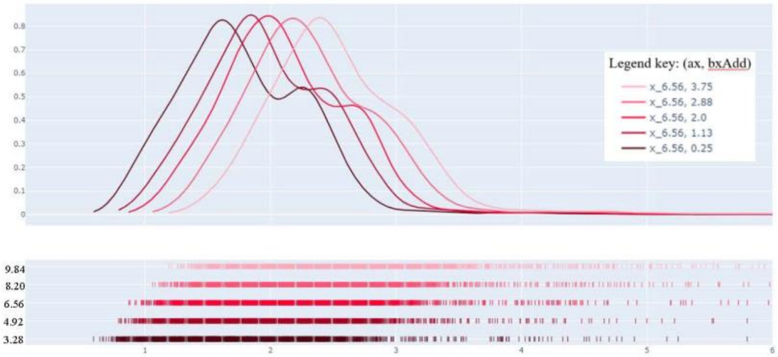


Figure 52. Graph. Effect of bxAdd on the headway distribution of vehicles in queue at onset of green. Top: prob density function of headway distributions for 5 different bx values (ax default). Bottom: rugplot of headway distributions for 5 different bx values (ax default).

Table 2. Median, first & third quartiles, and IQR for different bxAdd values.

bxAdd Value	**Median**	**First Quartile**	**Third Quartile**	**IQR**
0.25	2.47	2.16	2.86	0.70
1.13	2.26	1.96	2.65	0.69
2.00	2.06	1.76	2.47	0.71
2.88	1.93	1.63	2.35	0.72
3.75	1.72	1.41	2.16	0.75

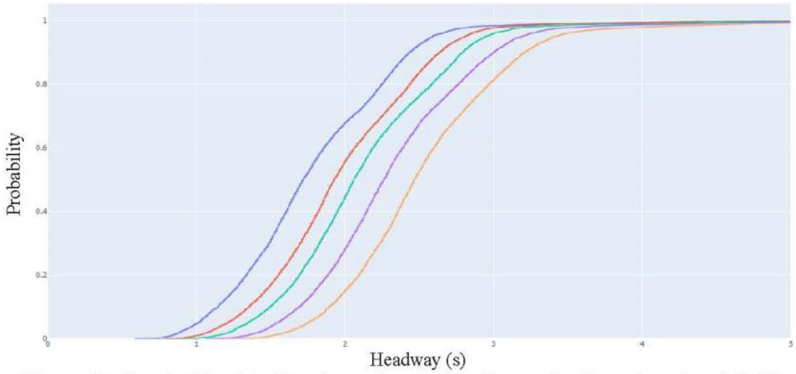


Figure 53. Graph. Simulated headway distribution for varying bx values (ax default).

By applying the procedure described in Steps 2.1 and 2.2, modelers can easily achieve a better fit to field measured headways, as shown in Figure 54. Depending on the use case, this level of calibration might meet the modeling needs identified for the project. However, should a greater accuracy be required, iterative fine tuning of ax and bx parameters is straightforward, as their effect on the headway distribution is clear.

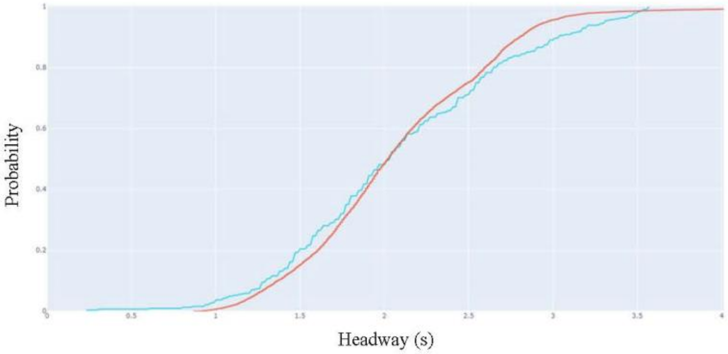


Figure 54. Graph. Example of calibrated W74 car following parameters (ax = 9.84, bxAdd = 1.13, bxMult = 2.13). Improved accuracy can be achieved by fine tuning of parameters.

Step 5: Check Desired Speed Distribution

Once the Wiedemann 74 parameters have been calibrated, the modeler should check the effects that the parameter calibration has had on the accuracy of the desired speed distribution, as in the Wiedemann 99 calibration. Generally, if changes to ax and bx parameters are minimal (in number and magnitude) then no significant changes in the simulated speed distribution should be observed, but this step should always be performed as a check.

Step 6: Model Validation

After the calibration process is complete, the model should be validated using field collected data. It is important that the data (speeds, headways, flow rates) that was stored for validation be collected in the same manner (and with the same precision) as the data used during calibration. The calibrated model should thus be run using the characteristics (traffic volumes, vehicle compositions, etc.) as the validation dataset and simulated results should lie within the acceptability criteria.

Summary

In summary, calibration of the Wiedemann 74 model consists of the following six steps:

Step 1) Checking default setting against existing conditions,
Step 2) Calibrating desired speed distribution,
Step 3) Calibrating car following parameters, ax,
Step 4) Calibration bxAdd and bxMult,
Step 5) Check desired speed distribution, and
Step 6) Model Validation

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