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VISSIM Calibration and Validation: Case Study of Freeway Weaving Segment

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***Abstract*:- Microscopic simulation models are becoming increasingly important tools in modeling transport systems. The main reason is that simulation is faster, safer, and less expensive than field implementation and testing. While these simulation models can be beneficial, the models must be calibrated and validated before they can be used to provide meaningful results.**
VISSIM is one of the most widely used microscopic traffic simulators with many applications and high potential. However, like other commercial microscopic traffic simulators, VISSIM has a very large number of input parameters which makes the model calibration rather difficult.

This work proposes a methodology for calibrating a micro-simulation model for freeway weaving segment. The data was collected for the freeway segment on northbound SH 360 between the entrance from eastbound IH20 to the exit for Mayfield Road in Arlington, Texas.

This work is a preliminary work to calibrate VISSIM in order to estimate the capacity of freeway weaving segment in the next step. Results present the most significant VISSIM parameters for capacity estimation.

Key Words: Traffic Operation, Simulation, VISSIM, Calibration, Validation, Freeway Weaving Segment.

INTRODUCTION

Microscopic simulation models have been widely used in both transportation operations and management analyses because simulation is safer, less expensive, and faster than field implementation and testing. In that regard, the calibration and validation of simulation model is crucial for appropriate decision-making process.

VISSIM implements a psycho-physical car-following model and thus provides a very realistic driving behavior. Many research has been performed in order to highlight the possibilities of calibrating and validating the microscopic traffic flow simulation model, VISSIM. Studies have presented examples of how certain parameters influence driving behavior are given by comparing a simulated approach and following process.

(Fellendorf et al. 2001) showed that microscopic calibration and validation of simulation tools based on the car-following model can reproduce traffic flow very realistically under different real-world conditions. A case study by (Park et al. 2003) appeared to be properly calibrating and validating the VISSIM simulation model for the test-bed network. The procedure consisted of measure of effectiveness selection, data collection, calibration parameter identification, experimental design, run simulation, surface function development, candidate parameter set generations, evaluation, and validation through new data collection. (Chu et al. 2003) also provided general scheme of model calibration and validation for network level simulation. They addressed various components in model calibration process.

In addition, (Shaaban et al. 2005) focused on model calibration to study an arterial segment. The proposed procedure consisted of identification of measures of effectiveness, data collection, identification of calibration parameters, determination of number of simulations runs per scenario, determination of total number of simulations runs, visualization of the animation, relative error, and validation with a new data. (Park et al. 2006) presented an effective procedure for the calibration and validation of a freeway work zone network. (Cunto et al. 2008) calibrated and validated a microscopic model in terms of safety performance. (Ge et al. 2012) also calibrated the VISSIM network model for the inner city of Zurich. The complex network of the inner city makes the computational cost of running the simulation very expensive.

Furthermore, (Manjunatha, et al. 2013) proposed a methodology for calibrating a micro simulation model for mixed traffic. They identified calibration parameters using multi parameter sensitivity analysis and obtained the optimum values for these parameters by minimizing the error between the simulated and field delay using a genetic algorithm.

In terms of VISSIM calibration several research have been done in different areas of transportation operations. However, the transportation profession has not established any formal or consistent guidelines for the development and application of these models. Thus, in this paper systematic procedure is presented for calibrating and validating a microscopic model, VISSIM.

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DATA

Data was obtained from the research by Denney and Williams (2005). The research was conducted from 1996 to 2000 with the intention of developing a new method for calculating the capacity and quality of service for weaving zones for the 2000 Highway Capacity Manual.

Specific capacity considerations must be made in weaving areas because drivers from two upstream roadways must merge into a single roadway, and then diverge into two different downstream roadways. Weaving areas are characterized by frequent lane changes, where vehicles compete for the same pavement.

The data was collected for the freeway segment on northbound SH 360 between the entrance from eastbound IH20 to the exit for Mayfield Road in Arlington, Texas (Figure 1). When entering this weaving area, northbound traffic on SH 360 required two lane changes to the right in order to exit at Mayfield.

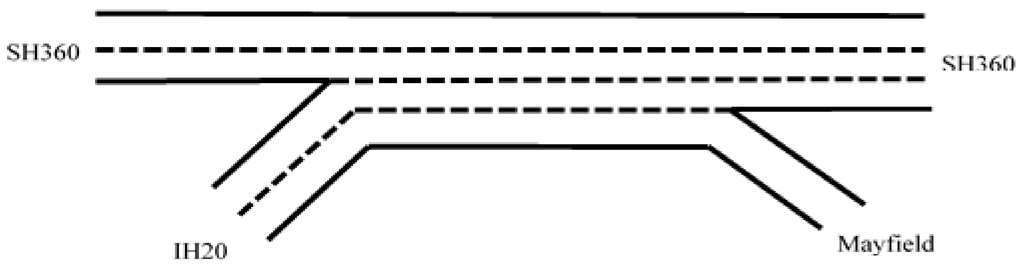

Figure 1: State Highway 360 Northbound

The above segment was fully modeled all the way back to IH20 due to the level of volume, weaving, and the distance needed for required lane changes. We did not model the exit ramp (to Mayfield) all the way to the signal, as the speed data showed that the right lane operates at free flow (over 70 mph) without any backups caused by the downstream traffic signal. Figure 2 shows the segments which we modeled for calibration purpose with a gore-to-gore distance of 1,460 ft.

In Figure 2, the darker green line is for eastbound IH 20 traffic exiting to go north on IH20 traffic. A dashed line represents where traffic streams merge and diverge.

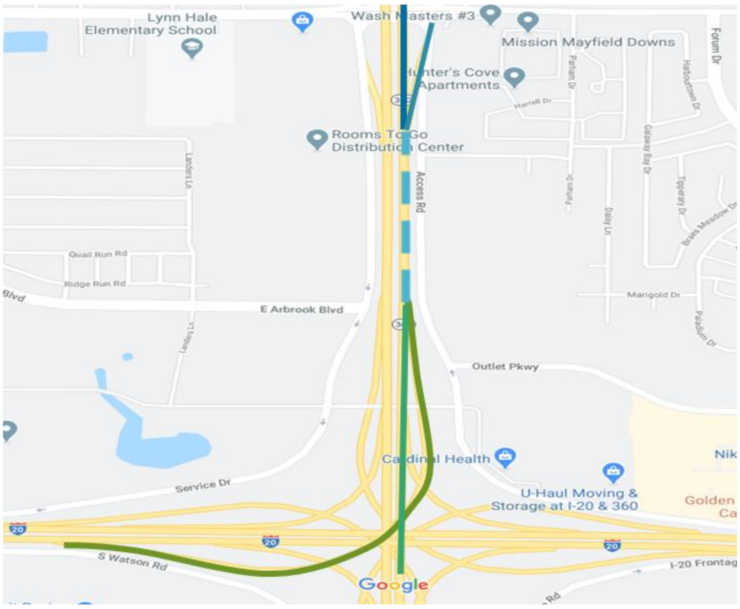

Figure 2: Calibration Segment

The site was subjected to a series of simulation runs for a range of volume and fraction of weaving traffic conditions. The proportion of weaving traffic is derived from the origin-destination information (freeway to freeway, freeway to ramp, etc.), and that for any one run, the sum of the freeway-to-freeway traffic and freeway to ramp traffic was equal to the freeway entry flow. Likewise, ramp to freeway and ramp to ramp flow summation is equal to entry ramp flow.

The weaving lanes were identified as the lanes on each side of the entrance ramp gore (right lane of the freeway and left lane of the two-lane entrance ramp), and the weaving traffic was that whose origin-destination was freeway to ramp or ramp to freeway.

At lower flows, the ramp-to-ramp traffic can largely be sorted into the right lane of the entrance ramp, and the ramp to freeway traffic can be sorted into the left lane of the entrance ramp.

VISSIM INPUT

Simulation is a key element of this research and the VISSIM 2020 platform was selected because of its capabilities. VISSIM is a microscopic, time-step and behavior-based simulation model using deterministic car following logic, and a driver behavior model. VISSIM simulates traffic flow by moving these "driver-vehicle-units" through a network. Every driver with his/her specific behavior characteristics is assigned to a specific vehicle. Therefore, the driver behavior corresponds to the technical/mechanical capabilities of his/her vehicle.

Network Geometry Coding

VISSIM networks are based on links and connectors. Links are used to define the width and number of lanes for a given roadway segment. There are different link types, and each link type is represented by its driving behavior model. Connectors are used to connect the links and implicitly have the same link types as the link from which they originate. Since this research focuses on freeway weaving, the link type for this model is freeway.

Vehicle Types and Traffic Compositions

A group of vehicles with similar performance characteristics and driving behavior is defined as a vehicle type. Typically, the following vehicle types are available: car, HGV (truck), bus, tram, pedestrian, and bike. Each vehicle type is characterized by minimum and maximum acceleration, minimum and maximum deceleration, weight, power, and length. Traffic mix is the proportion of each vehicle type present in the source flows. In calibration process, the traffic mix is: 95% car, and 5% HGV (truck).

Desired Speed Distributions

During coding, speed decisions are entered in the model based on actual measured speeds. The available time-mean speed on different lanes indicates that cars travel at speeds between 70 and 80 mph in the free-flowing lanes. Therefore, the desired speed distribution shown in Figure 3 was used in this work. In these simulations, twenty percent of the vehicles have a target speed between 70 and 72 mph; twenty percent of the vehicles are assigned a target speed between 78 and 80 mph, and the remaining vehicles are assigned a speed between 72 and 78 mph.

Figure 3: Desired Speed Distribution

Vehicle Inputs and Routing

Vehicle inputs are defined for a specific link and time period in vehicles per hour even if the time is different from one hour. Figure 4 shows time intervals for the calibration process. The total simulation time is 4,200 seconds which includes three time periods for each run; a five-minute time (0-300 seconds), one hour period (300-3900 seconds), followed by a five-minute period (3900-4200 seconds) at the end. The first period is the warm-up time, and the next hour-interval is the actual running time where the simulation outputs are collected. The 5-minute warm up time is included because the network starts empty. Time intervals are defined for vehicle input and vehicle weaving share.

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Figures 5 and 6 show vehicle input for different datasets. Data collected for the 7 to 8 pm data has total flows of 3,509 vph for the freeway entry and 3,040 vph for the entrance ramp (Figure 5). Data collected from 8 to 9 am has total flows of 3,020 vph for freeway entry and 2,578 vph for ramp entry (Figure 6).

Weaving shares are defined based on vehicles' origin-destination matrix. Traffic mix is defined in terms of cars and heavy vehicle classes. In the 7pm dataset, 8% of both classes (car and heavy vehicle) entering at ramp and the exit at off-ramp. For the vehicles entering freeway at 7pm, 6% exit at the off-ramp.

For 8am dataset, ramp to ramp distributions is 4% while freeway to ramp distribution is 96% (for both classes).

Time Intervals

Select layout... | Vehicle inputs

Count: 3	Start	End
1	0.0	300.0
2	300.0	3900.0
3	3900.0	MAX

Figure 4: Time Intervals

Vehicle Inputs / Vehicle Volumes By Time Interval

Select layout... | Vehicle volumes b

Count: 2	No	Name	Link	Volume(0)	VehComp(0)
1	1	Enterance Ramp	1: Entrance Ramp	3509.0	2: Entrance Ramp
2	2	Main Lane	2: Main Lane Entrance	3040.0	1: Main Lanes

Count: 6	Cont	TimeInt	Volume	VehComp	VolType
1		0-300	3509.0	2: Entrance Ramp	Exact
2	✓	300-36...	3509.0	2: Entrance Ramp	Exact
3	✓	3600-...	3509.0	2: Entrance Ramp	Exact
4		0-300	3040.0	1: Main Lanes	Exact
5	✓	300-36...	3040.0	1: Main Lanes	Exact
6	✓	3600-...	3040.0	1: Main Lanes	Exact

Figure 5: Vehicle Input (7pm)

Vehicle Inputs / Vehicle Volumes By Time Interval

Select layout... | Vehicle volumes b

Count: 2	No	Name	Link	Volume(0)	VehComp(0)
1	1	Enterance Ramp	1: Entrance Ramp	3020.0	2: Entrance Ramp
2	2	Main Lane	2: Main Lane Entrance	2578.0	1: Main Lanes

Count: 6	Cont	TimeInt	Volume	VehComp	VolType
1		0-300	3020.0	2: Entrance Ramp	Exact
2	✓	300-36...	3020.0	2: Entrance Ramp	Exact
3	✓	3600-...	3020.0	2: Entrance Ramp	Exact
4		0-300	2578.0	1: Main Lanes	Exact
5	✓	300-36...	2578.0	1: Main Lanes	Exact
6	✓	3600-...	2578.0	1: Main Lanes	Exact

Figure 6: Vehicle Input (8am)

VISSIM OUTPUTS

Simulation data output is collected from data collection data points. Simulation results (e.g., minimum speed, mean speed, maximum speed, number of vehicles, etc.) can be collected from a single point or a single cross section. In Figure 7, detectors are located at points midway between the ramp gores and shown by the red circles. And volume data was collected at the collected at the blue circles. Both the volumes and speeds collected at these points were used in the calibration process.

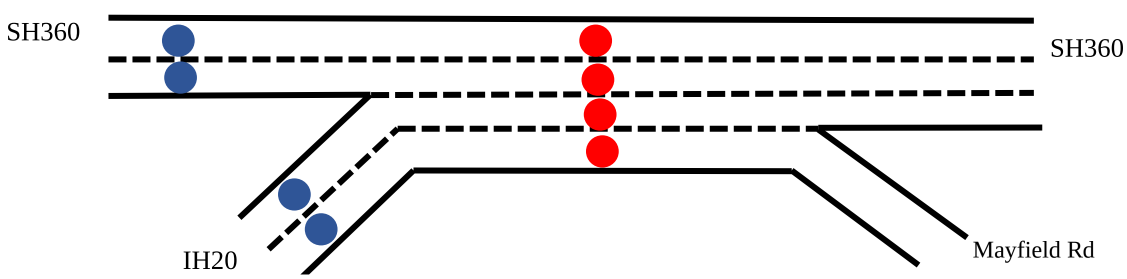

Figure 7: Data Collection Points

Number of Runs

The number of observations (simulation runs) required to find statistically significant data for the measures of effectiveness can be computed using the following equation:

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$$n = \left(\frac{Z \times \sigma}{e}\right)^2$$

Where n is the number of simulations runs required for each measure of effectiveness by location. Z is the standard normal deviation for the desired level of significance, and e is the tolerance (margin of error).

The standard deviation and mean are obtained from performing the simulation runs for 30 iterations each with a different random seed. The two major parameters, volumes for each entrance to weaving section (freeway entrance and entrance ramp) and speed for the middle freeway section were selected to calculate the required number of runs.

The number of simulations runs required for the calculation was found using the above equation, with a tolerance of (0.1) times the mean value obtained from 30 runs. The standard normal deviate for 95% confidence is 1.96. We found that three simulation runs are needed for the 7 pm dataset calibration. The average value from the three simulation runs was used to compare the results among models. However, the number of runs for validation is different from the number for calibration. The validation process using 8 am dataset is presented in the next section.

As shown in Table 1, sample size for volume on lane one of the entrance ramp (Entrance Ramp- L1) is significantly higher than other data collection points. The high entrance ramp volume (3,509 vph) combined with 92% of the entering vehicles desiring to stay on the freeway results in a greater variability, requiring a higher number of observations. Therefore, most vehicles must weave to the left at some point. This high number of lane-changes results in more variability in the outputs for the on-ramp link.

To summarize, more traffic results in more congestion resulting, in turn, in more variability, therefore, a greater number of runs are needed to get a statistically significant result.

Table 1: Sample Size (7pm)

	Volume			Speed			Confidence Interval	**Sample Size**	**Sample Size**
Data Collection Point Name	Std Dev	Mean	e(0.1)	Std Dev	Mean	e(0.1)	95%	Volume	Speed
Freeway L4				1.09	61.64	6.16	1.96		1
Freeway L3				1.05	59.03	5.90	1.96		1
Freeway L2				0.86	58.38	5.84	1.96		1
Freeway L1				0.97	63.40	6.34	1.96		1
Entrance Ramp- L2	21.9	2,400	240				1.96	1	
Entrance Ramp- L1	68.2	814	81.4				1.96	3	
Freeway Entrance- L2	16.8	1,464	146.4				1.96	1	
Freeway Entrance- L1	14.2	1,570	157				1.96	1	
								n=3	

CALIBRATION

The model is calibrated using the data collected in the field for the 7 pm interval. For calibration, a variety of simulation runs are made over a range of values of selected parameters until the best-fit model is found. The parameter selection methodology consists of iterated runs, visual evaluation, and volume and speed comparisons. Volume counts for each entrance lane (freeway entrance and entrance ramp) were available and compared with the output values of the VISSIM model. The locations where volumes were collected and compared are indicated in blue circles in Figure 7. Similarly, time-mean speeds for each lane on the freeway midway between adjacent ramps are compared with field values (red circles in Figure 7).

Field and VISSIM output speeds were found to be visually satisfactory and within a reasonable variance. Since only four travel speed samples were available, the speed comparison with a 5% tolerance interval is used to make sure that the travel speeds from the simulation output are reasonable when compared with the field values.

The accuracy of VISSIM's simulated volumes compared to the original field volumes is confirmed by the volume comparison in Table 2. The GEH measure was also calculated for each volume and evaluated using Table 2. M is the simulated volume and C is the is the measured volume (both are hourly volumes).

$$GEH = \sqrt{\frac{2(M-C)^2}{M+C}}$$

Calibration targets in Table 2 (coming from Wisconsin DOT VISSIM guide) show that for links that have flows less than 700 vph, 85% of model flows must be within 100 vph of the actual count. Links with the flows between 700 and 2,700 vph, 85% of model flows must be within 15% of the actual count. And for links with flows more than 2,700 vph, 85% of model flows must be within 400 vph of the actual count.

GEH should be less than 5 for individual links in 85% of link flows. The lower the GEH, the fitter the model is. In traffic modelling, a GEH of less than 5 is considered to be a good match between the modelled and observed hourly volumes. GEHs in the range of 5 to 10 may warrant investigation. If the GEH is greater than 10, there is a high probability that there is a problem with either the travel demand model or the data (FHA, 2019).

The Wisconsin DOT freeway model calibration target table (Table 2) leaves the acceptance of model speed to the analysts. The speed for individual link should be visually acceptable to the analyst's satisfaction and within reasonable variance from the field data.

Table 2: Freeway Model Calibration Targets (FHA, 2019)

	MOE Criteria	Calibration Acceptance Targets
Individual Link Flows	< 700 vph	Within 100 vph of field flow for > 85% of cases
	700 to 2,700 vph	Within 15% of field flow for > 85% of cases
	> 2,700 vph	Within 400 vph of field flow for > 85% of cases
	Sum of all links flows	Within 5% of sum of all link counts
GEH Statistic	For individual link flow	GEH < 5 for > 85% of cases
	For sum of link flow	GEH < 4 for sum of all link counts
	Individual link speed	Visually acceptable to analyst's satisfaction

PARAMETER ADJUSTMENT

Model calibration is the procedure where parameters are adjusted so that the model represents local driver behavior. Calibration is important because no single model is expected to have the ability to equally represent all possible traffic conditions. Every microscopic simulation software package includes a set of parameters for the purpose of calibrating the model to local conditions. The calibration process is an optimization procedure that requires an unpredictable number of iterations.

Lane Change Distance (LCD) refers to the location where a vehicle in the model will start trying to make a lane change prior to a decision point (i.e., freeway exit). The default setting for this distance is 656.2 ft. In most freeway networks, this distance is not realistic; causing vehicles to change lanes too late on freeways. It is important, however, to evaluate the network-wide impact of large LCDs, as overlapping lane change maneuvers can have adverse effects on upstream traffic. Moreover, LCD modifications greatly impact network performance within and outside the influence area and should be considered in the initial steps of the calibration process. The Emergency Stop Distance (ESD) can also be updated to more realistically match the location vehicles ultimately stop to wait for a lane change. It is important, however, to evaluate the network-wide impact of large LCDs, as overlapping lane change maneuvers can have adverse effects on upstream traffic.

Driving Behavior is one of the most important elements in a simulation a weaving segment. (PTV VISSIM 10 USER MANUAL, 2018)

VISSIM represents vehicular interactions using the Wiedemann 74 and Wiedemann 99 car-following models alongside additional proprietary lane changing models. Wiedemann 74 model is used for local/urban roads while Wiedemann 99 model is used for freeway modeling. These models are controlled by a set of parameters located in a driving behavior container. Driving behavior containers are assigned to each link in a network to dictate how vehicles traverse the link and interact with one another.

A new feature in VISSIM 2020 allows us to define these driving behaviors by individual lanes in every link. Previously, driving behavior was only applied to the entire link.

For this study calibration purpose, driving behaviors were defined in two categories, basic freeway (driving behavior 1) and weaving behavior (driving behavior 2). Weaving behavior was applied to the lanes on each side of the entrance ramp gore (freeway second and third lanes from right), and the weaving traffic was that whose origin-destination was freeway to ramp or ramp to freeway. The most right and the most left lanes of freeway are followed driving behavior 2.

Driving Behavior/ Lane Change logic is a key element in simulating a weaving section. There are two types of lane changes in VISSIM: necessary and free lane changes. A necessary lane change occurs when a vehicle must make a lane change in order to reach the next connector of a route while a free lane change occurs when drivers have more room and time to change their lanes. In the case of a free lane change, VISSIM checks for the desired safety distance of the trailing vehicles on the new lane, which depends on its speed and the speed of the vehicle that wants to change to that lane.

Cooperative Lane Change (CLC) is a binary parameter that is deactivated by default in VISSIM. By activating this parameter, vehicles are conditioned to identify opportunities to assist other vehicles in making lane change maneuvers. This feature allows a vehicle traveling on the freeway to make an unnecessary lane change to create space for a merging vehicle to enter the freeway. Activation of CLC in heavy weave and merge areas is beneficial to freeway operations and can be used to prevent unrealistic wait times as a vehicle merges into the network. The impact of activating CLC at a weave, merge, or diverge segments can be seen further upstream as the increased number of lane changes produces upstream traffic flow turbulence.

Advanced Merge is shown to improve the fluidity of traffic flow through heavy weave segments. If this option is selected, more vehicles can change lanes earlier, increasing the operational capacity of the roadway and reduce the probability that vehicles will come to a stop waiting for a gap.

The Emergency Stopping Distance is the distance where a vehicle will stop to wait for an opportunity to change lanes in order to stay on its route if the vehicles cannot change lanes because of heavy traffic.

The Waiting Time before Diffusion is the maximum time a vehicle can wait at the emergency stop position for a gap to change lanes in order to stay on its route. When the time is reached, the vehicle is taken out of the network. The original purpose of this feature was to prevent unrealistic queues caused by vehicles not being able to make a lane change. Proper measures should be taken to limit the number of vehicles removed from the network to less than 5%.

Minimum Headway (front/rear) defines the minimum distance to the vehicle in from that must be available for lane change in standstill condition.

Safety Distance Reduction Factor (SDRF) is a multiplier in lane-change algorithm that reduces the minimum safety distance required between the trailing and proceeding vehicles to initiate a lane change.

The lane change parameters in the calibration process are summarized in Table 3. Cooperative lane change, advanced merge, and vehicle static routing decision look ahead parameters have been activated as they have a positive effect on the traffic flow. Other lane change parameters have been kept as default except waiting time before diffusion that is reduced to 40 seconds, as opposed to the default value of 60 seconds, in order to prevent bottlenecks and queues in the network. Results show that this reduction does not have a negative effect on the network flow rate.

Table 3: Lane Change Parameters

Parameters	**Driving Behavior 1**	**Driving Behavior 2**	**Default Value**
Cooperative Lane Change	**Activated (with default value)**	-	-
Advanced Merge	**Activated**	**Activated**	-
Vehicle Weaving Share Look Ahead	**Activated**	**Activated**	-
Emergency Stopping Distance	**16.4 ft**	**16.4 ft**	**16.4 ft**
Waiting Time Before Diffusion	**40 s**	**40 s**	**60 s**
Minimum Headway	**1.64s**	**1.64s**	**1.64s**
Safety Distance Reduction Factor	**0.6**	**0.6**	**0.6**

Driving Behavior/ Car Following Model

Car-following models provide quantitative values of the acceleration/deceleration for one vehicle following another when the leading vehicle changes its speed over time. Since this project is about freeway weaves, only the Wiedemann 99 model is used. The Wiedemann 99 model consists of ten adjustable parameters: CC0 to CC9. Those CC-parameters that are modified from the default values were described below:

CC0 (Standstill Distance) represents the minimum allowable gap between vehicles at a complete stop. This parameter is used to calculate the desired following distance. It serves as the bare minimum following distance and remains a baseline as the following distance increases with increases in speed.

CC1 (Headway Time) is used as an input that reflects the average time headway maintained by vehicles and is used to calculate the desired following distance of each vehicle from the leading vehicle. The CC1 parameter should remain consistent throughout the entire freeway network.

CC0 and CC1 are used to calculate the safety distance defined as a minimum distance a driver will keep while following another car:

Safe distance= CC0+ V*CC1, where V is the speed of the trailing vehicle.

CC2, Following Variation rather than directly contributing to the computation of the desired following distance as the CC0 and CC1 parameters do this parameter is used to set the boundary or range of acceptable following distances a vehicle can maintain before corrective action (i.e., acceleration or deceleration) is taken. Essentially, the CC0 and CC1 parameters define the "average desired following distance" and the CC2 parameter defines the amount of allowable oscillation around that mean. A larger CC2 value provides a wider range in allowable following distance, while a smaller CC2 value gives a narrower range.

While CC0 and CC1 values should stay consistent among continuous freeway segments, CC2 values can be updated to more realistically model differences in observed behavior. In general, the value for CC2 along freeway basic segments should be less than the CC2 value at weave, diverge, and merge segments.

Due to the high volume entering the freeway from the entrance ramp (especially the left lane), queues occurred as the entering car could not find enough space between cars in the other lanes to perform a lane change. Adjusting CC0, CC1, and CC2 provides enough space for lane changing. CC0 is adjusting this space in the stopping situation and CC2 is for the stop and go situation.

Six models have been developed in terms of CC0, CC1, and CC2 adjustment as they were the most effective variables in terms of car following. The results have been compared to each other in terms of volume and speed to select the fittest model. Iterations have shown that other CC parameters do not have significant effect on the network performance.

Table 4: Car Following Parameters

Parameters	**Driving Behavior 1**	**Driving Behavior 2**	**Default Value**
CC0	**Iterative Parameters**		
CC1			
CC2			
CC3	**-8**	**-8**	**-8**
CC4	**-0.35**	**-0.35**	**-0.35**
CC5	**.35**	**.35**	**.35**
CC6	**11.44**	**11.44**	**11.44**
CC7	**0.82**	**0.82**	**0.82**
CC8	**11.48**	**11.48**	**11.48**
CC9	**4.92**	**4.92**	**4.92**

In models presentation:
Ent. R-L1: is the rightest lane entering ramp.
Ent. R-L2: is the second lane from right entering ramp.
Main Ent- L1: is the rightest lane entering freeway.
Main Ent- L2: is the second lane from right entering freeway.
Freeway L1: is the rightest lane on freeway.
Freeway L2: is the second lane from right on freeway.
Freeway L3: is the third lane from right on freeway.
Freeway L4: is the fourth lane from right on freeway.

- Basic freeway (driving behavior 1) applies to the most right and the most left lanes of freeway.
- Weaving behavior (driving behavior 2), applies to the lanes on each side of the entrance ramp gore (freeway second and third lanes from right), and the weaving traffic was that whose origin-destination was freeway to ramp or ramp to freeway.

Model 1

Model 1 has CC0 equal to 4.92 ft for both behaviors, CC1 equal to 0.9 for both behaviors, and CC2 equal to 12 for behavior 1, and equal to 14 for behavior 2 (Table 5). CC2 is less on behavior 1 than behavior 2 as vehicles in lanes with behavior 1 require less lane changing than weaving vehicles.

Results show that overall GEH is too high and speed on lanes 1 and 4 on the freeway are too far from desired speed. However, the volume comparison is not that off. (Table 6 and Figure 8 and Figure 9)

Table 5: Car Following Parameters- Model 1

Parameters	**Driving Behavior 1**	**Driving Behavior 2**	**Default Value**
CC0	**4.92**	**4.92**	**4.92**
CC1	**0.9**	**0.9**	**0.9**
CC2	**12**	**14**	**13.12**

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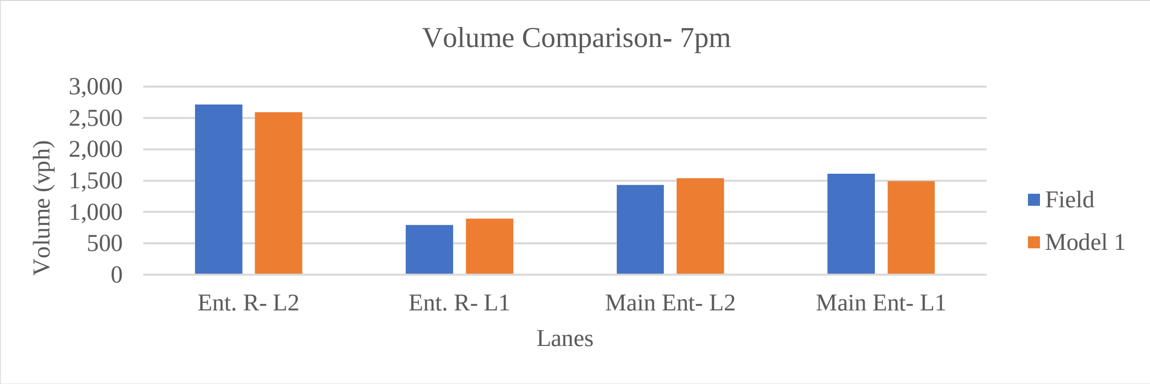

Figure 8: Model 1- 7pm- Volume

Table 6: Model 1- 7pm- GEH

Volume (vph)	Vehicle Input (vph)	Field Volume (vph)	VISSIM Volume (vph)	GEH
Ent. R- L2	3,509	2,716	2,594	2.4
Ent. R- L1		793	893	3.4
Main Ent- L2	3,040	1,430	1,538	2.8
Main Ent- L1		1,610	1,494	2.9

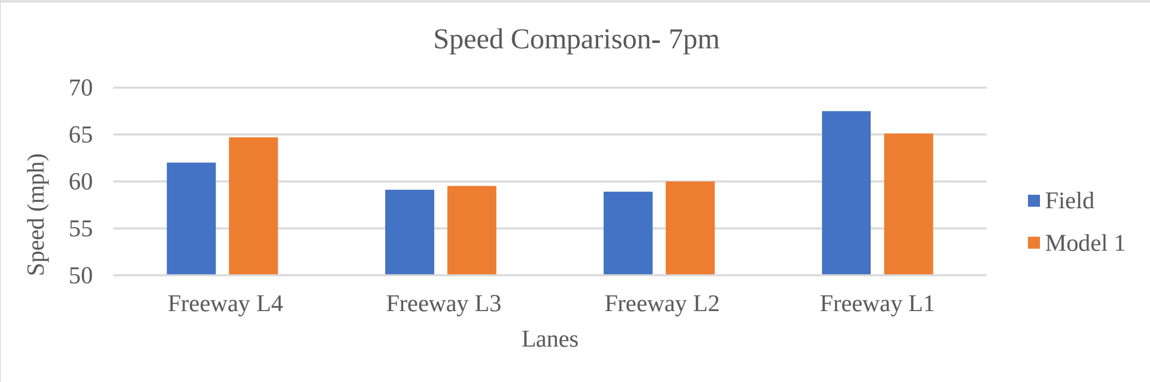

Figure 9: Model 1- 7pm- Speed

Model 2

Model 2 has CC0 equal to 9 and CC1 equal to 0.9 for both behaviors. CC2 is equal to 12 for behavior 1, and 14 for behavior 2 (Table 7). CC1 is higher in this model than model 1 to let vehicles change lanes.

Figure 10, and Figure 11 show that overall GEH and speed difference is better than Model 1.

Table 7: Car Following Parameters- Model 2

Parameters	Driving Behavior 1	Driving Behavior 2	Default Value
CC0	**9**	**9**	**4.92**
CC1	**0.9**	**0.9**	**0.9**
CC2	**12**	**14**	**13.12**

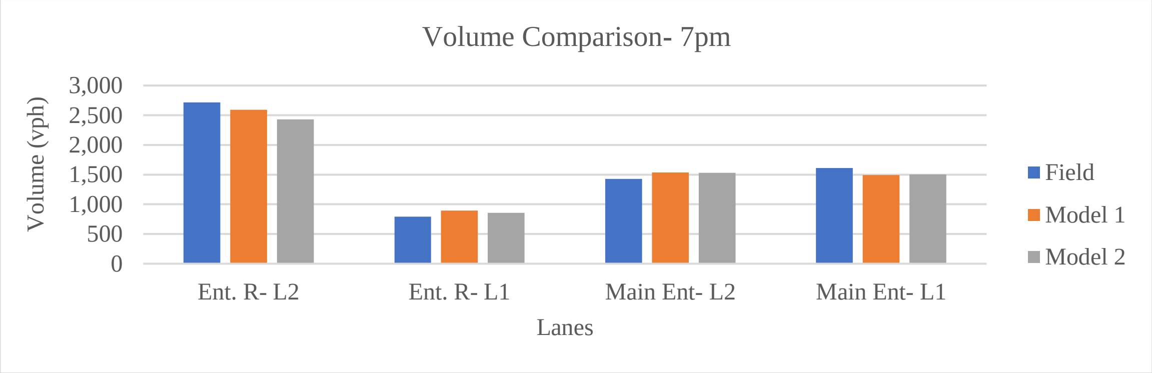

Figure 10: Model 2- 7pm- Volume

Table 8: Model 2- 7pm- GEH

Volume (vph)	Vehicle Input (vph)	Field Volume (vph)	VISSIM Volume (vph)	GEH
Ent. R- L2	3,509	2,716	2,428	5.7
Ent. R- L1		793	856	2.2
Main Ent- L2	3,040	1,430	1,530	2.6
Main Ent- L1		1,610	1,501	2.8

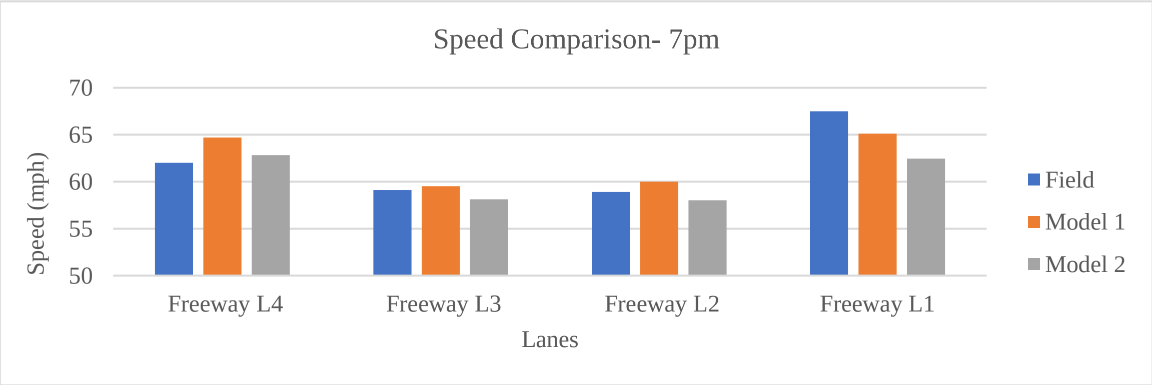

Figure 11: Model 2- 7 pm – Speed

Model 3

Model 3 has CC0 equal to 7, CC1 equal to 0.9, and CC2 is 13.12 for both behaviors (Table 9).

Results show that volume and GEH are the same as model 2, however, speed got worse (Table 10, Figure 12 and Figure 13).

Table 9: Car Following Parameters- Model 3

Parameters	**Driving Behavior 1**	**Driving Behavior 2**	**Default Value**
CC0	**7**	**7**	**4.92**
CC1	**0.9**	**0.9**	**0.9**
CC2	**13.12**	**13.12**	**13.12**

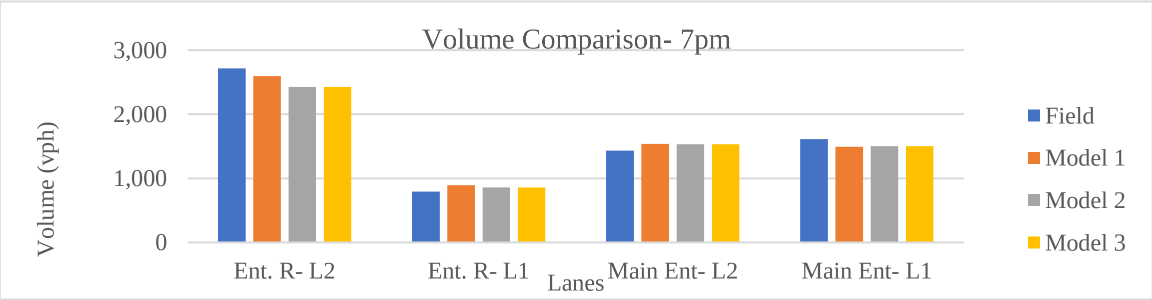

Figure 12: Model 3- 7pm- Volume

Table 10: Model 3- 7pm- GEH

Volume (vph)	Vehicle Input (vph)	Field Volume (vph)	VISSIM Volume (vph)	GEH
Ent. R- L2	3,509	2,716	2,428	5.7
Ent. R- L1		793	856	2.2
Main Ent- L2	3,040	1,430	1,530	2.6
Main Ent- L1		1,610	1,501	2.8

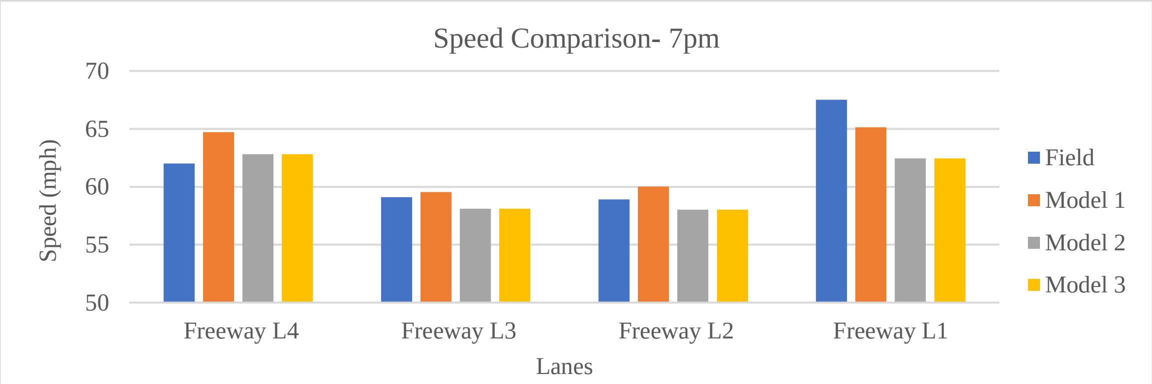

Figure 13: Model 3- 7 pm – Speed

Model 4

For model 4 CC0 is 7 and CC1 is 0.5 for both behaviors. CC2 is set to 12 for behavior 1 while it is 14 behavior 2. (Table 11) According to Table 12, and Figure 14 and Figure 15, volume, GEH, and speed all got worse by reducing headway (CC1).

Table 11: Car Following Parameters- Model 4

Parameters	**Driving Behavior 1**	**Driving Behavior 2**	**Default Value**
CC0	**7**	**7**	**4.92**
CC1	**0.5**	**0.5**	**0.9**
CC2	**12**	**14**	**13.12**

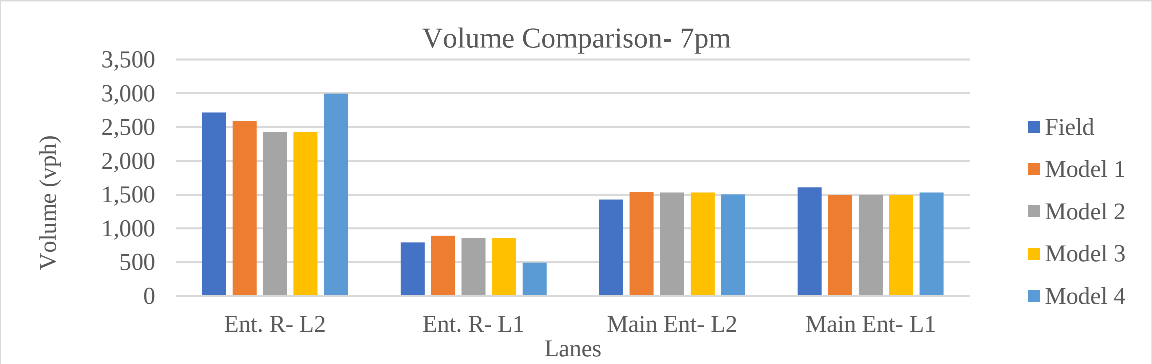

Figure 14: Model 4- 7pm- Volume

Table 12: Model 4- 7pm- GEH

Volume (vph)	Vehicle Input (vph)	Field Volume (vph)	VISSIM Volume (vph)	GEH
Ent. R- L2	3,509	2,716	2,996	5.2
Ent. R- L1		793	495	11.7
Main Ent- L2	3,040	1,430	1,506	2.0
Main Ent- L1		1,610	1,530	2.0

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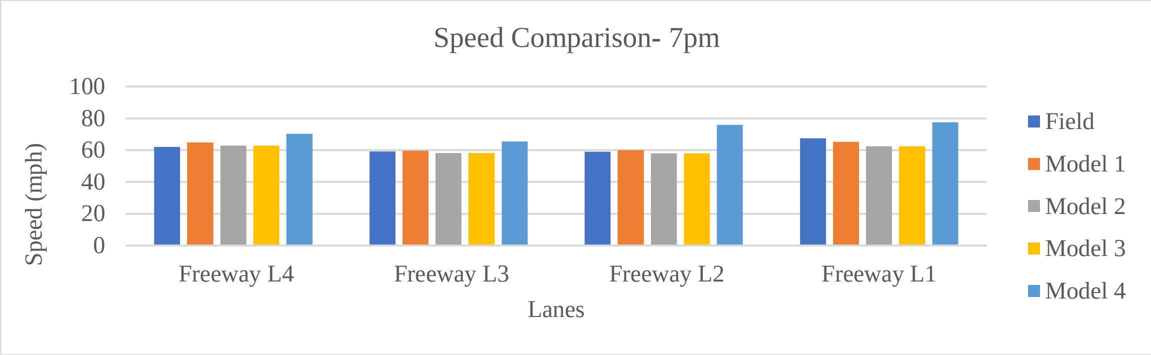

Figure 15: Model 4- 7pm- Speed

Model 5

Model 5 parameters include CC0 as 7 and CC1, 1.5 for both behaviors. CC2 is equal to 12 for behavior 1, and equal to 14 behavior 2. (Table 13)

Results claim that, volume, GEH, and speed while increasing headway (CC1) is as bad as when we decrease it (Table 13and Table 14, and Figure 14, Figure 15, Figure 16, Figure 17).

Model 4 and 5 suggests that the optimal value for CC1 is 0.9.

Table 13: Car Following Parameters- Model 5

Parameters	Driving Behavior 1	Driving Behavior 2	Default Value
CC0	**7**	**7**	**4.92**
CC1	**1.5**	**1.5**	**0.9**
CC2	**12**	**14**	**13.12**

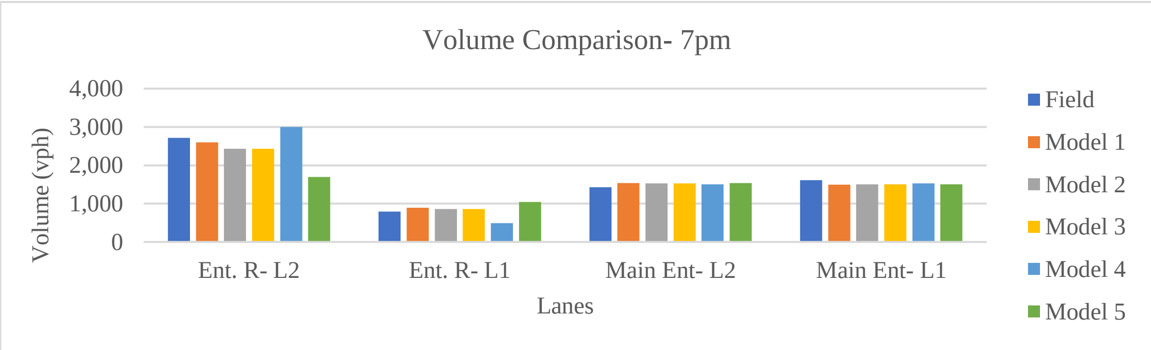

Figure 16: Model 5- 7pm- Volume

Table 14: Model 5- 7pm- GEH

Volume (vph)	Vehicle Input (vph)	Field Volume (vph)	VISSIM Volume (vph)	GEH
Ent. R- L2	3,509	2,716	1,695	21.7
Ent. R- L1		793	1,047	8.4
Main Ent- L2	3,040	1,430	1,533	2.7
Main Ent- L1		1,610	1,500	2.8

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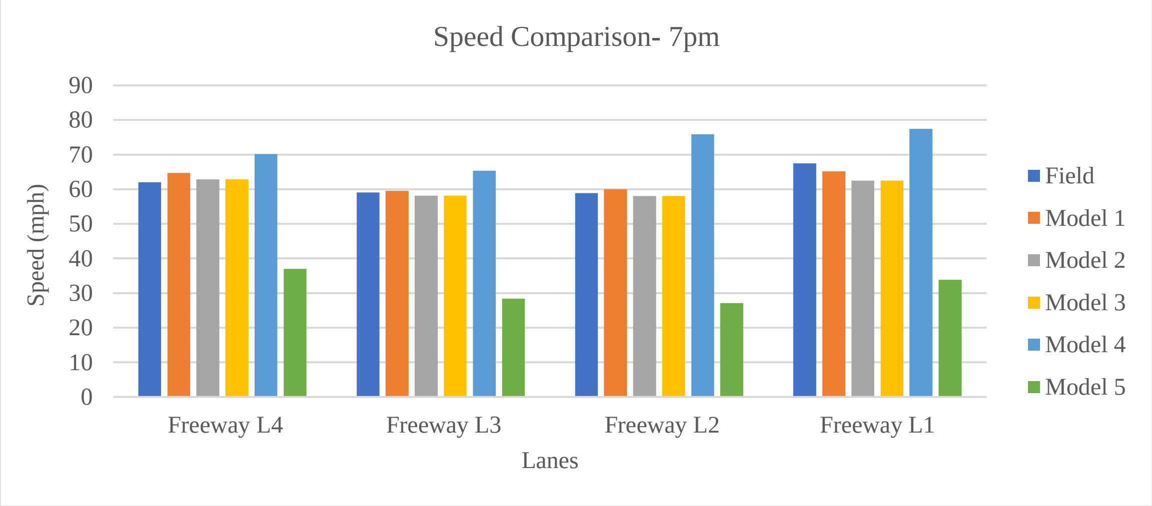

Figure 17: Model 5- 7pm- Speed

Model 6

Model 6 applied following parameters on network. CC0= 7, and CC1= 0.9 for both behaviors. CC2 equals to 12 for behavior 1 and equals to 14 for behavior 2. (Table 15)

Volume, GEH, and speed all represent their best feasible values. (Table 16, Figure 18 and Figure 19)

Table 15:Car Following Parameters- Model 6

Parameters	Driving Behavior 1	Driving Behavior 2	Default Value
CC0	**7**	**7**	**4.92**
CC1	**0.9**	**0.9**	**0.9**
CC2	**12**	**14**	**13.12**

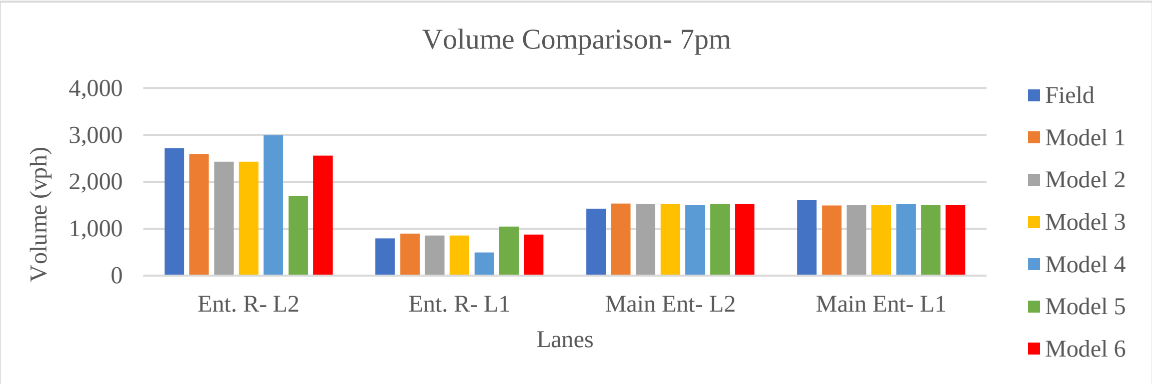

Figure 18: Model 6- 7pm- Volume

Table 16: Model 6- 7pm- GEH

Volume (vph)	Vehicle Input (vph)	Field Volume (vph)	VISSIM Volume (vph)	GEH
Ent. R- L2	3,509	2,716	2,559	3.1
Ent. R- L1		793	874	2.8
Main Ent- L2	3,040	1,430	1,533	2.7
Main Ent- L1		1,610	1,503	2.7

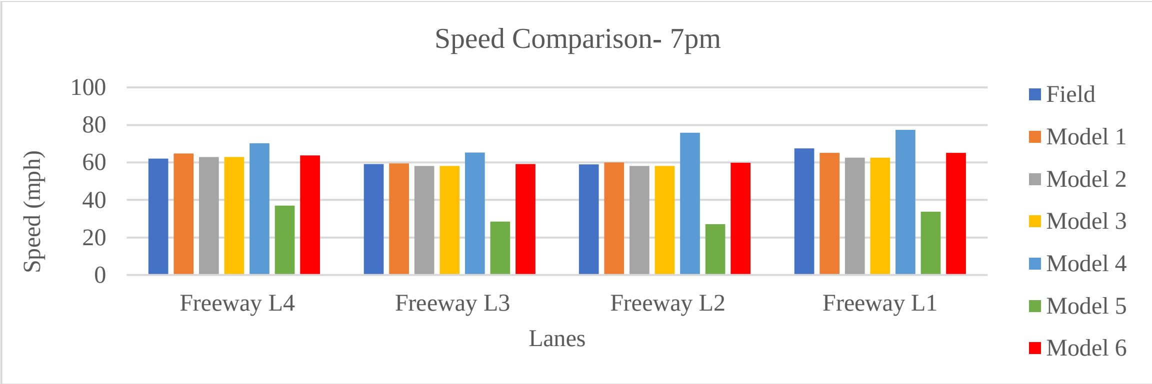

Figure 19: Model 6- 7pm- Speed

MODEL SELECTION

Six models are introduced. Each model performs well with some measure of effectiveness (MOEs) but performs poorly with others. In order to select the fittest model, a multi-criteria analysis process was conducted using the Simple Additive Weighting (SAW) method (Vo, 2007). In this method, a score is obtained by adding the contributions from each of the chosen criteria. The overall weight score, V_a, for model a, using this method can be written as follows. The model with the largest value of V_a is selected.

$$V_a = \sum_{j=1}^{j=n} W_j r_{aj}$$

W_j = Weight for criterion j

r_{aj} = rating for model on criterion j

12 criteria are used to rate each model: Four for volume on each entrance lane, four for GEH for each entrance lane, and four speed measurements, one in each lane midway from the two ramps. For volume and GEH comparison, we had "Entrance ramp, lane 1", "Entrance ramp, lane 2", "Freeway entrance, lane 1", and "Freeway entrance, lane 2". For speed measurement, we had "Middle section, lane 1", "Middle section, lane 2", "Middle section, lane 3", and "Middle section, lane 4".

Each of the 12 criteria in this SAW model has the same weight score. The criterion with the largest difference to the field value has the rating of 0 and the field data has the rating of 1. The largest possible score for each model is 12. The raw criterion scores on each criteria option of each model are determined by the difference between the criteria value on each model and the field value.

The raw score of models is calculated using following equation:

$$Raw\ Score = 1 - \frac{difference}{\max difference}$$

This technique can quantify the performance of each model compared to the field data. The model with the highest score out of 12 MOEs will be the best candidate for validation.

Table 17: Raw Score

Speed (mph)- 7pm			
	Lane 2- Freeway L4	Difference	Raw Score
Field	62	0	1
Model 1	64.7	2.72	0.891
Model 2	62.8	0.82	0.967
Model 3	62.8	0.82	0.967
Model 4	70.2	8.19	0.672
Model 5	37.0	24.96	0.000
Model 6	63.7	1.66	0.934
	Max	24.96	

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Table 18: Scoring- 7pm

Performance Measures		Lanes	Lanes	Model 2	Model 3	Model 4	Model 5	Model 6
7:00 PM	Volume	Ent. R- L2	0.881	0.718	0.718	0.726	0.000	0.846
	Volume	Ent. R- L1	0.664	0.789	0.789	0.000	0.148	0.728
	Volume	Main Ent- L2	0.000	0.074	0.074	0.296	0.046	0.046
	Volume	Main Ent- L1	0.000	0.060	0.060	0.310	0.052	0.078
	GEH	Ent. R- L2	0.891	0.739	0.739	0.759	0.000	0.859
	GEH	Ent. R- L1	0.707	0.813	0.813	0.000	0.287	0.761
	GEH	Main Ent- L2	0.000	0.073	0.073	0.292	0.045	0.045
	GEH	Main Ent- L1	0.000	0.061	0.061	0.314	0.053	0.079
	Speed	Freeway L4	0.891	0.967	0.967	0.672	0.000	0.934
	Speed	Freeway L3	0.983	0.960	0.960	0.751	0.228	1.000
	Speed	Freeway L2	0.956	0.965	0.965	0.319	0.273	0.961
	Speed	Freeway L1	0.905	0.798	0.798	0.602	0.349	0.904
			6.877	7.018	7.018	5.041	1.481	7.242

VALIDATION

Based on calibration results (Table 18), models 1, 2, 3 and 6 got the highest criterion scores and are selected to be validated using a different dataset (8 am). The number of runs is calculated using the same equation as calibration section (Table 19). Five simulation runs conducted for 8 am data set over the four selected models. Results show that models 2 and 6 have a better performance in terms of volume, GEH, and speed than model 1 and 3. Summary of validation results are presented in Figure 20, and Figure 21 and Table 21. Scoring result for validation is presented in Table 22.

It is preferred to use the same car following model for both datasets (calibration and validation ones) unless we have significant difference in volumes, driving behaviors, or type of drivers.

Table 19: Sample Size (8am)

Data Collection Point Name	Volume			Speed			Confidence Interval	**Sample Size**	**Sample Size**
	Std Dev	Mean	e(0.05)	Std Dev	Mean	e(0.05)	95%	Volume	Speed
Freeway L4				1.07	64.92	3.25	1.96		1
Freeway L3				0.93	62.88	3.14	1.96		1
Freeway L2				1.07	62.53	3.13	1.96		1
Freeway L1				1.22	67.63	3.38	1.96		1
Ent. R- L2	30.0	2452	122.6				1.96	1	
Ent. R- L1	31.0	565	28.25				1.96	5	
Main Ent- L2	14.0	1258	62.9				1.96	1	
Main Ent- L1	13.0	1316	65.8				1.96	1	
								n=5	

Table 20: Car Following Parameters (Validation)

	Parameters	Driving Behavior 1	Driving Behavior 2	Default Value
Model 1	CC0	4.92	4.92	4.92
	CC1	0.9	0.9	0.9
	CC2	12	14	13.12
Model 2	CC0	9	9	4.92
	CC1	0.9	0.9	0.9
	CC2	12	14	13.12
Model 3	CC0	7	7	4.92
	CC1	0.9	0.9	0.9
	CC2	13.12	13.12	13.12
Model 6	CC0	7	7	4.92
	CC1	0.9	0.9	0.9
	CC2	12	14	13.12

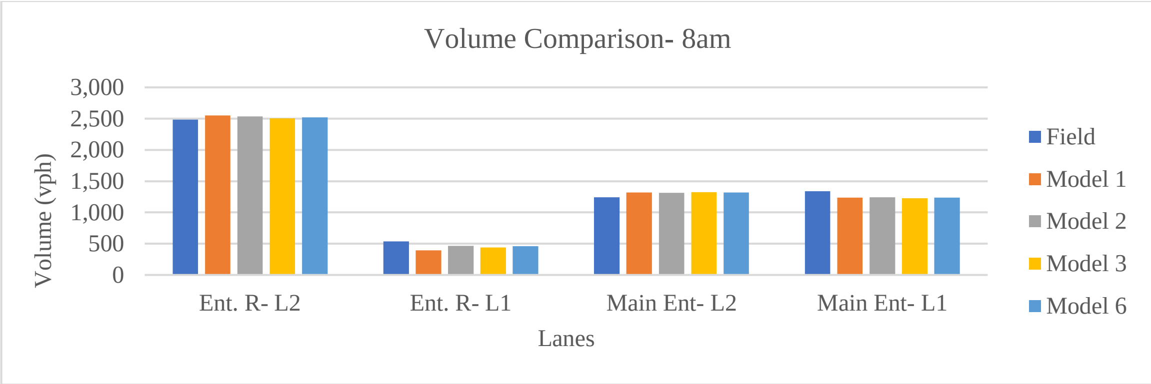

Figure 20: Volume Comparison- 8 am

Table 21: GEH Comparison- 8 am

Volume (vph)	Vehicle Input (vph)	Field Volume (vph)	Model 1 GEH	Model 2 GEH	Model 3 GEH	Model 6 GEH
Ent. R- L2	3,020	2,483	1.3	1.1	0.5	0.8
Ent. R- L1		537	6.6	3.3	4.5	3.5
Main Ent- L2	2,578	1,241	2.2	2.0	2.3	2.2
Main Ent- L1		1,337	2.8	2.7	3.1	2.8

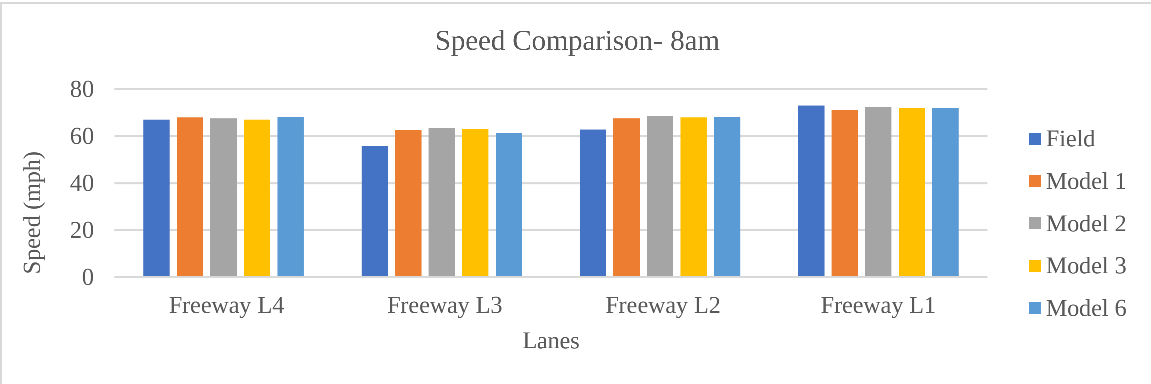

Figure 21: Speed Comparison- 8 am

The summation of calibration and validation results show that however, model 2 has a slightly higher score in validation section, as model 6 has the better overall score (on the 7pm and 8 am datasets), therefore, the selected model is model 6. (Table 23)

So, the selected parameters values are CC0 = 7, CC1 = 0.9, and CC2 = 12 for behavior 1, and CC2= 14 behavior 2.

Table 22: Models Scoring- 8am

	Performance Measures	Lanes	Model 1	Model 2	Model 3	Model 6
8:00 AM	Volume	Ent. R- L2	0.897	0.914	0.962	0.939
	Volume	Ent. R- L1	0.684	0.839	0.781	0.826
	Volume	Main Ent- L2	0.072	0.120	0.000	0.048
	Volume	Main Ent- L1	0.091	0.127	0.000	0.073
	GEH	Ent. R- L0	0.904	0.920	0.965	0.943
	GEH	Ent. R- L1	0.596	0.801	0.727	0.784
	GEH	Main Ent- L0	0.071	0.119	0.000	0.047
	GEH	Main Ent- L1	0.093	0.130	0.000	0.074
	Speed	Freeway L4	0.933	0.961	0.998	0.917
	Speed	Freeway L3	0.495	0.448	0.475	0.597
	Speed	Freeway L2	0.664	0.585	0.629	0.620
	Speed	Freeway L1	0.868	0.953	0.937	0.934
			6.369	6.917	6.475	6.802

Table 23: Total Scoring

Data set	Performance Measures	Lanes	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
7:00 PM	Volume	Ent. R- L2	0.881	0.718	0.718	0.726	0.000	0.846
	Volume	Ent. R- L1	0.664	0.789	0.789	0.000	0.148	0.728
	Volume	Main Ent- L2	0.000	0.074	0.074	0.296	0.046	0.046
	Volume	Main Ent- L1	0.000	0.060	0.060	0.310	0.052	0.078
	GEH	Ent. R- L0	0.891	0.739	0.739	0.759	0.000	0.859
	GEH	Ent. R- L1	0.707	0.813	0.813	0.000	0.287	0.761
	GEH	Main Ent- L0	0.000	0.073	0.073	0.292	0.045	0.045
	GEH	Main Ent- L1	0.000	0.061	0.061	0.314	0.053	0.079
	Speed	Freeway L4	0.891	0.967	0.967	0.672	0.000	0.934
	Speed	Freeway L3	0.983	0.960	0.960	0.751	0.228	1.000
	Speed	Freeway L2	0.956	0.965	0.965	0.319	0.273	0.961
	Speed	Freeway L1	0.905	0.798	0.798	0.602	0.349	0.904
			6.877	7.018	7.018	5.041	1.481	7.242
	Performance Measures	Lanes	Model 1	Model 2	Model 3			Model 6
8:00 AM	Volume	Ent. R- L2	0.897	0.914	0.962			0.939
	Volume	Ent. R- L1	0.684	0.839	0.781			0.826
	Volume	Main Ent- L2	0.072	0.120	0.000			0.048
	Volume	Main Ent- L1	0.091	0.127	0.000			0.073
	GEH	Ent. R- L0	0.904	0.920	0.965			0.943
	GEH	Ent. R- L1	0.596	0.801	0.727			0.784
	GEH	Main Ent- L0	0.071	0.119	0.000			0.047
	GEH	Main Ent- L1	0.093	0.130	0.000			0.074
	Speed	Freeway L4	0.933	0.961	0.998			0.917
	Speed	Freeway L3	0.495	0.448	0.475			0.597
	Speed	Freeway L2	0.664	0.585	0.629			0.620
	Speed	Freeway L1	0.868	0.953	0.937			0.934
			6.369	6.917	6.475			6.802
Total Score			13.246	13.935	13.493			14.044

SENSITIVITY ANALYSIS

During the calibration process, we found a set of parameters and the optimal model which fits the observed traffic operations. The car-following sensitivity is analyzed in this section to evaluate the network sensitivity to the selected parameter's value.

CC0, CC1, and CC2 were shown to have most significant effect on network performance. Over a range of reasonable values, including those that provided the best fit for both AM and PM data sets (calibration and validation datasets), the results showed that these parameters had a significant effect on network performance.

It is examined to see what may happen to the calibrated network if CC0, or CC2 change by ±10% or ±20%. Network is monitored to see if it is sensitive to these changes or if they cause any unreasonable queues.

CC1 was not examined for this analysis as the value of this parameter has fixed values in VISSIM and we cannot change it up and down by desirable factors manually.

Results for sensitivity analysis are presented in Table 24 and Figure 22 and Figure 23. Each scenario represents by S (for example, S1 stands for scenario 1). For each scenario, only one is changed at the time to see how sensitive the network is. Not only the throughput is important, but also, network is monitored in term of queue, bottleneck, and volume on each ramp. Driving behavior are considered as well.

This analysis illustrated that only extreme changes in CC0, and CC2 have a substantial effect on network.

Table 24: Sensitivity Analysis Scenarios

Scenario	Parameter	Optimal Value	Change by	Value	Queue/Bottleneck
1	CC0	7	+10%	7.70	No
2			-10%	6.30	No
3			+20%	8.40	No
4			-20%	5.60	No
5	CC2- Behavior 1	12	+10%	13.20	No
6			-10%	10.80	No
7			+20%	14.40	No
8			-20%	9.60	No
9	CC2-Behavior 2	14	+10%	15.40	No
10			-10%	12.60	No
11			+20%	16.80	No
12			-20%	11.20	No

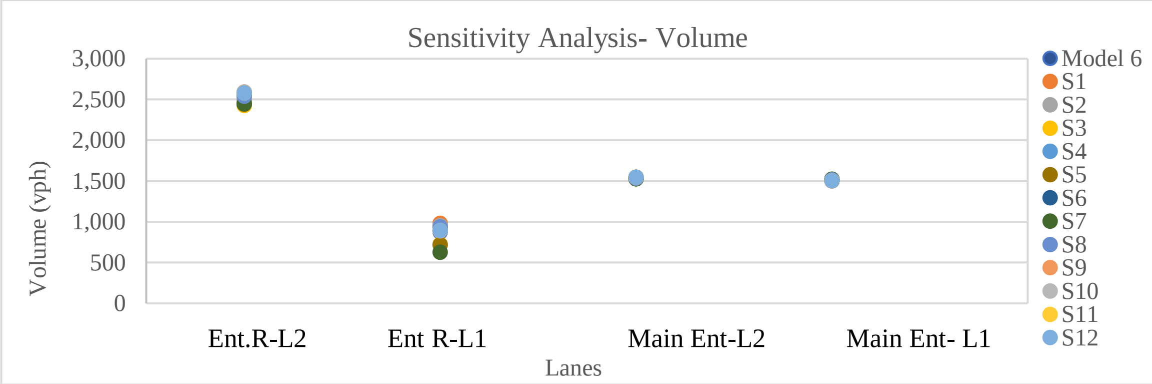

Figure 22: Sensitivity Analysis- Volume

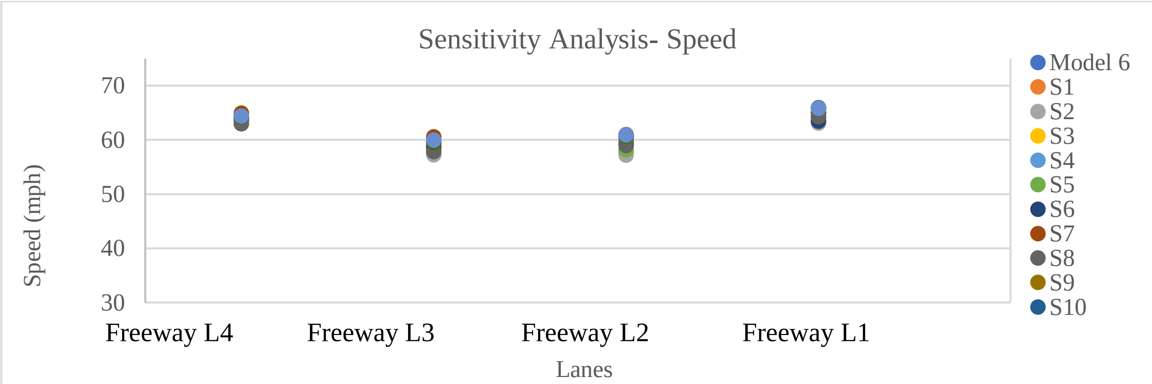

Figure 23: Sensitivity Analysis- Speed

CONCLUSION

This work proposes a methodology for calibrating a micro simulation model for freeway weaving segment. The data was collected for the freeway segment on northbound SH 360 between the entrance from eastbound IH20 to the exit for Mayfield Road in Arlington, Texas.

This work is a preliminary work to calibrate VISSIM in order to estimate the capacity of freeway weaving segment in the next step. Results represent that the most significant VISSIM parameters affecting capacity estimation for freeway weaving segment are the following driving behavior/ car following parameters. CC0 (Standstill Distance), CC1 (Headway Time), and CC2 (Following Variation).

Also, sensitivity analysis shows that only extreme changes in CC0 and CC2 significantly effect network.

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