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Calibration of Microscopic Traffic Flow Models Enabling Simultaneous Selection of Specific Links and Parameters

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CALIBRATION OF MICROSCOPIC TRAFFIC FLOW MODELS ENABLING
SIMULTANEOUS SELECTION OF SPECIFIC LINKS AND PARAMETERS

By

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Bachelor in Civil Engineering
Tribhuvan University
2011

A thesis submitted in partial fulfillment
of the requirements for the

Master of Science in Engineering – Civil and Environmental Engineering

Department of Civil and Environmental Engineering and Construction
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ABSTRACT

This study proposes a methodology for the calibration of microscopic traffic flow simulation models by enabling simultaneous selection of traffic links and associated parameters. That is, any number and combination of links and model parameters can be selected for calibration. Most calibration approaches consider the entire network without enabling a specific selection of location and associated parameters. In practice, only a subset of links and parameters are used for calibration based on a number of factors such as expert local knowledge of the system. In this study, the calibration problem for the simultaneous selection of links and parameters was formulated using a mathematical programming approach. The proposed methodology is capable of calibrating model parameters, taking into consideration multiple time periods and performance measures simultaneously. The performance measures used in this study were volume and speed. The methodology was developed without considering the characteristics of a specific traffic flow model. So, the methodology could be applied to any traffic flow model. A genetic algorithm was implemented to determine the solution to the proposed mathematical program for the calibration of microscopic traffic flow models. In the experiments, two traffic models were calibrated. The first set of experiments included selection of links only, while all associated parameters were considered for calibration. The second set of experiments considered simultaneous selection of links and parameters. Results showed that the models were calibrated successfully subject to selection of a minimum number of links. All parameter values were reasonable and within constraints after successful calibration.

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DEDICATION

To my Mother, who inspires me to rise beyond the failures and challenges of life.

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CHAPTER 1: INTRODUCTION

Microscopic traffic flow simulation is increasingly being used to analyze complex scenarios for a broad range of objectives. One of the most important and challenging aspects for obtaining meaningful results is calibration which involves adjusting the parameters to enhance the ability of the model to generate local traffic conditions (Dowling, Skabardonis, Halkias, McHale, & Zammit, 2004; Holm, Tomich, Sloboden, & Lowrance, 2007). Existing calibration approaches propose various optimization algorithms and varying sets of calibration parameters. Sequential as well as simultaneous calibration of model parameters is proposed in the literature.

For example, the calibration approach provided by Federal Highway Administration (FHWA) in the Traffic Analysis Toolbox Volume IV (Holm et al., 2007) suggests a sequential process of calibrating capacity at key bottlenecks, traffic volumes and system performance. Model parameters are adjusted by modifying global parameters first, then link parameters and then route choice parameters. Ma, Dong, & Zhang (2007) used a sequential approach to calibrate global and local parameters separately. Jha et al. (2004) calibrated driver behavior parameters separately from other parameters such as route choice factors and O-D flows. An iterative approach was used where one group of parameters were calibrated while others remained fixed. Issues associated with the use of a sequential calibration process include difficulty to reach convergence and stable solutions (Paz, Molano, & Gaviria, 2012; Paz, Molano, Martinez, Gaviria, & Arteaga, 2015)

Many mathematical programming formulations have been proposed to characterize and solve the problem of calibrating simulation-based traffic flow models. A simplex algorithm was proposed to calibrate microscopic traffic flow simulation models using Intelligent Transportation Systems data (Kim & Rilett, 2003). The proposed algorithm produced better results for congested conditions compared with uncongested traffic. Slow convergence was observed after an adequate

set of parameters was found. Manual calibration provided better results for uncongested conditions compared with congested traffic scenarios. Various Genetic Algorithms (GAs) have been proposed to calibrate microscopic simulation models (Cheu, Jin, K-C. Ng, Y-L. Ng, & Srinivasan, 1998; Cunha, Bessa, & Setti, 2009; Jha et al., 2004; Kim & Rilett, 2001; J. Ma et al., 2007; T. Ma & Abdulhai, 2002) with great results and relative fast convergence. Simultaneous Perturbation Stochastic Approximation (SPSA) algorithms have also been widely used to calibrate microscopic simulation models (Balakrishna, Antoniou, Ben-Akiva, & Koutsopoulos, 2007; Lee, 2008; J. Ma et al., 2007; Paz et al., 2012). SPSA was found to provide similar level of accuracy and less number of iterations and computation time compared with GAs and trial-and-error Iterative Adjustment (IA) algorithms (Balakrishna et al., 2007). A memetic algorithm (MA) was found to be superior to a SPSA algorithm because the required fine-tuning process was significantly quicker for the MA (Paz et al., 2015). Cobos et al. (2016) proposed that when a MA was adapted using Solis and Wets local search chains (MA-SW-Chains), it provided better and faster convergence compared to both SPSA and MA. A multi-objective MA based on NSGA-II and simulated annealing (NSGA-II-SA), also provided better results for runtime and convergence compared to a single objective MA (Cobos et al., 2016).

Microscopic traffic flow simulation models use the concept of car-following and lane changing theories to represent vehicle interactions and driver behavior dynamics (Holm et al., 2007; Halati, Lieu, & Walker, 1997). Typically, calibration parameters are related to driver characteristics, such as car-following behavior and gap-acceptance. Balakrishna et al. (2007) proposed the calibration of demand and supply parameters simultaneously. However, the calibration was performed only with link counts and used pre-calibrated values for driver behavior parameters. Cheu et al. (1998) used parameters such as free flow speeds, car-following distance,

car-following sensitivity factors, lag to accelerate/decelerate and lane changing factors. Results showed that free flow speeds, car-following distance and car-following sensitivity factors were the most sensitive and important. That is, calibration using only these three parameters could be performed instead of using all the parameters. Kim & Rilett (2003, 2001) considered for calibration parameters associated with acceleration/deceleration, car-following and lane-changing behavior. The lane change probability and car following distance were found to have relatively close calibrated and default values suggesting that calibration could be performed without the inclusion of these parameters. Performance measures after calibration showed consistency with actual field values; however, no standard criteria for calibration was defined. Paz et al. (2012, 2015) calibrated microscopic traffic flow models considering the entire set of model parameters simultaneously. The simultaneous selection of all parameters was motivated by the need to seek convergence and stability of the solutions. All parameters were treated equally and a subset of parameters that may significantly affect a traffic model were not identified.

Most of the existing literature considers the entire set of links and parameters for calibration. In practice, only a subset of links and parameters can be used for calibration. For example, certain links of a network may be pre-calibrated and/or default or pre-specified values are required by the owner of the facilities or model. That is, development and calibration may be restricted to adjust only a subset of all the potentially available parameters in the traffic flow model. Based on local knowledge and experience, owners usually have preferences about what parameters to adjust for specific traffic facilities (S.J. Kim, 2006; Ciuffo, Punzo & Torrieri, 2008). If all parameters are calibrated simultaneously, less known parameters may yield values that are unexplainable or inconsistent with real-world traffic behavior.

Contribution

This research does not aim to identify the parameters that most significantly affect a traffic model, but to analyze the process of selection of required parameters for calibration of a traffic model. Unlike the traditional approaches that either involve a sequential process or consider all parameters simultaneously, this research proposes a methodology that enables the simultaneous selection of specific links/facilities and parameters for calibration. That is, any combination of traffic facilities and model parameters within each facility can be selected simultaneously for calibration. Local and global calibration parameters are considered. The capability of selecting where and what to calibrate is motivated by the requirements to use local knowledge and constraints to define the parameters to calibrate.

Objectives

The objectives of this study are:

1. To develop and propose a framework and solution algorithm that enables simultaneous selection of specific links and parameters to calibrate microscopic traffic simulation models.
2. To perform extensive sensitivity analysis using different parameters on multiple traffic models.

CHAPTER 2: METHODOLOGY

The calibration methodology used in this study is a modified approach from Paz et al., (2015). The modified calibration approach has the capability to select links and model parameters. The calibration problem was formulated using a mathematical programming approach. The normalized root mean square error, which is the objective function (1) for this study, measures the relative difference between actual and simulated traffic volumes and speeds. Normalization allows multiple performance measures to be considered simultaneously (Paz et al., 2015).

Problem Formulation

Notation and Terms

K	Set of links selected for calibration
K	Subscript for a link selected for calibration, $k \in K$
P	Set of local model parameters
P	Superscript for a local model parameter, $p \in P$
α_k^p	Local parameter p on link k selected for calibration, $\forall k \in K, p \in P$
α_k	Set of local parameters on link k selected for calibration, $\forall k \in K$
δ_k^p	Indicator variable for local parameter p on link k selected for calibration, $\forall k \in K, p \in P, \delta_k^p = 1 \Leftrightarrow \alpha_k^p \in \alpha_k$; otherwise, $\delta_k^p = 0$
α	Set of local parameters selected for calibration, $\alpha \in P$
G	Set of global model parameters
G	Superscript for a global model parameter, $g \in G$
β^g	Global parameter selected for calibration $g, \forall g \in G$
β	Set of global parameters selected for calibration, $\beta \in G$
δ^g	Indicator variable for global parameter g selected for calibration, $\forall g \in G, \delta^g = 1 \Leftrightarrow \beta^g \in \beta$; otherwise, $\delta^g = 0$
θ	Set of all parameters selected for calibration, $\theta = \alpha \cup \beta$
L	Set of links with actual field data
L	Subscript for a link with actual field data, $l \in L$
T	Total number of time periods

T	Subscript for a time period, $t \in T$
$V_{l,t}$	Actual volume for link l at time period t , $\forall t \in T, l \in L$
$S_{l,t}$	Actual speed for link l at time period t , $\forall t \in T, l \in L$
W_v	Weigh factor for volumes
$\hat{V}(\theta)_{l,t}$	Simulated volume for link l at time period t , $\forall t \in T, l \in L$
$\hat{S}(\theta)_{l,t}$	Simulated speed for link l at time period t , $\forall t \in T, l \in L$

In this study, any number and combination of local and global parameters can be selected for calibration. Indicator variables, δ_k^p and δ^g , are used to define which parameters are selected for calibration. The objective function and the calibration criteria are evaluated using links L with available actual field data.

Objective Function

The normalized root mean square error (NRMS) is calculated as follows:

Minimize NRMS

$$= \frac{1}{\sqrt{|L|}} * \sum_{t=1}^T \left(W_v * \sqrt{\sum_l^{|L|} \left(\frac{V_{l,t} - \hat{V}(\theta)_{l,t}}{V_{l,t}} \right)^2} + (1 - W_v) * \sqrt{\sum_l^{|L|} \left(\frac{S_{l,t} - \hat{S}(\theta)_{l,t}}{S_{l,t}} \right)^2} \right) \quad (1)$$

Constraints

$$\alpha_k = \{ \alpha_k^p \mid \forall \delta_k^p = 1, k \in K, p \in P \} \quad (2.1)$$

$$\alpha = \bigcup_{k \in K} \alpha_k \quad (2.2)$$

$$\beta = \{ \beta^g \mid \forall \delta^g = 1, g \in G \} \quad (2.3)$$

$$\theta = \alpha \cup \beta \quad (2.4)$$

$$\text{Lower bound} \leq \alpha_k^p \leq \text{Upper bound} \quad (2.5)$$

$$\text{Lower bound} \leq \beta^g \leq \text{Upper bound} \quad (2.6)$$

The Objective (1) is to minimize the normalized weighted root mean square error over T number of time periods and links L .

Constraints (2.1) and (2.2) ensure that local parameters selected for calibration are included in vector θ . Similarly, constraint (2.3) ensures that global parameters selected for calibration are included in vector θ . Eq. (2.4) is a definitional constraint for calibration vector θ . Constraints (2.5) and (2.6) provided lower and upper bounds for each parameter selected for calibration.

Calibration Criteria

The criterion for calibration is based on guidelines provided by FHWA (Holm et al., 2007). For individual links, for more than 85% of cases, the difference between actual and simulated counts should be within 100 vehicles/hour for link volumes less than 700 vehicles/hour; within 15% of field flow for link volumes between 700 and 2700 vehicles/hour; and within 400 vehicles/hour for link volumes greater than 2700 vehicles/hour. The sum of all simulated link count errors should be within 5% of all actual link counts. The GEH statistic for individual link flows should be less than 5 for more than 85% of cases (Dowling et al., 2004; Holm et al., 2007). The GEH statistic is given by:

$$\text{GEH} = \sqrt{\frac{2(V_l - \hat{V}(\theta)_l)^2}{V_l + \hat{V}(\theta)_l}} \quad (3)$$

where, V_l is the actual traffic volume for link l , and $\hat{V}(\theta)_l$ is the corresponding simulated traffic volume.

Solution Algorithm

The proposed mathematical program, (Eq. 1 – 2.6), is solved using a GA which was found to converge relatively quickly for CORSIM models with many parameters (Kim & Rilett, 2001). The GA searches solutions trying to avoid stopping at local optima and seeking to increase the probability of locating a global optimum (Cheu et al., 1998; Cunha et al., 2009; Gen & Cheng, 2000; Goldberg, 1989; Jha et al., 2004; Kim & Rilett, 2001; J. Ma et al., 2007; T. Ma & Abdulhai, 2002). In the context of GA, a population is generated at random initially. An individual in a

population is represented by a set of calibration parameter values, which is a viable solution. The quality of the resulting solution is evaluated by a fitness or objective function as in (1). GA creates successive generations of individuals. The best individuals are stored to create a new population. The GA performs the following steps as described by Paz et.al (2015), and depicted by the flowchart in Figure 1.

Step 1 – Initialization

An initial population of θ s is randomly generated but constrained by lower and upper bounds to maintain model realism.

Step 2 – Parents selection

The best 60% of parameter sets from the initial population are saved. Then, sets of θ that represent parents in the population are generated and paired using a ‘roulette wheel selection’.

Step 3 – Crossover

A crossover is performed at 50%. This process combined parent θ s to generate new sets of calibration parameters (offsprings).

Step 4 – Mutation

Approximately 30% of the parameters of each offspring are subject to small perturbations ($\pm 1\%$) to investigate neighboring solutions.

Step 5 – Population management strategy

The new offspring θ replace the worst θ s when new θ provides a better fitness function than older θ s.

Step 6 – Stopping Criteria

If the stopping criterion is met, the best θ is stored and the algorithm ends. Otherwise, it returns to Step 2. The stopping rule is determined by reaching a pre-specified maximum number of generations/iterations.

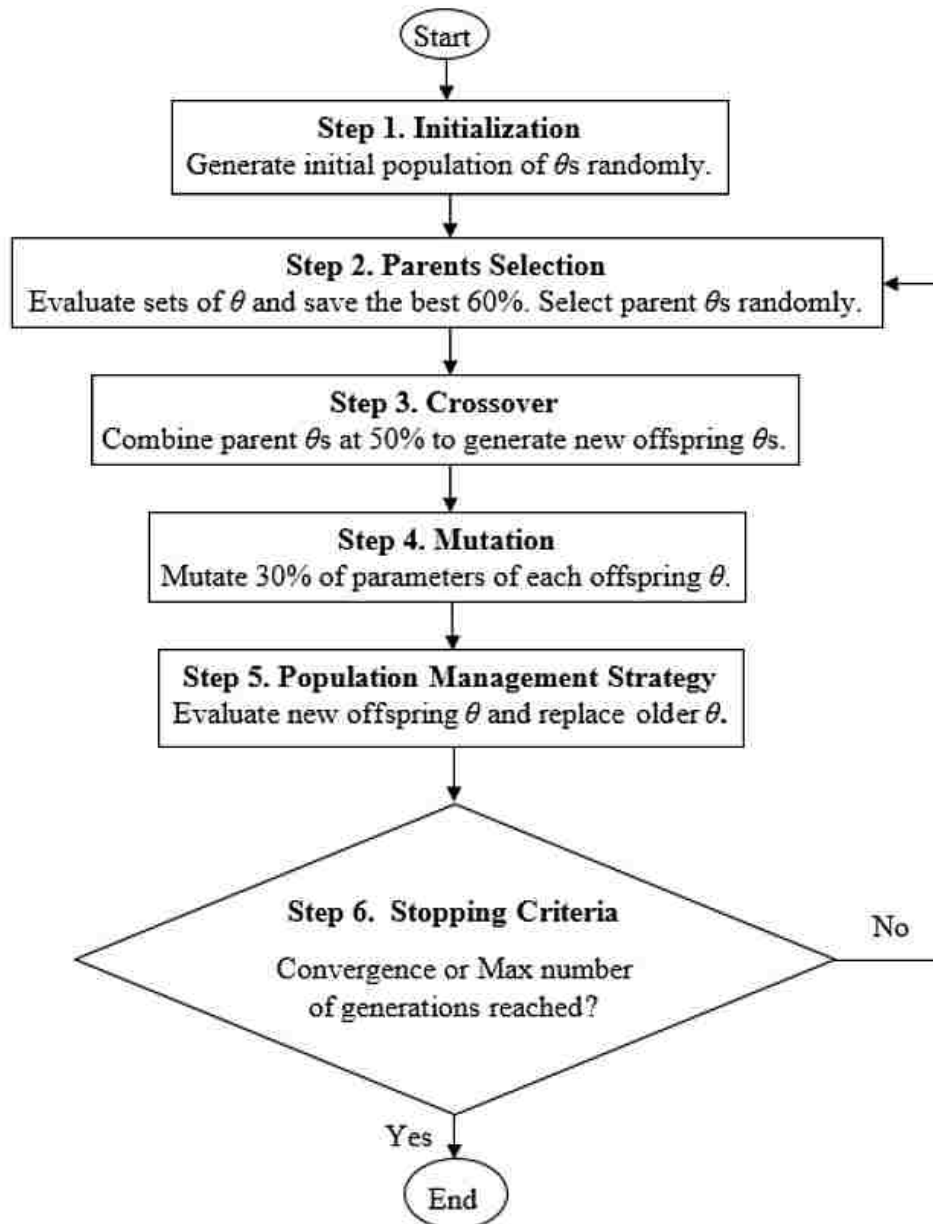


Figure 1. Flowchart Illustrating the Proposed Solution Algorithm.

CHAPTER 3: EXPERIMENTS AND RESULTS

The proposed methodology and solution algorithm was tested using CORSIM models. CORSIM incorporates two microscopic simulation models, NETSIM and FRESIM, that together constitute a whole traffic environment. NETSIM is for surface street simulation, and FRESIM is for freeway simulation. CORSIM includes driver behavior and vehicle performance parameters (McTrans™ Center, 2017). Table 1 lists the various calibration parameters in CORSIM (Paz et al., 2015, p. 5)

Table 1. Calibration Parameters in CORSIM Models (Paz et al., 2015)

Driver Behavior	Vehicle Performance	Demand Patterns
<i>NETSIM model (Surface Streets)</i>		
❖ Queue discharge headway	❖ Speed and acceleration characteristics	❖ Surface street turn movements
❖ Start-up lost time		
❖ Distribution of free-flow speed by driver type	❖ Fleet distribution and passenger occupancy	
❖ Mean duration of parking maneuvers		
❖ Lane change parameters		
❖ Maximum left and right turning speeds		
❖ Probability of joining spillback		
❖ Probability of left turn jumpers and laggards		
❖ Gap acceptance at stop signs		
❖ Gap acceptance for left and right turns		
❖ Pedestrian delays		
❖ Driver familiarity with their path		
<i>FRESIM model (Freeways)</i>		
❖ Mean start-up delay at ramp meters	❖ Speed and acceleration characteristics	❖ Freeway turn movements
❖ Distribution of free flow speed by driver type		
❖ Incident rubbernecking factor	❖ Fleet distribution and passenger occupancy	
❖ Car-following sensitivity factor		
❖ Lane change gap acceptance parameters	❖ Maximum deceleration values	
❖ Parameters that affect the number of discretionary lane changes		

Two CORSIM models were used in the experiments. Both models include surface streets (arterials) with signalized intersections. For signal controlled intersections, one of the important parameters is the discharge headway of individual vehicles (Hung, Tian, and Tong, 2002; Holm et al., 2007).

Experimental Setup

The proposed solution algorithm was implemented using Java, which is capable of handling complex data structures and mathematical functions. As mentioned in Paz et al., (2015), the implementation uses a basic layered architecture and each layer performs a group of related functions.

Volume and speed data were used for calibration. The CORSIM models were run for a simulation time period of 15 minutes. The first set of experiments incorporated selection of links in the network. The second set of experiments incorporated simultaneous selection of links and parameters.

First Set of Experiments: Selection of Links in the Network

In the first set of experiments, links were selected for calibration randomly. All global and local parameters for the selected links were considered simultaneously for calibration.

The first group of experiments was completed using the Reno network, which is a CORSIM model of the Pyramid Highway in Reno, Nevada. Figure 2 illustrates this network. This model consists of 126 arterial links; 45 of them had calibration data. A link is a segment of a network that receives/exits traffic from/to adjoining subnetworks.

The local parameters included mean queue discharge headway and mean value of start-up lost time. The global parameters included lane change, acceptable gap in near-side cross traffic for

vehicles at a sign, additional time for far-side cross traffic in acceptable gap for vehicles at a sign, and driver's familiarity with paths distribution.

When 70% of links were selected, the model was calibrated successfully. Figure 3 shows how the objective function converges when 70% of the links were selected for calibration. The NRMS shows improvement through the iterations of the calibration process. Initially, the value of NRMS was 0.22. After 845 iterations, the NRMS decreased by 63% to 0.08.

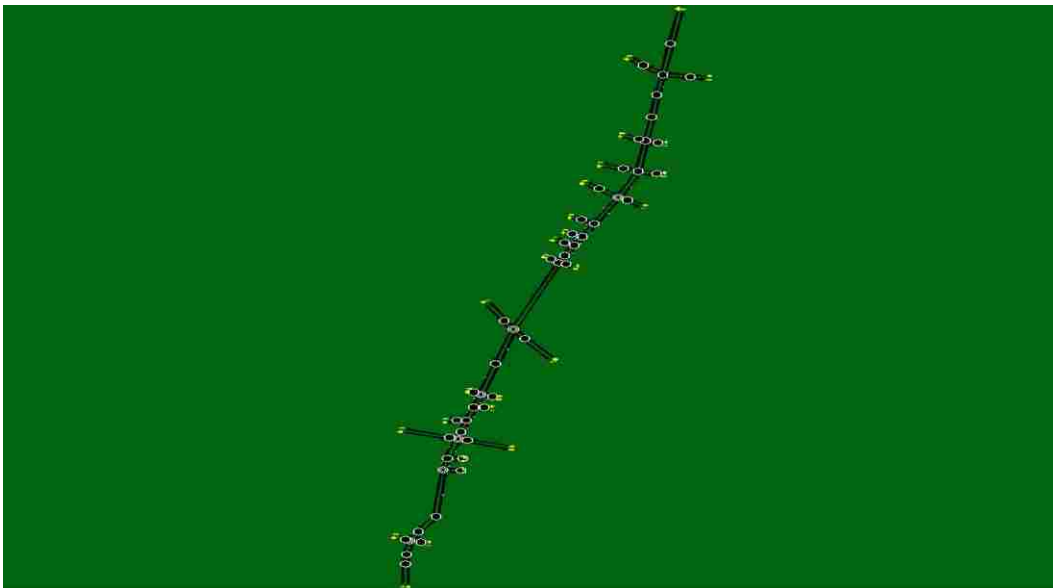


Figure 2. Reno Network

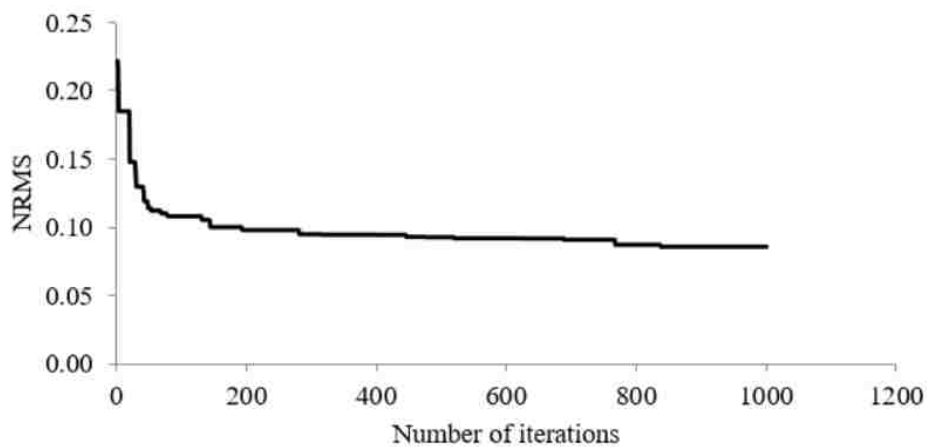


Figure 3. Objective Function when All Parameters were Considered and 70% Links were Selected for Calibration of Reno Network.

Figure 4 shows vehicle counts before and after calibration. Before calibration, the actual and simulated counts do not match, especially for higher values. After calibration, the difference between actual and simulated counts is reduced as illustrated by their alignment along the 45° line in Figure 4. Figure 5 shows the vehicle speeds before and after calibration. The speed data are scattered away from the 45° line more than the volume data. The reason could be that a higher weight was assigned to volume than speed data because of greater confidence in volume data. From the observation of Figure 4 and Figure 5, higher volumes and lower speeds were calibrated better. This suggests that networks under congested conditions could be calibrated better than their counterparts. Figure 6 shows the GEH statistic for the model before and after calibration. Initially, the GEH value was less than 5 for 46% of the selected links. After calibration, the GEH value was less than 5 for 93% of the selected links.

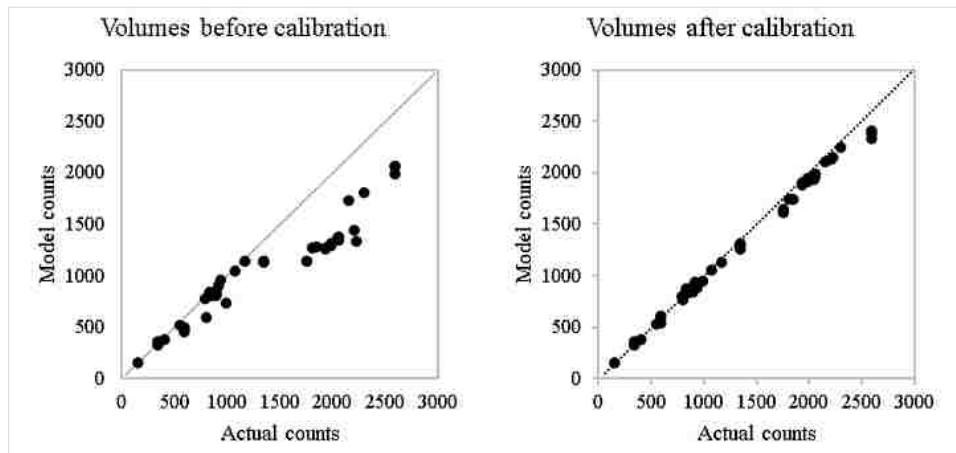


Figure 4. Volumes Before and After Calibration when All Parameters were Considered and 70% Links were Selected in Reno Network.

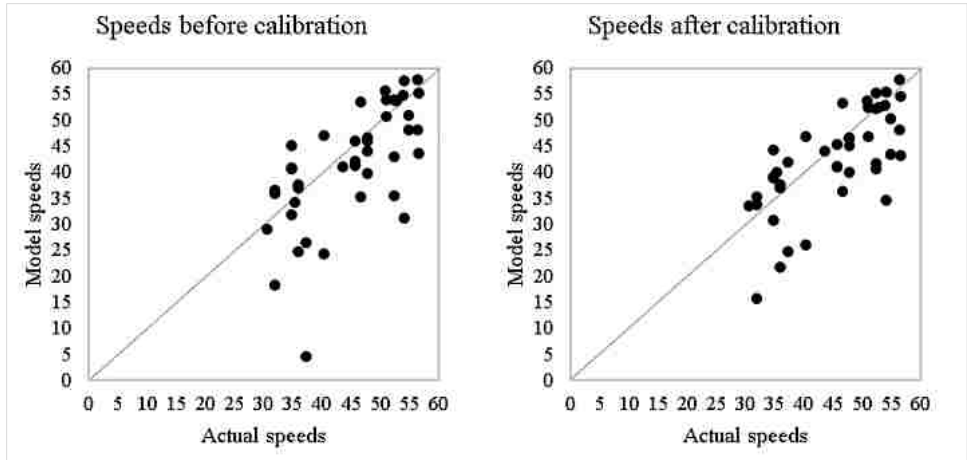


Figure 5. Speeds Before and After Calibration when All Parameters were Considered and 70% Links were Selected in Reno Network.

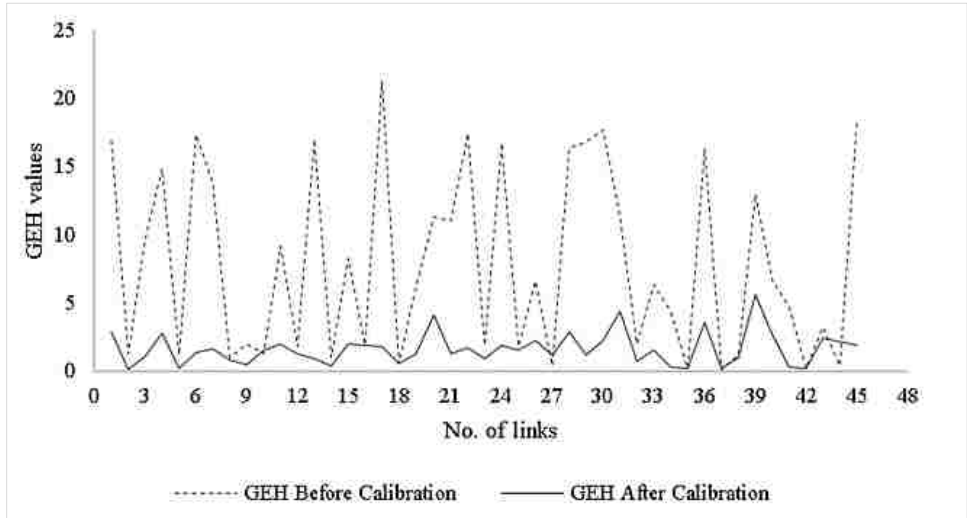


Figure 6. GEH Statistics when All Parameters were Considered and 70% Links were Selected for Calibration in Reno Network.

Table 2 shows the percentage of selected links and the corresponding calibration results when all parameters were selected simultaneously for calibration. The network was successfully calibrated when at least 60 % of links were selected.

Table 2. Calibration Results for Reno Network when All Parameters were Considered

Percentage of links selected for calibration	NRMS	Individual link flows			Relative difference between total actual and simulated counts	GEH statistic for individual link flows
		< 700 veh/hr	700 to 2700 veh/hr	> 2700 veh/hr		
100	0.0751	100%	100%	N/A	1.20%	<5 for 100%
90	0.0966	100%	100%	N/A	4.50%	<5 for 97%
80	0.0845	100%	100%	N/A	3.30%	<5 for 100%
70	0.0862	100%	100%	N/A	4.20%	<5 for 93%
60	0.0919	100%	100%	N/A	4.50%	<5 for 100%
50	0.1068	88.90%	100%	N/A	6.90%	<5 for 93%
40	0.1119	100%	100%	N/A	7.30%	<5 for 88%
30	0.1285	90%	88.60%	N/A	10.20%	<5 for 73%
20	0.1555	90%	57.10%	N/A	13.70%	<5 for 57%

A second group of experiments was completed using another model illustrated in Figure 7 and provided by McTrans. This model consists of 20 arterial links. The default parameters were considered as calibrated conditions. The outputs from this model, vehicle counts and speed, were used as field data for the experiments. Model parameters were randomly modified to represent an uncalibrated model.

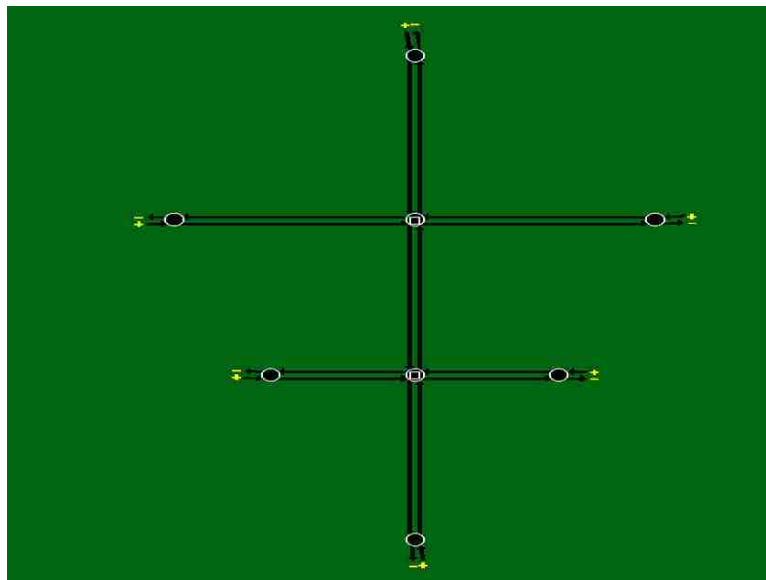


Figure 7. McTrans Model.

Links were randomly selected for calibration. Local parameters included mean queue discharge headway and mean start-up lost time. Global parameters included driver's familiarity with paths distribution that included percentage of drivers that know only one turn movement and percentage of drivers that know two turn movements.

When 70% of links were selected, the network was calibrated successfully. Figure 8 shows the convergence of the objective function. The initial value of NRMS was 0.29. After 370 iterations, the NRMS decreased by 79% to 0.06.

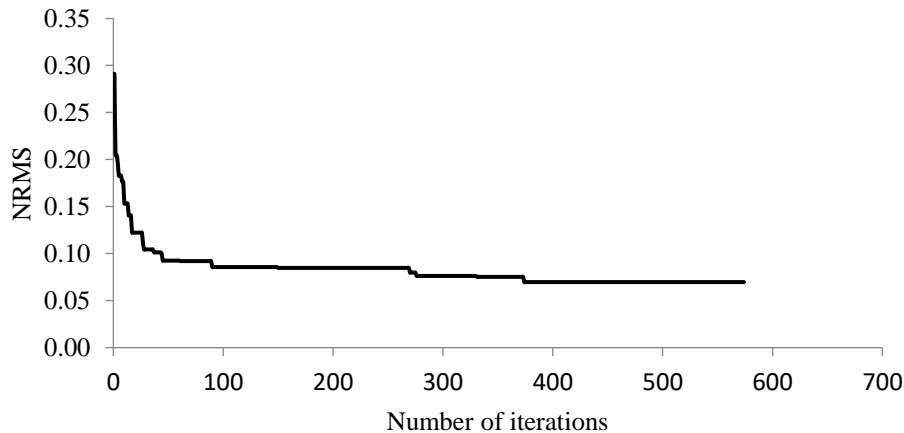


Figure 8. Objective Function when All Parameters were Considered and 70% Links were Selected for Calibration of McTrans Model.

Figure 9 shows the vehicle counts before and after calibration. The difference between actual and simulated counts is minimized by the calibration process. This is illustrated by the alignment of results along the 45° line. Figure 10 shows the speeds before and after calibration. Lower speeds suggest congested conditions. After calibration, actual and simulated speeds align along the 45°line. Figure 11 shows the GEH statistic for the model before and after calibration. The initial GEH value was less than 5 for 55% of the selected links. After calibration, the GEH value was less than 5 for 100% of links.

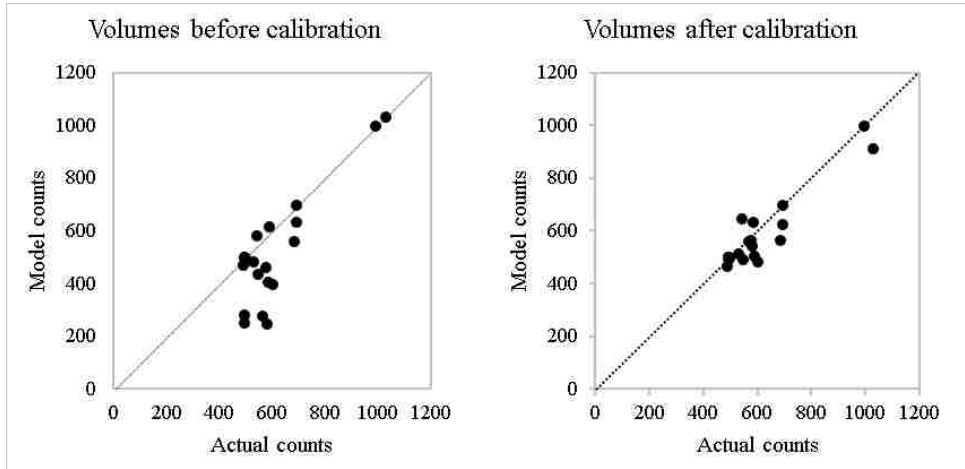


Figure 9. Volumes Before and After Calibration when All Parameters were Considered and 70% Links were Selected in McTrans Model.

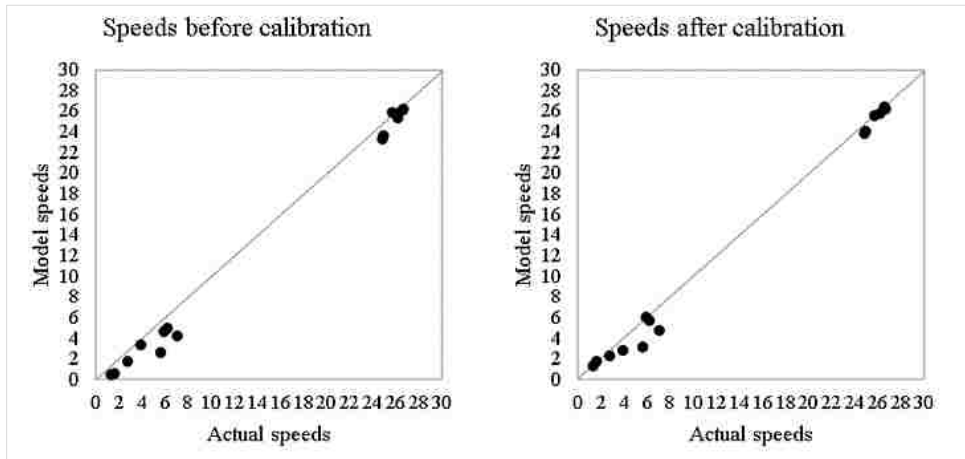


Figure 10. Speeds Before and After Calibration when All Parameters were Considered and 70% Links were Selected in McTrans Model.

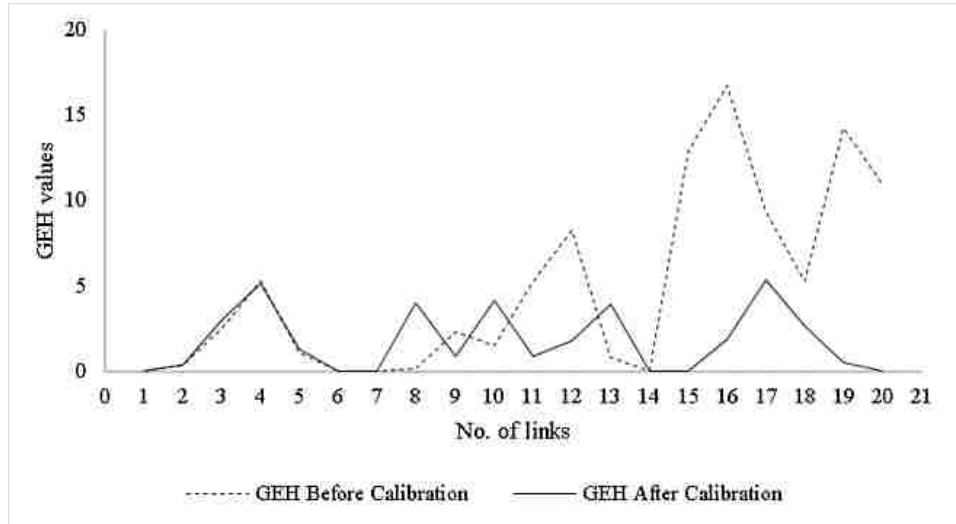


Figure 11. GEH statistics when All Parameters were Considered and 70% Links were Selected for Calibration of McTrans Model.

Table 3 shows the percentage of links selected and their respective calibration criteria when all parameters were selected simultaneously for calibration. The network was successfully calibrated when at least 60 % of links were selected.

Table 3. Calibration Results for McTrans Model when All Parameters were Considered

Percentage of links selected for calibration	NRMS	Individual link flows			Relative difference between total actual and simulated counts	GEH statistic for individual link flows
		< 700 veh/hr	700 to 2700 veh/hr	> 2700 veh/hr		
100	0.0305	100%	100%	N/A	0.30%	<5 for 100%
90	0.0463	100%	100%	N/A	0.20%	<5 for 100%
80	0.0317	100%	100%	N/A	0.40%	<5 for 100%
70	0.0697	100%	100%	N/A	0.50%	<5 for 100%
60	0.1366	89%	100%	N/A	2.60%	<5 for 95%
50	0.1835	72%	100%	N/A	5.00%	<5 for 85%
40	0.1980	78%	100%	N/A	9.60%	<5 for 80%

Second Set of Experiments: Simultaneous Selection of Links and Parameters

In the second set of experiments, links and associated parameters were selected simultaneously. These experiments were conducted using different combinations of parameters.

First Combination

First, local parameters were selected for every link while global parameters were set as default. Table 4 shows the selected percentage of links and the corresponding results when only local parameters were selected for calibration of the Reno network. The network was successfully calibrated when at least 70 % of links were selected for calibration.

Table 4. Calibration Results for Reno Network when Local Parameters were Considered

Percentage of links selected for calibration	NRMS	Individual link flows			Relative difference between total actual and simulated counts	GEH statistic for individual link flows
		< 700 veh/hr	700 to 2700 veh/hr	> 2700 veh/hr		
100	0.0884	100%	100%	N/A	4.00%	<5 for 100%
90	0.0860	100%	100%	N/A	3.20%	<5 for 100%
80	0.0873	100%	100%	N/A	3.10%	<5 for 100%
70	0.0946	100%	100%	N/A	3.40%	<5 for 95%
60	0.1369	100%	71.4%	N/A	11%	<5 for 64%

Figure 12 shows the convergence of the objective function when 70% of links were selected for calibration. The NRMS decreased from 0.22 to 0.09 after calibration.

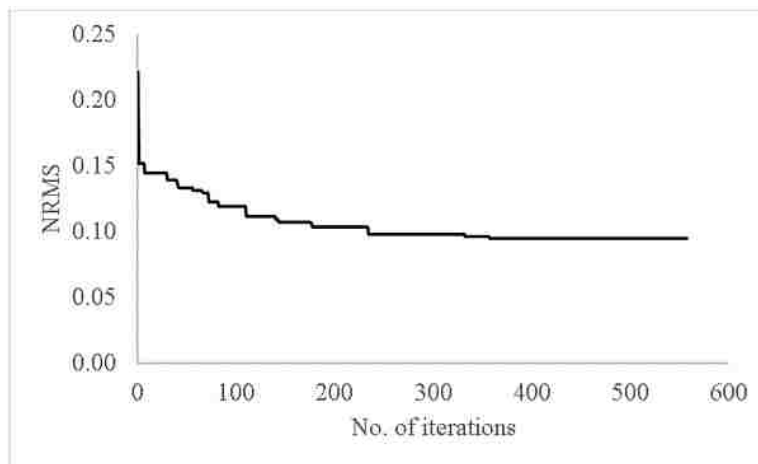


Figure 12. Objective Function when Local Parameters were Considered and 70% Links were Selected for Calibration of Reno Network.

Figure 13 and Figure 14 shows the vehicle counts and speeds before and after calibration respectively. Both vehicle counts and speeds align closer to the 45° line after calibration.

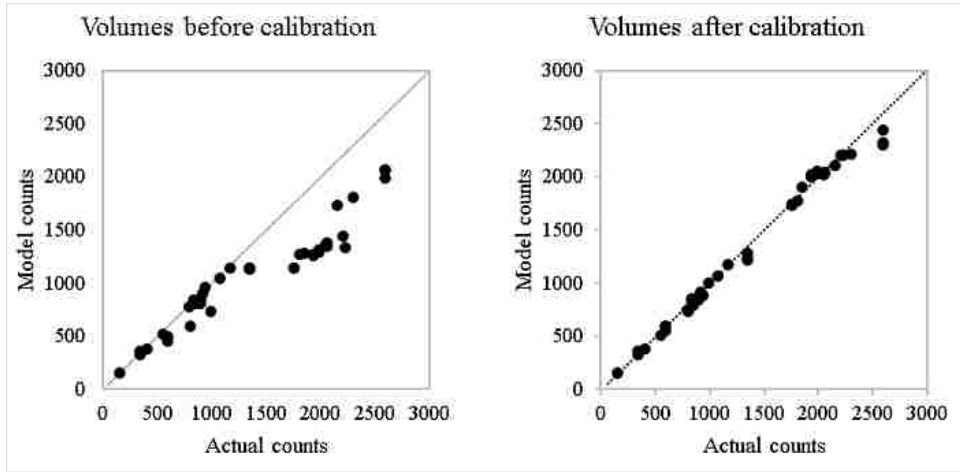


Figure 13. Volumes Before and After Calibration when Local Parameters were Considered and 70% Links were Selected in Reno Network.

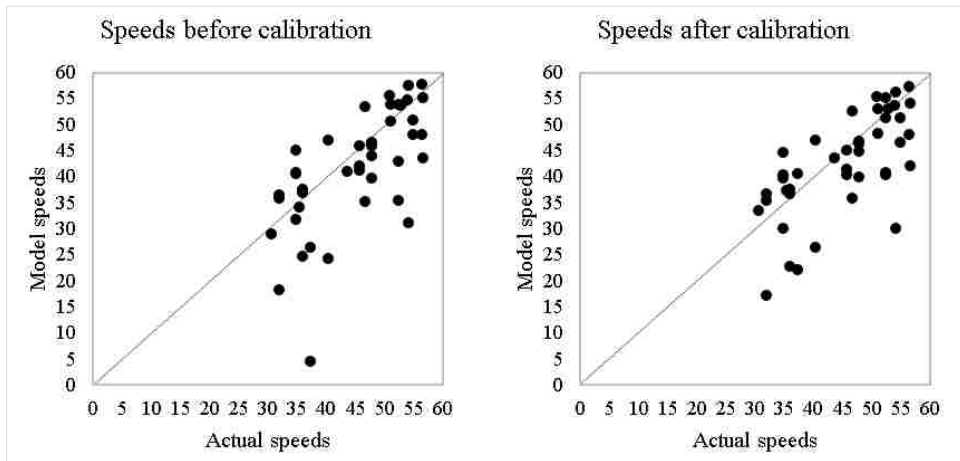


Figure 14. Speeds Before and After Calibration when Local Parameters were Considered and 70% Links were Selected in Reno Network.

Figure 15 shows the GEH statistic for the model after calibration. The initial GEH value was less than 5 for 46% of the selected links. After calibration, the GEH value was less than 5 for 95% of links.

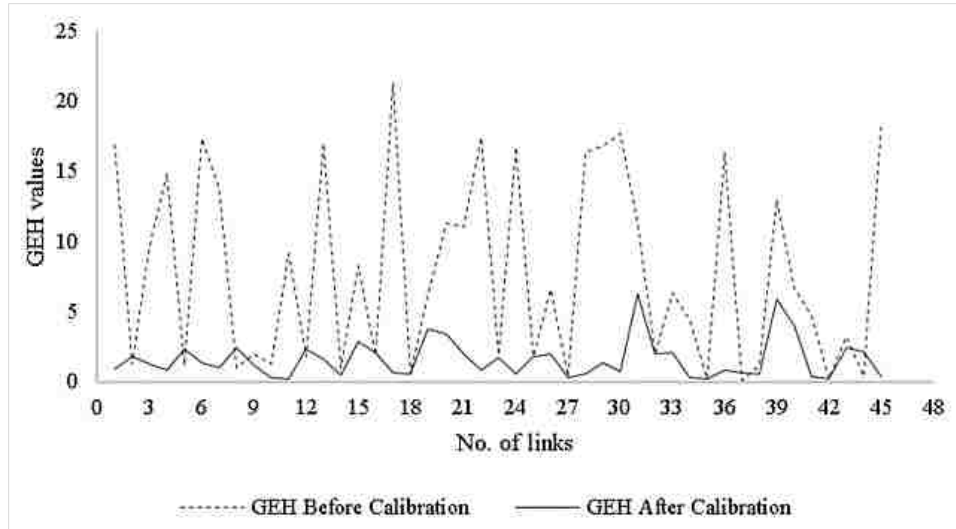


Figure 15. GEH Statistics when Local Parameters were Considered and 70% Links were Selected for Calibration of Reno Network.

Table 5 provides results when only local parameters were selected for calibration of the McTrans model. The model was successfully calibrated using at least 50% of the links for calibration.

Table 5. Calibration Results for Mctrans Model when Local Parameters were Considered

Percentage of links selected for calibration	NRMS	Individual link flows			Relative difference between total actual and simulated counts	GEH statistic for individual link flows
		< 700 veh/hr	700 to 2700 veh/hr	> 2700 veh/hr		
100	0.0480	100%	100%	N/A	0.60%	<5 for 100%
90	0.0421	100%	100%	N/A	0.40%	<5 for 100%
80	0.1249	89%	100%	N/A	3.60%	<5 for 100%
70	0.0924	94.40%	100%	N/A	1.40%	<5 for 100%
60	0.0974	100%	100%	N/A	2.70%	<5 for 100%
50	0.0959	94.40%	100%	N/A	3%	<5 for 100%
40	0.1367	88.20%	66.70%	N/A	2.70%	<5 for 90%

Figure 16 shows the convergence of the objective function when 70% of links were selected for calibration. The network was successfully calibrated. The NRMS decreased from 0.29 to 0.09 after calibration.

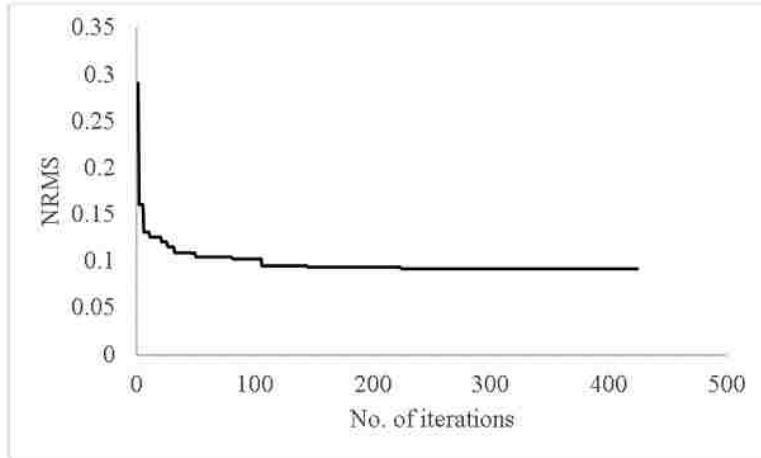


Figure 16. Objective Function when Local Parameters were Considered and 70% Links were Selected for Calibration of McTrans Model.

Figure 17 and Figure 18 shows the vehicle counts and speeds before and after calibration, respectively. Both vehicle counts and speeds align closer to the 45° line after calibration.

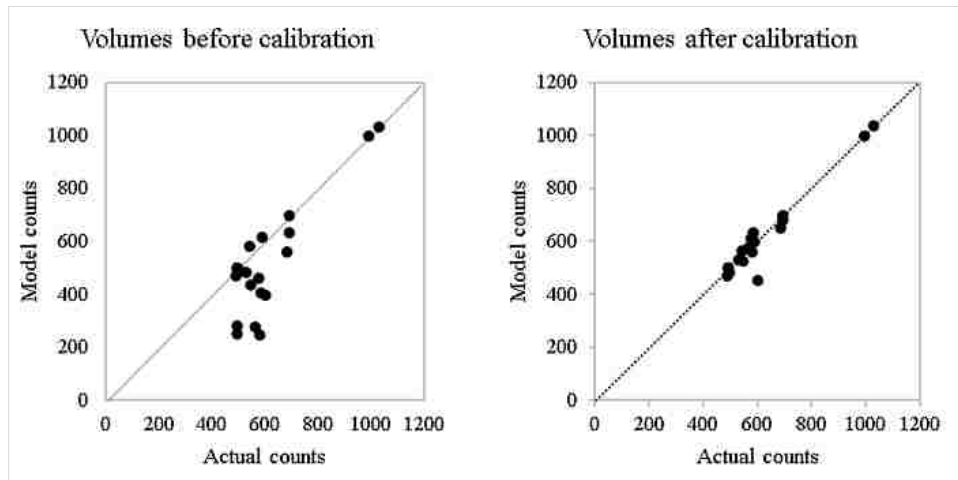


Figure 17. Volumes Before and After Calibration when Local Parameters were Considered and 70% Links were Selected in McTrans Model.

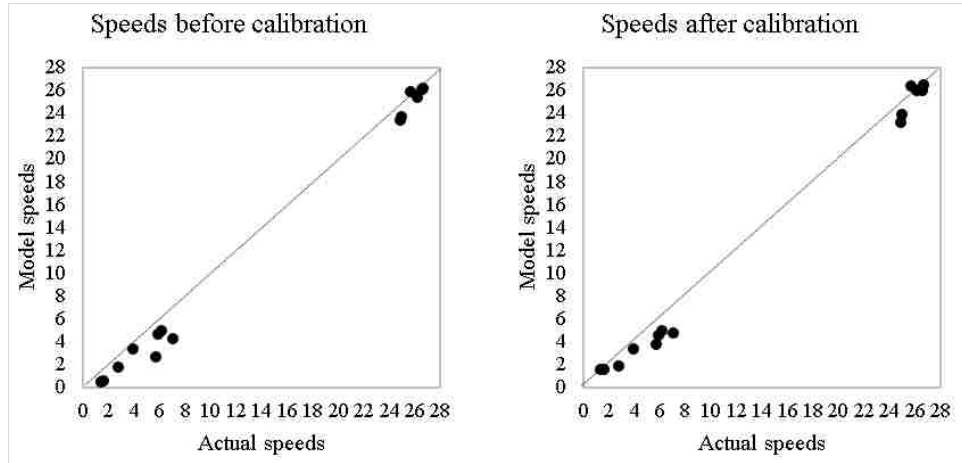


Figure 18. Speeds Before and After Calibration when Local Parameters were Considered and 70% Links were Selected in McTrans Model.

Figure 19 shows the GEH statistic for the model after calibration. The initial GEH value was less than 5 for 55% of the selected links. After calibration, the GEH value was less than 5 for 100% of links.

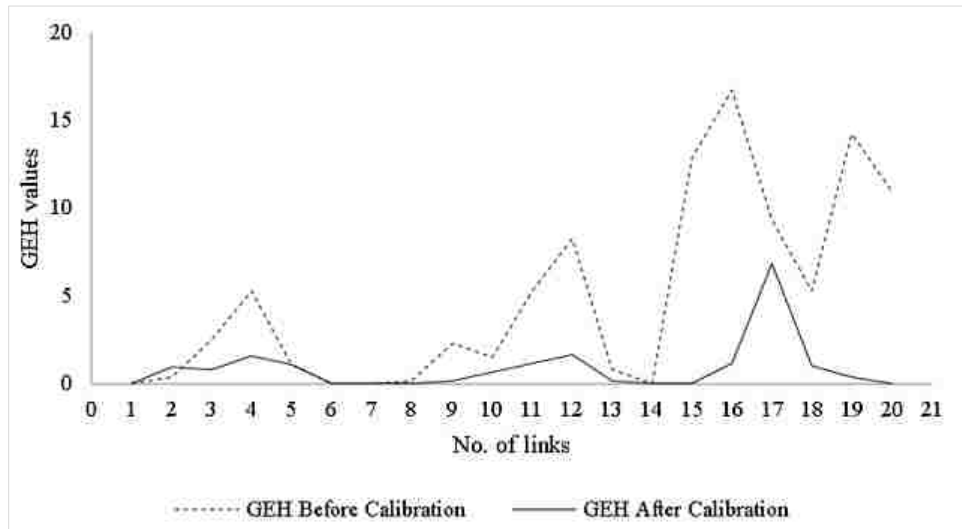


Figure 19. GEH Statistics when Local Parameters were Considered and 70% Links were Selected for Calibration of McTrans Model.

Second Combination

Second, mean queue discharge headway was selected as the only local parameter for calibration; all global parameters were considered. Table 6 provides results when the mean queue discharge

headway and all global parameters were selected for calibration of the Reno network. The network was successfully calibrated when at least 60% of the links were selected for calibration.

Table 6. Calibration Results for Reno Network when All Global Parameters and Mean Queue Discharge Headway was Considered

Percentage of links selected for calibration	NRMS	Individual link flows			Relative difference between total actual and simulated counts	GEH statistic for individual link flows
		< 700 veh/hr	700 to 2700 veh/hr	> 2700 veh/hr		
100	0.0872	100%	100%	N/A	2.70%	<5 for 100%
90	0.0970	100%	100%	N/A	5.20%	<5 for 93%
80	0.0976	100%	100%	N/A	4.00%	<5 for 97%
70	0.0897	100%	100%	N/A	3.90%	<5 for 100%
60	0.0916	100%	100%	N/A	5%	<5 for 100%
50	0.1037	100%	100%	N/A	5.9%	<5 for 93%

Figure 20 shows the convergence of the objective function when 70% of links were selected for calibration. The NRMS decreased from 0.22 to 0.08 after calibration.

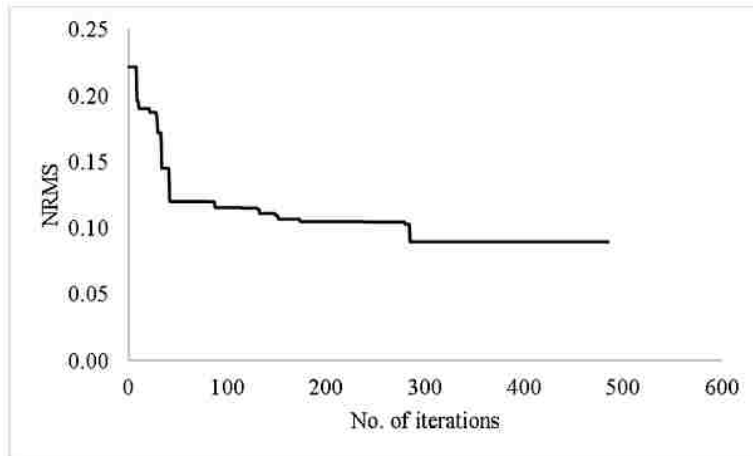


Figure 20. Objective Function when All Global Parameters and Mean Queue Discharge Headway was Considered for Calibration with 70% Link Selection in Reno Network.

Figure 21 and Figure 22 shows the vehicle counts and speeds before and after calibration respectively. Both vehicle counts and speeds align closer to the 45° line after calibration.

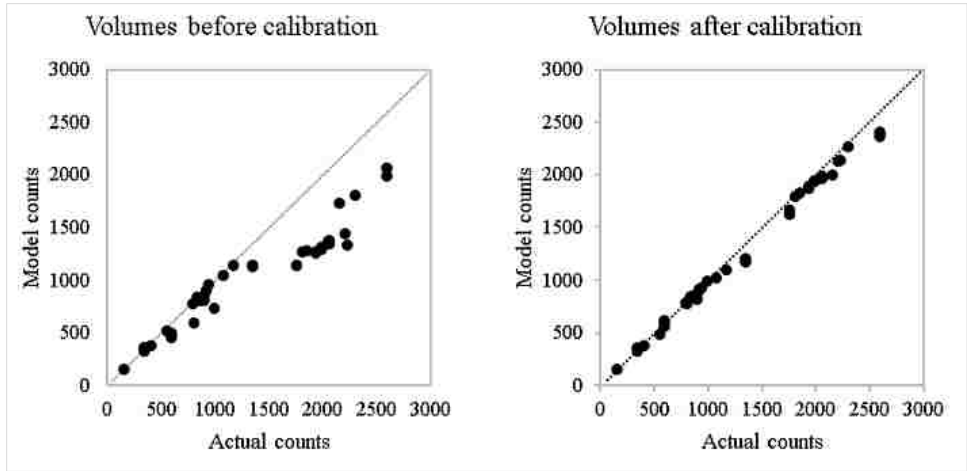


Figure 21. Volumes Before and After Calibration when All Global Parameters and Mean Queue Discharge Headway was Considered with 70% Link Selection in Reno Network.

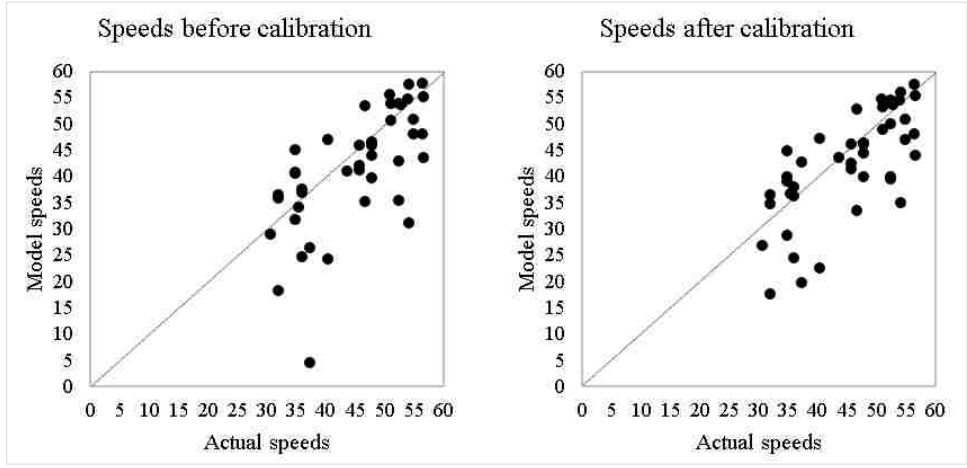


Figure 22. Speeds Before and After Calibration when All Global Parameters and Mean Queue Discharge Headway was Considered with 70% Link Selection in Reno Network.

Figure 23 shows the GEH statistic for the model after calibration. The initial GEH value was less than 5 for 46% of the selected links. After calibration, the GEH value was less than 5 for 100% of links.

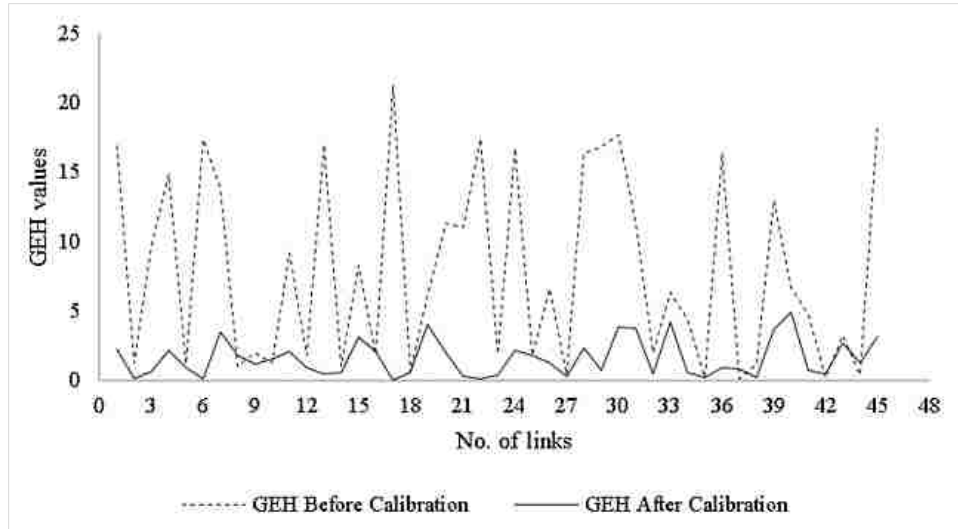


Figure 23. GEH Statistics when All Global Parameters and Mean Queue Discharge Headway was Considered for Calibration with 70% Link Selection in Reno Network.

Table 7 provides results when mean queue discharge headway and all global parameters were selected for calibration of the McTrans model. The network was successfully calibrated with at least 60% of links selected for calibration.

Table 7. Calibration Results for Mctrans Model when All Global Parameters and Mean Queue Discharge Headway was Considered

Percentage of links selected for calibration	NRMS	Individual link flows			Relative difference between total actual and simulated counts	GEH statistic for individual link flows
		< 700 veh/hr	700 to 2700 veh/hr	> 2700 veh/hr		
100	0.0860	94.10%	100.00%	N/A	1.30%	<5 for 95%
90	0.0588	100.00%	100.00%	N/A	0.60%	<5 for 100%
80	0.0980	94.40%	100.00%	N/A	0.90%	<5 for 95%
70	0.1279	88.90%	100.00%	N/A	2.20%	<5 for 95%
60	0.1257	94.1%%	100.00%	N/A	2.70%	<5 for 95%
50	0.1737	77.80%	100.00%	N/A	5.50%	<5 for 80%

Figure 24 shows the convergence of the objective function when 70% of links were selected for calibration. The NRMS decreased from 0.29 to 0.12 after calibration.

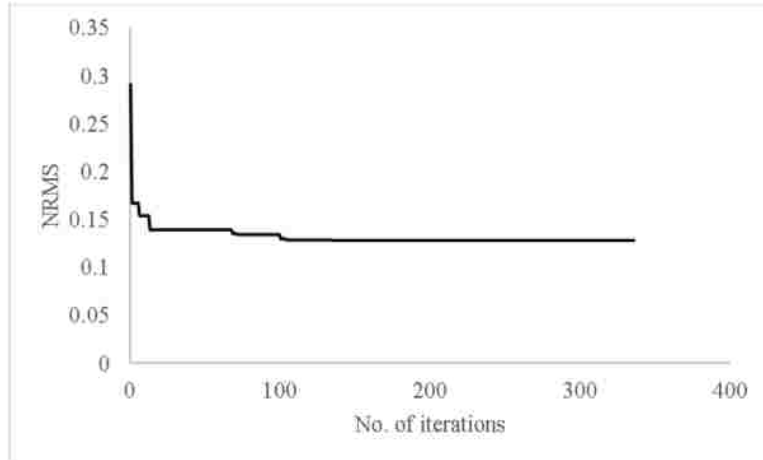


Figure 24. Objective Function when All Global Parameters and Mean Queue Discharge Headway was Considered for Calibration with 70% Link Selection in McTrans Model.

Figure 25 and Figure 26 shows the vehicle counts and speeds before and after calibration respectively. Both vehicle counts and speeds align closer to the 45° line after calibration.

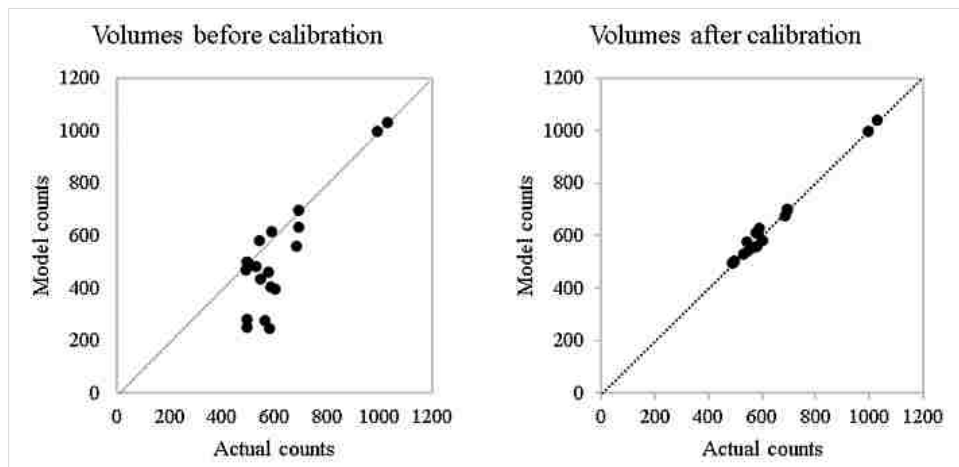


Figure 25. Volumes Before and After Calibration when All Global Parameters and Mean Queue Discharge Headway was Considered with 70% Link Selection in McTrans Model.

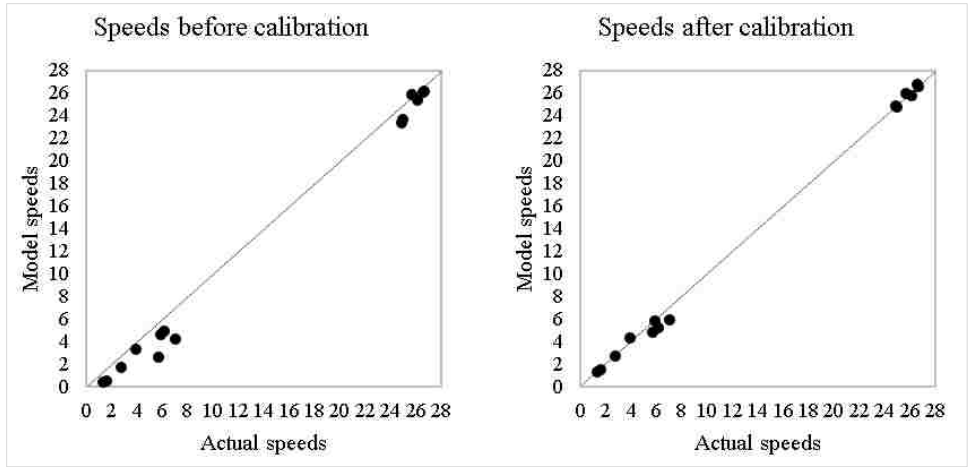


Figure 26. Speeds Before and After Calibration when All Global Parameters and Mean Queue Discharge Headway was Considered with 70% Link Selection in McTrans Model.

Figure 27 shows the GEH statistic for the model after calibration. The initial GEH value was less than 5 for 55% of the selected links. After calibration, the GEH value was less than 5 for 95% of links.

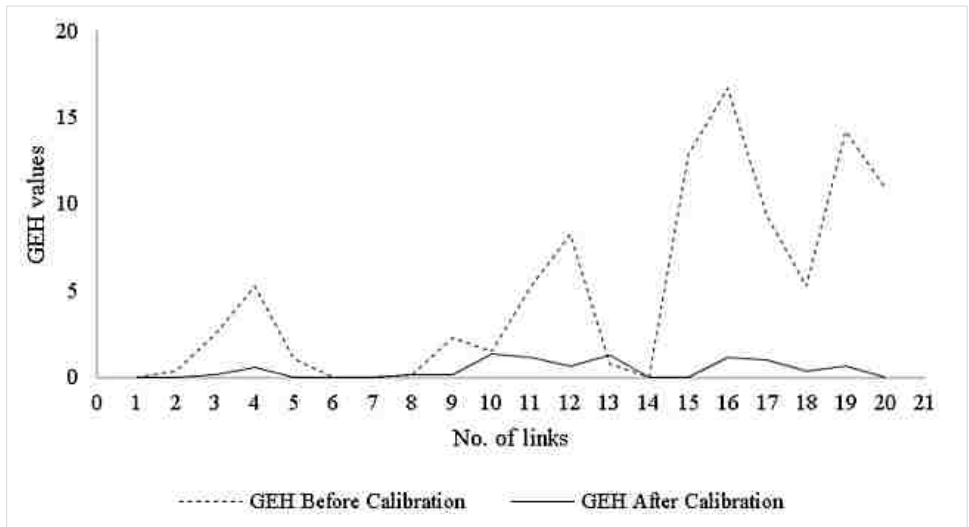


Figure 27. GEH Statistics when All Global Parameters and Mean Queue Discharge Headway was Considered for Calibration with 70% Link Selection in McTrans Model.

Third Combination

Third, mean start-up lost time was selected as the only local parameter for calibration; all global parameters were considered. The results show that it was not possible to calibrate the model under

this scenario. Table 8 provides results when mean start-up lost time and all global parameters were selected for calibration of the Reno network.

Table 8. Calibration Results for Reno Network when All Global Parameters and Mean Start-Up Lost Time was Considered

Percentage of links selected for calibration	NRMS	Individual link flows			Relative difference between total actual and simulated counts	GEH statistic for individual link flows
		< 700 veh/hr	700 to 2700 veh/hr	> 2700 veh/hr		
100	0.1243	90.00%	91.00%	N/A	9.50%	<5 for 75%
70	0.1264	90.00%	85.70%	N/A	8.50%	<5 for 77%

Table 9 provides results when mean start-up lost time and all global parameters were selected for calibration of the McTrans model.

Table 9. Calibration Results for Mctrans Model when All Global Parameters and Mean Start-Up Lost Time was Considered

Percentage of links selected for calibration	NRMS	Individual link flows			Relative difference between total actual and simulated counts	GEH statistic for individual link flows
		< 700 veh/hr	700 to 2700 veh/hr	> 2700 veh/hr		
100	0.2022	72.20%	100.00%	N/A	10.00%	<5 for 75%
70	0.2384	61.10%	100.00%	N/A	12.70%	<5 for 70%

Fourth Combination

Fourth, mean queue discharge headway and mean start-up lost time were selected as mutually exclusive while all global parameters were considered for calibration. Table 10 provides the results using different percentages of mean queue discharge headway and mean start-up lost time while all global parameters were considered for calibration of the Reno network. This network was successfully calibrated when mean queue discharge headway was selected for at least 80% of links and mean start-up lost time was selected for the remaining 20% of links.

Table 10. Calibration Results for Reno Network when Selectin of Mean Queue Discharge Headway and Mean Start-Up Lost Time was Mutually Exclusive

Percentage of links selected with mean queue discharge headway	Percentage of links selected with mean start-up lost time	NRMS	Individual link flows			Relative difference between total actual and simulated counts	GEH statistic for individual link flows
			< 700 veh/hr	700 to 2700 veh/hr	> 2700 veh/hr		
90	10	0.0909	100%	100%	N/A	4.2%	<5 for 97%
80	20	0.0930	100%	100%	N/A	4.7%	<5 for 100%
70	30	0.0947	100%	100%	N/A	5.4%	<5 for 97%

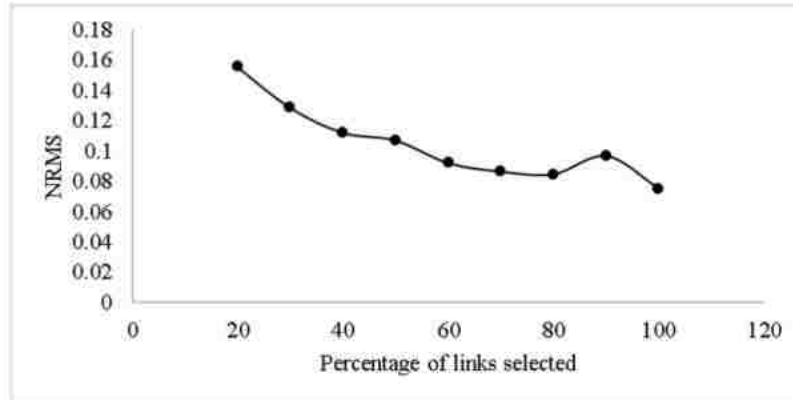
Table 11 provides the results using different percentages of mean queue discharge headway and mean start-up lost time while all global parameters were considered for calibration of the McTrans model. This network was successfully calibrated when mean queue discharge headway was selected for at least 90% of links and mean start-up lost time was selected for the remaining 10% of links.

Table 11. Calibration Results for McTrans Model when Selection of Mean Queue Discharge Headway and Mean Start-Up Lost Time was Mutually Exclusive

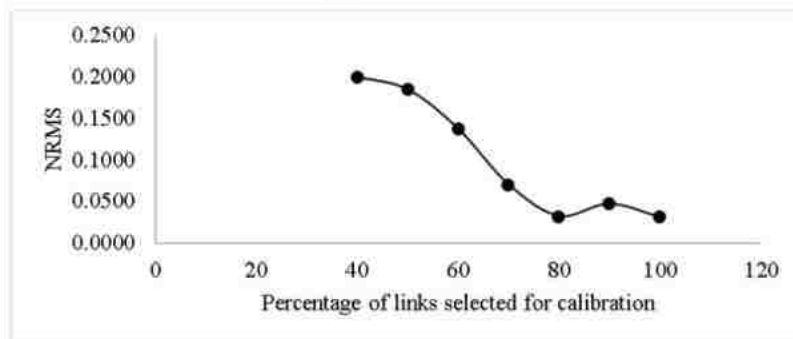
Percentage of links selected with mean queue discharge headway	Percentage of links selected with mean start-up lost time	NRMS	Individual link flows			Relative difference between total actual and simulated counts	GEH statistic for individual link flows
			< 700 veh/hr	700 to 2700 veh/hr	> 2700 veh/hr		
90	10	0.0679	94.1%	100.00%	N/A	0.7%	<5 for 100%
80	20	0.1827	72.2%	100.00%	N/A	8.2%	<5 for 80%
70	30	0.1746	82.4%	66.7%	N/A	6.2%	<5 for 80%

CHAPTER 4: SENSITIVITY ANALYSIS

Various sensitivity analyses were conducted to observe the effects on NRMS of different percentage selection of links and different combination of parameters. The results are illustrated in Figure 28 and Figure 29. Figure 28 shows the effects on NRMS due to various percentages of link selection for calibration.



(a) Reno Network

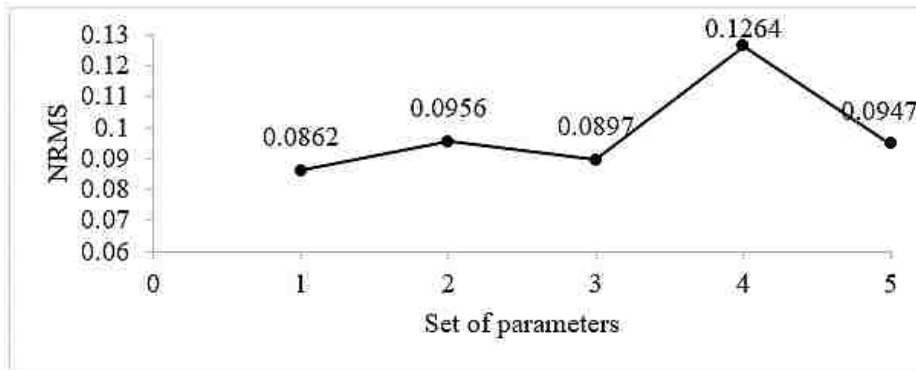


(b) McTrans Model

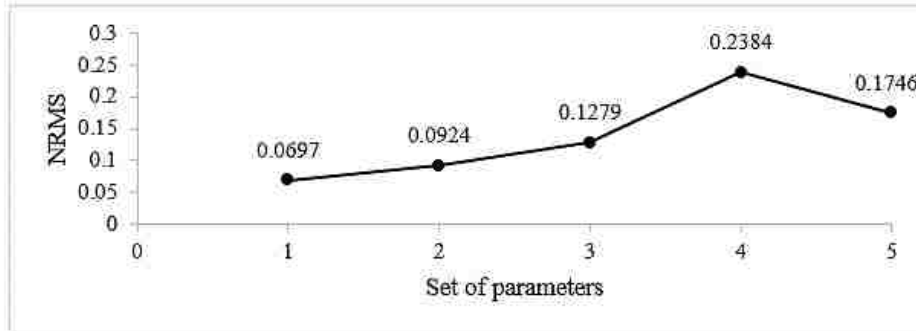
Figure 28. Effect on NRMS of Various Percentages of Link Selection for Calibration.

In Figure 29, set 1 includes all global and local parameters that were selected simultaneously for 70% of the links; set 2 includes global parameters set as default and all local parameters selected for 70% of the links; set 3 includes all global parameters and mean queue discharge headway selected for 70% of the links; set 4 includes all global parameters and mean start-up lost selected for 70% of the links; and set 5 includes all global parameters, and mutually

exclusive mean queue discharge headway and mean start-up lost selected at 70% and 30% of the links respectively.



(a) Reno Network



(b) McTrans Model

Figure 29. Effect on NRMS of Various Sets of Parameters for Calibration.

As expected, the results show that most of the times the NRMS decreases with the increase in the percentage of selected links for calibration. The NRMS value changes for various sets of parameters for the same percentage of links selected for calibration. Similar values of NRMS between a calibrated and an uncalibrated condition do not suggest that all calibration criteria have been met in both cases.

CHAPTER 5: CONCLUSION

This study proposed a methodology that enables the selection of any combination of facilities and local and global parameters for the calibration of micro-simulation traffic flow models. A mathematical program and solution algorithm were proposed to implement the methodology. Results using two network models and various sensitivity analyses show the effectiveness of the methodology. The models were successfully calibrated for volumes and speeds subject to selection of a minimum number of links for calibration.

The percentage of links selected for calibration was varied from a minimum to a 100 percent. Similarly, various local parameters were selected for the corresponding links. Multiple experiments were performed varying the selection of global and local calibration parameters. Unselected parameters were assigned default values.

The experiments were tested using CORSIM models. However, the methodology was developed without considering the characteristics of a specific traffic flow model. Future work involves testing the methodology using other traffic flow models. New algorithms and methods could be developed and explored to reduce the number of links that are required to calibrate a traffic network. Similarly, a multi-objective optimization approach could be proposed (Cobos et al., 2016) in contrast to the single objective function used in this study to get superior results.

APPENDIX A: USER’S GUIDE TO THE CALIBRATION TOOL

The proposed methodology was implemented by developing a calibration tool that uses a Graphical User Interface (GUI). The calibration tool visualizes the process of calibration in a number of steps, which are as shown below.

Step 1: Network Selection

For CORSIM models, the input (“trf”) file consists of Record Types (RT) that contain information on geometry, traffic flow and calibration parameters. From the main menu of the calibration tool, as shown in Figure A1. Main Menu of the Calibration tool, go to the “Select a trf file” option, then find the input file to open. Figure A2. Browse to Select the Input File of the Network shows the first step in which the input file of a network is located.



Figure A1. Main Menu of the Calibration tool.

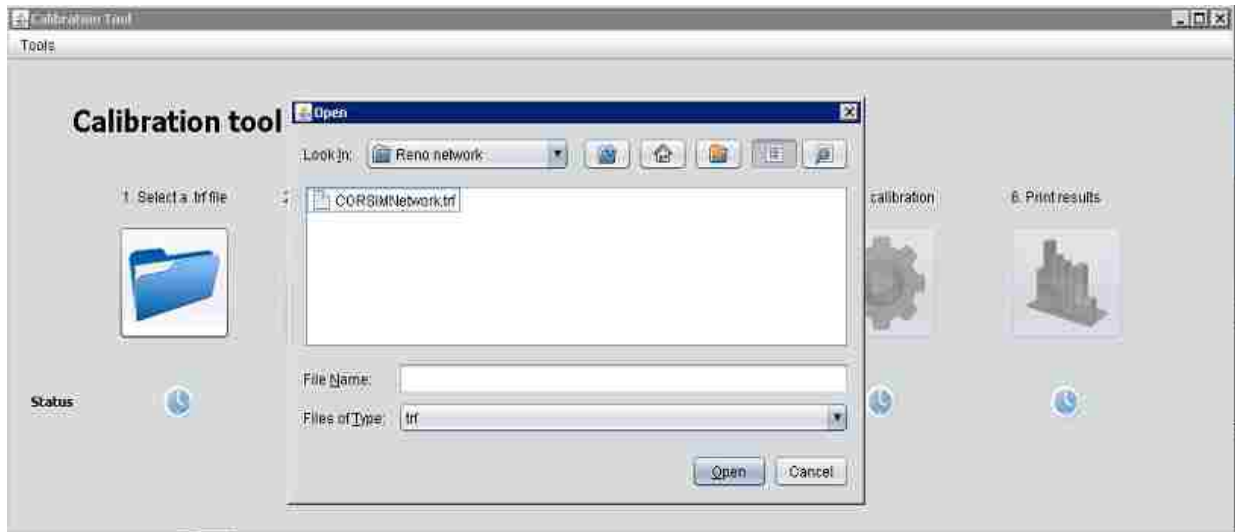


Figure A2. Browse to Select the Input File of the Network.

Step 2: Parameter Selection

In the second step, the calibration parameters along with their initial values are selected. Click on the “Use default parameters” button to load default values of the parameters. The users can enter a parameter of any record type as required and edit their minimum and maximum values by using the “Parameter Selection” menu, which is as shown in Figure A3.

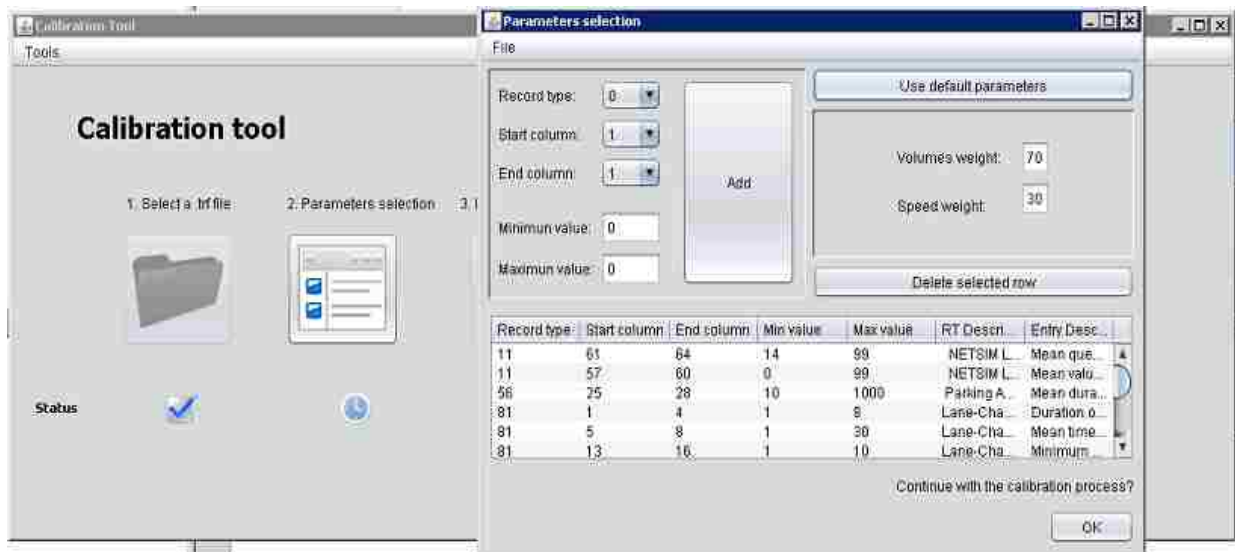


Figure A3. Parameters Selection.

Step 3: Selection of Specific Links and Parameters

In the third step, the tool allows users to select specific links and parameters as desired for calibration. The users have an option to check or uncheck any link or any record type or any of its entries (the parameters) within the tool, which is shown in Figures A4 – A7. The unselected parameters have default values.



Figure A4. Interface for Specific Links and Parameters Selection.

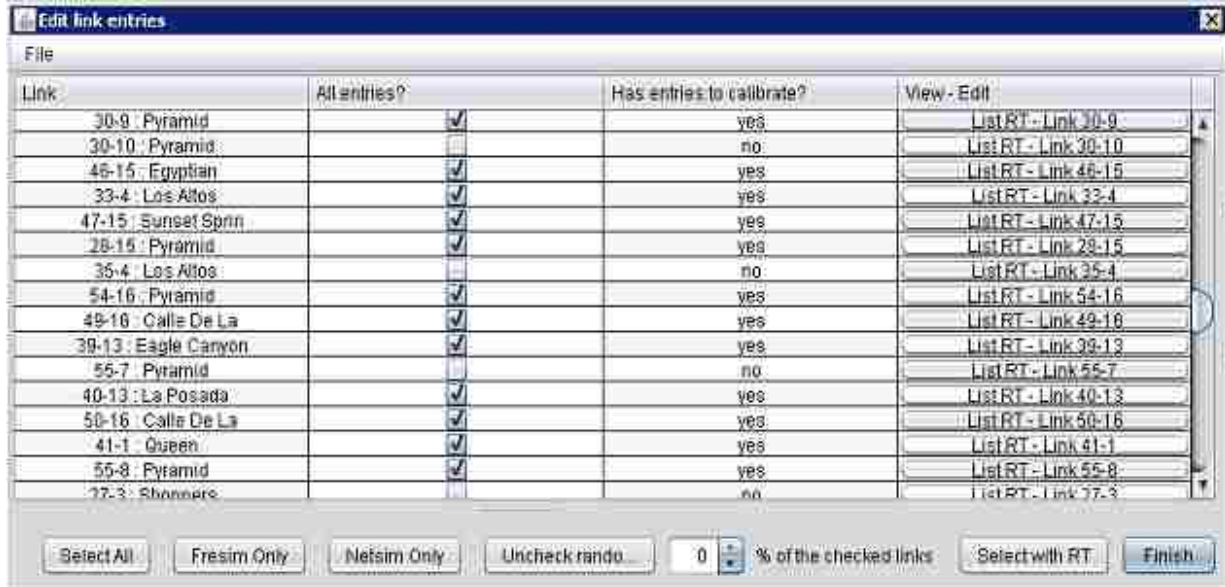


Figure A5. Link Selection for Calibration.



Figure A6. Parameters Selection for Calibration.

Entry	Min Value	Max Value	Calibrate for all links ?	Links
1: Duration of a lane-c...	1	8	<input checked="" type="checkbox"/>	Links
2: Mean time for a driv...	1	30	<input checked="" type="checkbox"/>	Links
3: Minimum decelerati...	1	10	<input checked="" type="checkbox"/>	Links
4: Difference in maxim...	5	15	<input checked="" type="checkbox"/>	Links
5: Difference in maxim...	5	15	<input checked="" type="checkbox"/>	Links
6: Deceleration rate of ...	10	15	<input checked="" type="checkbox"/>	Links
7: Deceleration rate of ...	10	15	<input checked="" type="checkbox"/>	Links
8: Driver type factor us...	15	50	<input type="checkbox"/>	Links
9: Urgency threshold	0	5	<input type="checkbox"/>	Links
10: Safety factor x 1.0	6	10	<input type="checkbox"/>	Links
11: Percentage of drive...	10	100	<input type="checkbox"/>	Links
12: Headway below w...	1	30	<input type="checkbox"/>	Links
13: Headway above w...	30	100	<input type="checkbox"/>	Links
14: Mean longitudinal ...	50	2500	<input type="checkbox"/>	Links

Back (Global RT List)

Figure A7. List of Entries for Record Type.

Step 4: Loading of Actual Data

In this step, the actual vehicle counts and/or speeds are loaded for calibration. Users can manually enter, save and modify data to an editable table. Figure A8 and Figure A9 show the process of loading actual data.



Figure A8. Loading of Actual Data.

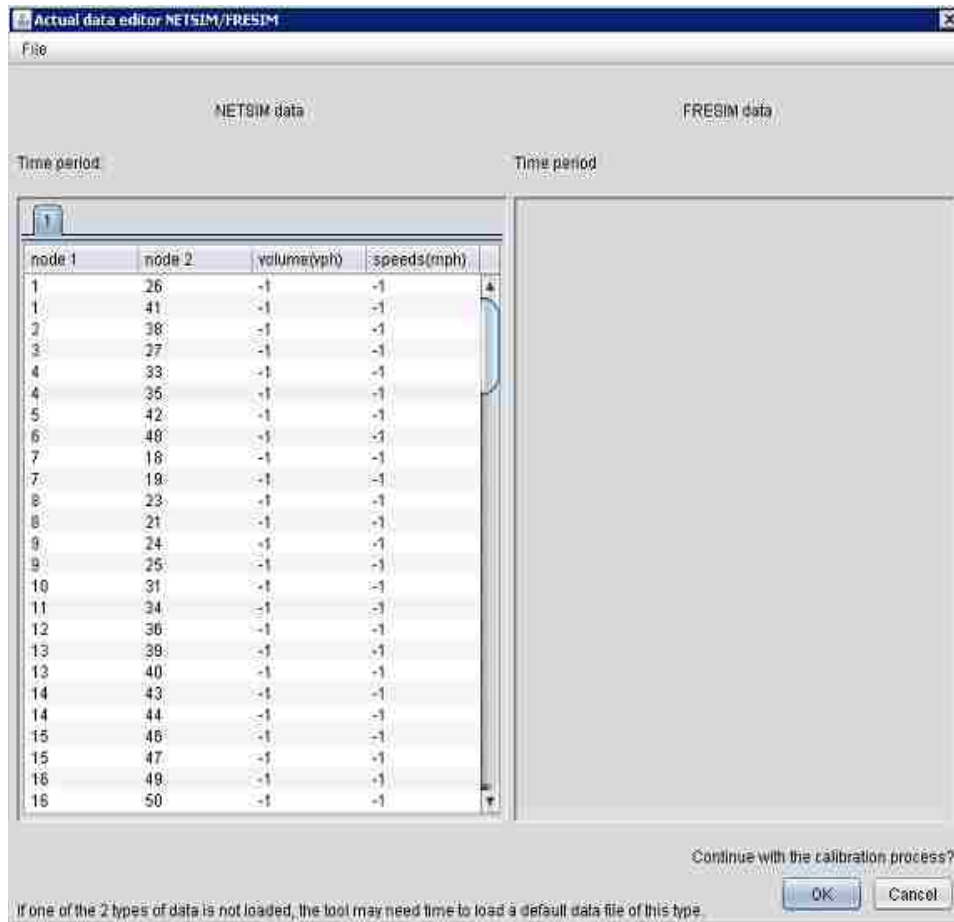


Figure A9. Data Editor.

Step 5: Search of Solution Set of Parameters

In this step, the calibration is run by selecting an appropriate optimization algorithm for calibration, which is shown in Figure A10 – A11.



Figure A10. Run Calibration.

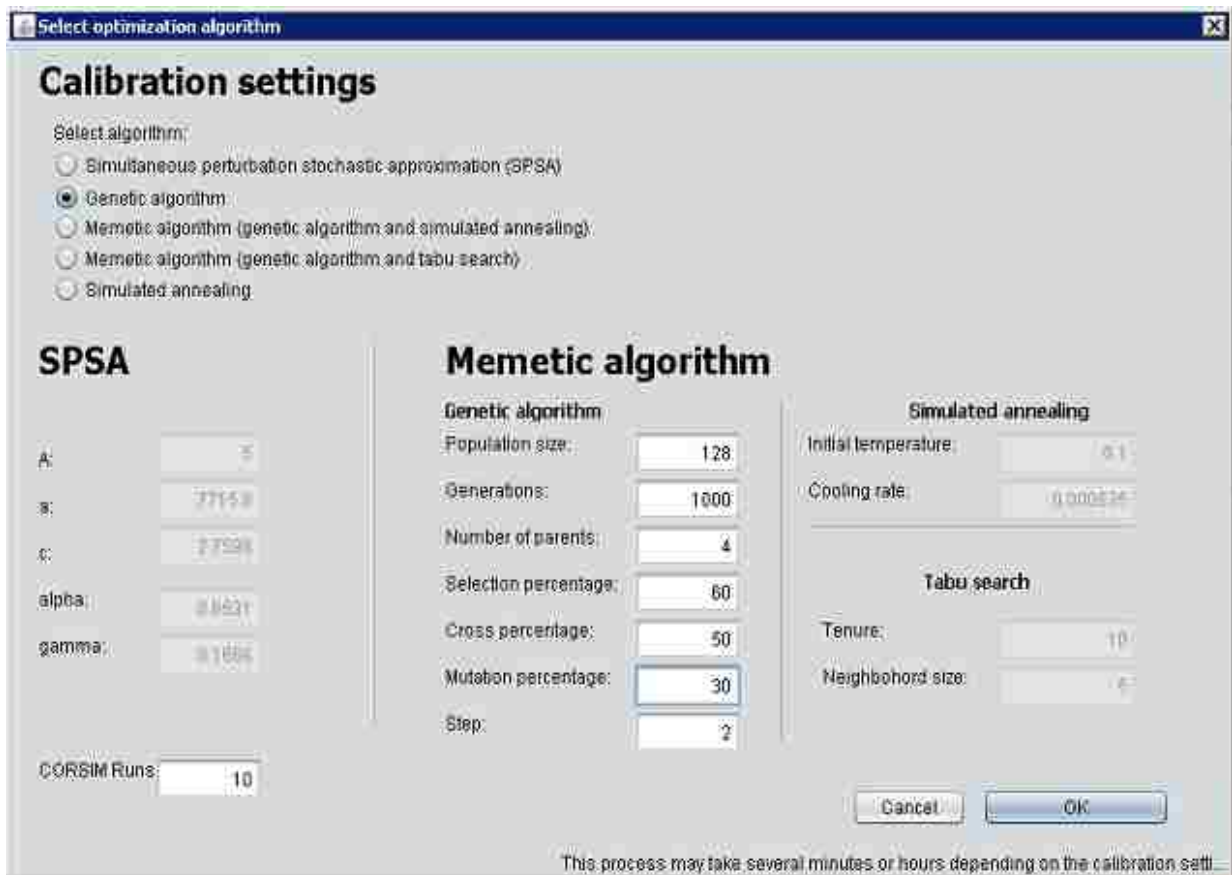


Figure A11. Algorithm Setup.

Step 6: Visualization of Results

In this step, the tool provides the results of calibration. It generates graphs showing the GEH statistics, vehicle counts, and speeds before and after calibration, which are shown in Figures A12 – A15. The input (“trf”) file is replaced by the calibrated (“trf”) file.



Figure A12. Visualization of Results.

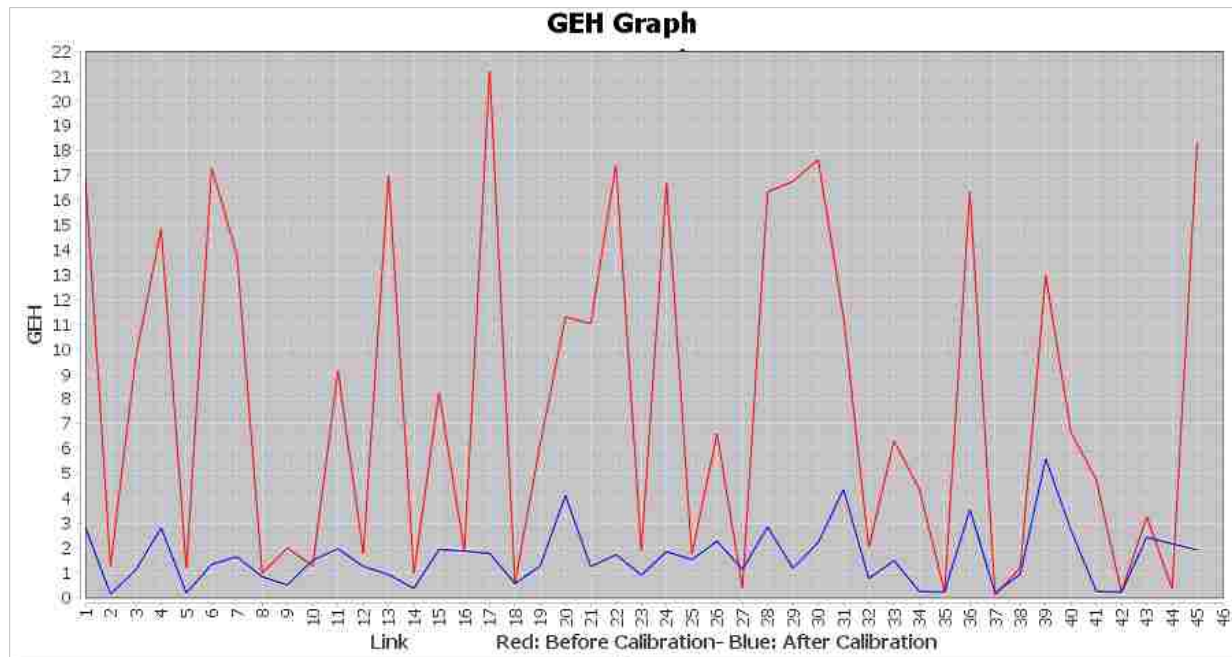


Figure A13. GEH Statistics.

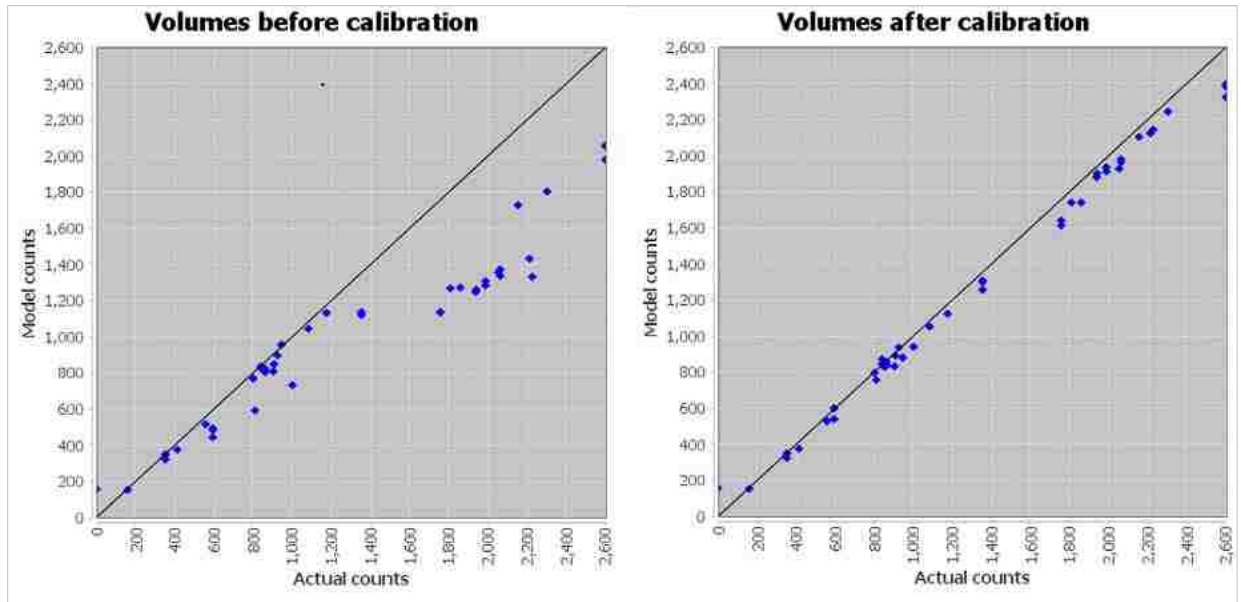


Figure A14. Volumes before and after Calibration.

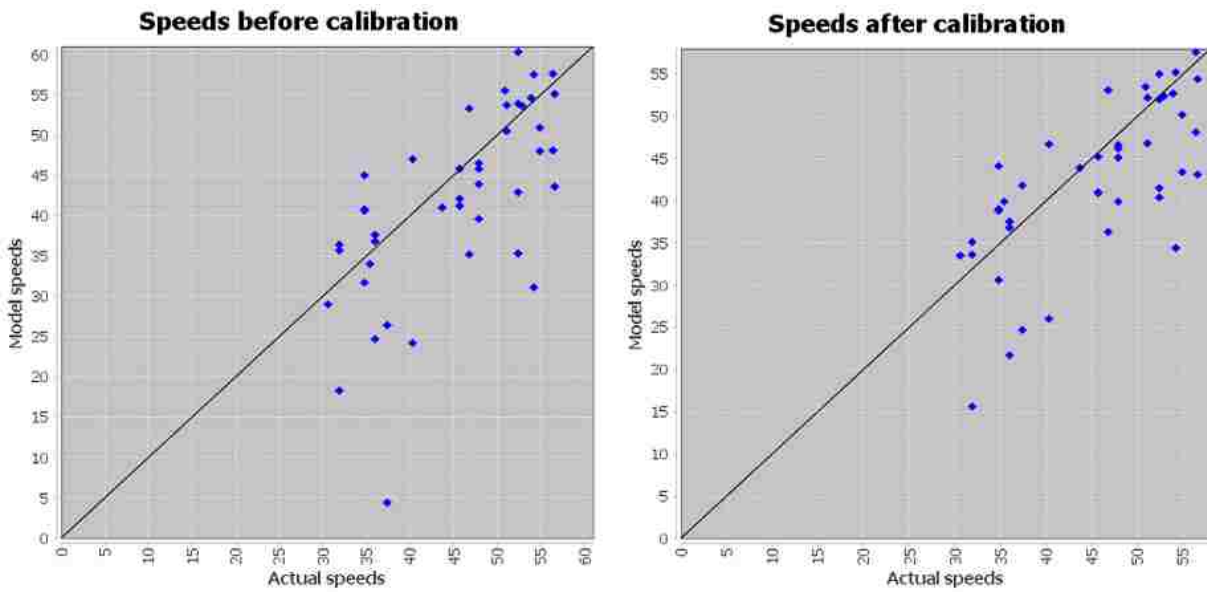


Figure A15. Speeds before and after Calibration.

APPENDIX B: CALIBRATION PARAMETERS IN CORSIM MODELS

Table B1–B6 shows the calibration parameters used in the experiments performed with the CORSIM models in this study. A few experiments that selected 70% of links are included, which are as follows.

Table B1. Calibration Parameters in the First Experiment with Reno Network

SN	Model	Parameter	Lower bound	Upper bound	Units	Links	Value before calibration	Value after calibration
1	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	1-26	38	41
2	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	1-41	36	42
3	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	2-38	40	42
4	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	3-27	38	38
5	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	4-33	36	48
6	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	4-35	38	85
7	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	5-42	38	30
8	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	6-48	38	75
9	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	7-19	38	48
10	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8-21	40	81
11	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	9-25	36	38
12	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	10-31	40	56
13	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	13-39	36	89
14	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	13-40	38	34
15	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	14-43	36	40
16	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	14-44	40	42
17	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	15-47	40	48
18	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	16-49	26	48
19	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	16-51	28	61
20	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	22-45	28	26
21	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	11-10	28	48
22	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	2-3	26	36
23	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	11-12	30	44
24	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	12-11	30	32
25	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	5-6	26	50
26	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	12-13	23	21
27	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	13-12	30	22
28	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	6-5	30	30
29	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	13-14	30	38
30	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	14-15	48	90
31	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	15-14	48	18
32	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	3-4	45	15
33	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	51-16	38	28
34	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	17-1	34	38
35	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	20-2	34	38
36	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	43-14	30	34
37	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	21-8	38	28

SN	Model	Parameter	Lower bound	Upper bound	Units	Links	Value before calibration	Value after calibration
38	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	22-1	34	24
39	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	23-8	34	19
40	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	44-14	38	90
41	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	24-9	30	34
42	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	52-5	38	38
43	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	26-1	30	57
44	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	30-9	30	67
45	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	30-10	28	70
46	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	33-4	26	20
47	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	28-15	30	74
48	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	35-4	30	26
49	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	54-16	28	30
50	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	49-16	28	32
51	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	55-7	26	26
52	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	40-13	20	14
53	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	41-1	28	14
54	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	55-8	30	22
55	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	27-3	36	38
56	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	4-52	36	38
57	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	31-10	38	74
58	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	17-20	38	32
59	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	2-20	36	96
60	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	34-11	38	89
61	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	28-54	40	87
62	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	16-54	36	22
63	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	7-55	40	48
64	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	38-2	36	24
65	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8-55	36	59
66	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	25-9	50	50
67	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8018-18	40	42
68	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8021-21	50	46
69	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8023-23	44	40
70	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8024-24	48	50
71	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8027-27	46	36
72	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8031-31	48	45
73	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8033-33	44	50
74	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8035-35	50	87
75	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8038-38	48	23
76	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8039-39	49	51
77	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8040-40	40	92
78	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8041-41	50	21
79	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8043-43	48	46
80	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8045-45	18	14
81	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8046-46	26	34
82	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8048-48	26	76
83	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8050-50	26	93
84	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8051-51	40	38
85	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	20-17	40	24

SN	Model	Parameter	Lower bound	Upper bound	Units	Links	Value before calibration	Value after calibration
86	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	54-28	48	52
87	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	9-8	48	18
88	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8-9	40	32
89	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	1-26	40	46
90	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	1-41	42	20
91	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	2-38	40	26
92	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	3-27	42	40
93	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	4-33	42	93
94	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	4-35	42	40
95	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	5-42	42	26
96	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	6-48	38	20
97	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	7-19	40	52
98	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8-21	40	42
99	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	9-25	38	40
100	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	10-31	38	37
101	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	13-39	42	50
102	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	13-40	40	92
103	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	14-43	20	81
104	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	14-44	20	60
105	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	15-47	21	15
106	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	16-49	20	43
107	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	16-51	20	71
108	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	22-45	20	20
109	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	11-10	21	34
110	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	2-3	21	20
111	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	11-12	22	13
112	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	12-11	21	72
113	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	5-6	28	38
114	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	12-13	35	27
115	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	13-12	30	39
116	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	6-5	30	27
117	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	13-14	30	29
118	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	14-15	32	33
119	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	15-14	28	70
120	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	3-4	35	33
121	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	51-16	30	63
122	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	17-1	42	47
123	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	20-2	45	50
124	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	43-14	42	44
125	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	21-8	40	25
126	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	22-1	42	49
127	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	23-8	46	36
128	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	44-14	40	1
129	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	24-9	40	81
130	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	52-5	38	2
131	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	26-1	40	31
132	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	30-9	42	13
133	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	30-10	42	76

SN	Model	Parameter	Lower bound	Upper bound	Units	Links	Value before calibration	Value after calibration
134	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	33-4	46	52
135	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	28-15	18	6
136	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	35-4	20	16
137	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	54-16	20	14
138	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	49-16	18	4
139	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	55-7	20	23
140	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	40-13	25	19
141	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	41-1	30	89
142	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	55-8	32	24
143	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	27-3	32	26
144	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	4-52	30	34
145	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	31-10	30	47
146	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	17-20	30	90
147	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	2-20	30	34
148	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	34-11	30	34
149	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	28-54	40	50
150	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	16-54	42	44
151	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	7-55	48	29
152	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	38-2	42	30
153	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8-55	42	0
154	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	25-9	42	44
155	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8018-18	40	38
156	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8021-21	40	42
157	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8023-23	42	99
158	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8024-24	42	38
159	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8027-27	40	40
160	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8031-31	40	70
161	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8033-33	46	40
162	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8035-35	40	45
163	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8038-38	40	74
164	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8039-39	47	92
165	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8040-40	43	51
166	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8041-41	41	33
167	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8043-43	41	64
168	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8045-45	42	42
169	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8046-46	40	10
170	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8048-48	42	23
171	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8050-50	40	48
172	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8051-51	40	50
173	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	20-17	42	61
174	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	54-28	38	24
175	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	9-8	38	38
176	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8-9	32	28
177	NETSIM	Duration of a lane-change maneuver	1	8	Seconds		2	3
178	NETSIM	Mean time for a driver to react to a sudden deceleration of the lead vehicle	1	30	Tenths of seconds		5	7

SN	Model	Parameter	Lower bound	Upper bound	Units	Links	Value before calibration	Value after calibration
179	NETSIM	Minimum deceleration for lane changing	1	10	Feet per second square		3	3
180	NETSIM	Difference in maximum and minimum acceptable deceleration for a mandatory lane change	5	15	Feet per second square		7	15
181	NETSIM	Difference in maximum and minimum acceptable deceleration for a discretionary lane change	5	15	Feet per second square		5	5
182	NETSIM	Deceleration rate of lead vehicle	10	15	Feet per second square		10	10
183	NETSIM	Deceleration rate of follower vehicle	10	15	Feet per second square		10	11
184	NETSIM	Driver type factor used to compute driver aggressiveness	15	50	N/A		20	39
185	NETSIM	Urgency threshold	0	5	Tenths of a second squared per foot		1	3
186	NETSIM	Safety factor x 10	6	10	Tenths of units		6	8
187	NETSIM	Percentage of drivers who cooperate with a lane changer	10	100	Percentage		30	60
188	NETSIM	Headway below which all drivers will attempt to change lanes	1	30	Tenths of seconds		15	3
189	NETSIM	Headway above which no drivers will attempt to change lanes	30	100	Tenths of seconds		40	40
190	NETSIM	Mean longitudinal distance over which drivers decide to perform one lane change	50	2500	Feet		240	387
191	NETSIM	Acceptable Gap for Driver Type 1	15	75	Tenths of seconds		45	42
192	NETSIM	Acceptable Gap for Driver Type 2	15	75	Tenths of seconds		40	67
193	NETSIM	Acceptable Gap for Driver Type 3	15	75	Tenths of seconds		37	39
194	NETSIM	Acceptable Gap for Driver Type 4	15	75	Tenths of seconds		34	32
195	NETSIM	Acceptable Gap for Driver Type 5	15	75	Tenths of seconds		31	17
196	NETSIM	Acceptable Gap for Driver Type 6	15	75	Tenths of seconds		30	31
197	NETSIM	Acceptable Gap for Driver Type 7	15	75	Tenths of seconds		27	25
198	NETSIM	Acceptable Gap for Driver Type 8	15	75	Tenths of seconds		24	42
199	NETSIM	Acceptable Gap for Driver Type 9	15	75	Tenths of seconds		21	19
200	NETSIM	Acceptable Gap for Driver Type 10	15	75	Tenths of seconds		16	16
201	NETSIM	Additional Gap Time for Crossing 1 Lane	10	75	Tenths of seconds		10	41
202	NETSIM	Additional Gap Time for Crossing 2 Lanes	10	75	Tenths of seconds		19	19
203	NETSIM	Additional Gap Time for Crossing 3 Lanes	10	75	Tenths of seconds		23	25
204	NETSIM	Additional Gap Time for Crossing 4 Lanes	10	75	Tenths of seconds		28	31
205	NETSIM	Additional Gap Time for Crossing 5 Lanes	10	75	Tenths of seconds		31	24

SN	Model	Parameter	Lower bound	Upper bound	Units	Links	Value before calibration	Value after calibration
206	NETSIM	Additional Gap Time for Crossing 6 Lanes	10	75	Tenths of seconds		35	69
207	NETSIM	Additional Gap Time for Crossing 7 Lanes	10	75	Tenths of seconds		38	52
208	NETSIM	Additional Gap Time for Crossing 8 Lanes	10	75	Tenths of seconds		41	61
209	NETSIM	Additional Gap Time for Crossing 9 Lanes	10	75	Tenths of seconds		44	46
210	NETSIM	Additional Gap Time for Crossing 10 Lanes	10	75	Tenths of seconds		46	47
211	NETSIM	Percentage of Drivers that know only one turn movement	0	100	Percentages		5	22
212	NETSIM	Percentage of Drivers that know two turn movements	0	100	Percentages		95	78

Table B2. Calibration Parameters in the First Experiment with McTrans Model

SN	Model	Parameter	Lower bound	Upper bound	Units	Links	Value before calibration	Value after calibration
1	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8001-9	58	37
2	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	1-9	58	68
3	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	1-4	58	99
4	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	4-1	58	14
5	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	3-1	58	73
6	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	1-2	58	80
7	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	2-1	58	38
8	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	7-2	68	45
9	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8004-7	68	69
10	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	6-2	68	26
11	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	2-6	68	46
12	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	2-5	68	89
13	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	5-2	68	14
14	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8006-5	68	72
15	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8001-9	40	59
16	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	1-9	40	42
17	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	1-4	40	86
18	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	4-1	40	17
19	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	3-1	40	65
20	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	1-2	50	43
21	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	2-1	50	35
22	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	7-2	50	80
23	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8004-7	50	47
24	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	6-2	50	57
25	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	2-6	50	89
26	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	2-5	50	66
27	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	5-2	50	8
28	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8006-5	50	99
29	NETSIM	Percentage of Drivers that know only one turn movement	0	100	Percentages		5	79
30	NETSIM	Percentage of Drivers that know two turn movements	0	100	Percentages		95	21

Table B3. Calibration Parameters in the Second Experiment with Reno network

SN	Model	Parameter	Lower bound	Upper bound	Units	Links	Value before calibration	Value after calibration
1	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	1-26	38	40
2	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	1-41	36	23
3	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	2-38	40	42
4	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	3-27	38	42
5	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	4-35	38	43
6	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	5-42	38	38
7	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	6-48	38	32
8	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	7-19	38	44
9	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8-23	38	38
10	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8-21	40	16
11	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	9-24	36	34
12	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	9-25	36	86
13	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	12-36	40	42
14	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	13-40	38	38
15	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	14-43	36	42
16	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	15-46	38	40
17	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	15-47	40	42
18	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	16-49	26	18
19	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	16-51	28	30
20	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	22-45	28	86
21	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	1-22	28	28
22	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	10-11	30	26
23	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	11-10	28	38
24	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	2-3	26	30
25	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	11-12	30	20
26	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	5-6	26	49
27	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	12-13	23	17
28	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	13-12	30	30
29	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	3-2	25	27
30	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	13-14	30	26
31	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	14-13	22	20
32	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	6-7	26	24
33	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	18-7	34	30
34	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	19-7	38	34
35	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	17-1	34	17
36	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	20-2	34	32
37	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	21-8	38	36
38	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	23-8	34	28
39	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	44-14	38	36
40	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	24-9	30	34
41	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	52-5	38	50
42	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	30-9	30	34
43	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	46-15	28	28
44	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	33-4	26	22
45	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	28-15	30	34
46	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	35-4	30	16

SN	Model	Parameter	Lower bound	Upper bound	Units	Links	Value before calibration	Value after calibration
47	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	49-16	28	24
48	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	39-13	27	29
49	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	55-7	26	22
50	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	40-13	20	24
51	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	50-16	28	34
52	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	27-3	36	90
53	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	4-52	36	36
54	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	9-30	38	44
55	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	31-10	38	36
56	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	2-20	36	38
57	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	34-11	38	36
58	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	28-54	40	34
59	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	16-54	36	36
60	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	36-12	38	42
61	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	7-55	40	40
62	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	38-2	36	37
63	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8-55	36	40
64	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	42-5	40	40
65	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	25-9	50	52
66	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8018-18	40	46
67	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8019-19	50	50
68	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8023-23	44	42
69	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8024-24	48	48
70	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8025-25	48	52
71	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8026-26	46	42
72	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8027-27	46	46
73	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8031-31	48	55
74	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8033-33	44	44
75	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8035-35	50	44
76	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8036-36	50	46
77	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8038-38	48	48
78	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8040-40	40	19
79	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8042-42	48	85
80	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8043-43	48	50
81	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8044-44	50	48
82	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8045-45	18	83
83	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8048-48	26	22
84	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	1-17	48	46
85	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	20-17	40	38
86	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	54-28	48	44
87	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	5-4	48	38
88	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	9-8	48	46
89	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	1-26	40	38
90	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	1-41	42	40
91	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	2-38	40	32
92	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	3-27	42	44
93	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	4-35	42	44
94	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	5-42	42	40

SN	Model	Parameter	Lower bound	Upper bound	Units	Links	Value before calibration	Value after calibration
95	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	6-48	38	55
96	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	7-19	40	40
97	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8-23	42	16
98	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8-21	40	43
99	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	9-24	40	44
100	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	9-25	38	11
101	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	12-36	40	40
102	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	13-40	40	42
103	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	14-43	20	24
104	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	15-46	21	21
105	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	15-47	21	17
106	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	16-49	20	14
107	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	16-51	20	18
108	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	22-45	20	16
109	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	1-22	21	80
110	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	10-11	20	28
111	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	11-10	21	27
112	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	2-3	21	25
113	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	11-12	22	22
114	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	5-6	28	30
115	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	12-13	35	87
116	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	13-12	30	28
117	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	3-2	33	84
118	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	13-14	30	24
119	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	14-13	35	29
120	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	6-7	30	26
121	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	18-7	30	34
122	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	19-7	32	72
123	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	17-1	42	40
124	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	20-2	45	47
125	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	21-8	40	9
126	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	23-8	46	38
127	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	44-14	40	42
128	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	24-9	40	44
129	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	52-5	38	36
130	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	30-9	42	87
131	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	46-15	40	44
132	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	33-4	46	46
133	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	28-15	18	14
134	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	35-4	20	16
135	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	49-16	18	66
136	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	39-13	27	29
137	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	55-7	20	20
138	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	40-13	25	27
139	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	50-16	18	68
140	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	27-3	32	31
141	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	4-52	30	28
142	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	9-30	30	32

SN	Model	Parameter	Lower bound	Upper bound	Units	Links	Value before calibration	Value after calibration
143	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	31-10	30	32
144	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	2-20	30	36
145	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	34-11	30	28
146	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	28-54	40	38
147	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	16-54	42	42
148	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	36-12	40	73
149	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	7-55	48	38
150	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	38-2	42	42
151	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8-55	42	99
152	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	42-5	40	47
153	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	25-9	42	31
154	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8018-18	40	40
155	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8019-19	40	44
156	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8023-23	42	38
157	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8024-24	42	42
158	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8025-25	42	38
159	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8026-26	40	44
160	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8027-27	40	40
161	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8031-31	40	40
162	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8033-33	46	44
163	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8035-35	40	54
164	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8036-36	42	40
165	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8038-38	40	38
166	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8040-40	43	47
167	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8042-42	41	45
168	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8043-43	41	74
169	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8044-44	40	32
170	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8045-45	42	30
171	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8048-48	42	42
172	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	1-17	40	44
173	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	20-17	42	40
174	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	54-28	38	48
175	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	5-4	32	28
176	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	9-8	38	40

Table B4. Calibration Parameters in the Second Experiment with McTrans Model

SN	Model	Parameter	Lower bound	Upper bound	Units	Links	Value before calibration	Value after calibration
1	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8001-9	58	31
2	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	1-9	58	14
3	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	4-1	58	42
4	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8003-3	58	83
5	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	3-1	58	21
6	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	1-3	58	89
7	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	1-2	58	99
8	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	2-7	68	16
9	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8004-7	68	55
10	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8005-6	68	23
11	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	6-2	68	14
12	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	2-5	68	27
13	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	5-2	68	18
14	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8006-5	68	85
15	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8001-9	40	70
16	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	1-9	40	97
17	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	4-1	40	12
18	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8003-3	40	90
19	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	3-1	40	4
20	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	1-3	40	43
21	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	1-2	50	45
22	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	2-7	50	61
23	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8004-7	50	25
24	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8005-6	50	26
25	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	6-2	50	3
26	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	2-5	50	69
27	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	5-2	50	35
28	NETSIM	Mean value of start-up lost time	0	99	Tenths of seconds	8006-5	50	70

Table B5. Calibration Parameters in the Third Experiment with Reno network

SN	Model	Parameter	Lower bound	Upper bound	Units	Links	Value before calibration	Value after calibration
1	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	1-26	38	89
2	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	2-38	40	53
3	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	4-33	36	36
4	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	4-35	38	38
5	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	5-42	38	42
6	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	6-48	38	26
7	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	7-18	38	63
8	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8-23	38	41
9	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	9-24	36	62
10	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	9-25	36	87
11	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	10-31	40	44
12	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	13-40	38	94
13	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	14-43	36	53
14	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	15-46	38	34
15	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	16-49	26	41
16	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	16-50	26	24
17	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	16-51	28	20
18	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	22-45	28	80
19	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	11-10	28	64
20	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	2-3	26	30
21	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	11-12	30	97
22	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	12-13	23	27
23	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	6-5	30	60
24	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	3-2	25	25
25	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	15-14	48	48
26	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	3-4	45	14
27	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	18-7	34	30
28	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	51-16	38	40
29	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	19-7	38	36
30	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	17-1	34	30
31	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	20-2	34	37
32	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	43-14	30	26
33	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	21-8	38	36
34	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	22-1	34	21
35	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	23-8	34	28
36	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	44-14	38	35
37	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	30-9	30	14
38	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	47-15	26	26
39	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	28-15	30	30
40	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	35-4	30	26
41	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	54-16	28	31
42	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	49-16	28	30
43	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	39-13	27	31
44	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	55-7	26	65
45	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	50-16	28	17
46	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	55-8	30	30

SN	Model	Parameter	Lower bound	Upper bound	Units	Links	Value before calibration	Value after calibration
47	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	27-3	36	86
48	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	4-52	36	78
49	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	9-30	38	64
50	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	31-10	38	48
51	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	17-20	38	34
52	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	2-20	36	97
53	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	34-11	38	38
54	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	28-54	40	38
55	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	16-54	36	64
56	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	38-2	36	32
57	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	4-3	40	46
58	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	42-5	40	40
59	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	45-22	32	30
60	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	25-9	50	50
61	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8018-18	40	27
62	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8019-19	50	33
63	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8021-21	50	52
64	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8024-24	48	42
65	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8025-25	48	49
66	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8027-27	46	44
67	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8031-31	48	52
68	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8033-33	44	45
69	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8034-34	48	46
70	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8036-36	50	66
71	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8038-38	48	44
72	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8039-39	49	95
73	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8041-41	50	42
74	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8042-42	48	46
75	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8043-43	48	52
76	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8044-44	50	48
77	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8045-45	18	24
78	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8046-46	26	18
79	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8047-47	30	54
80	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8048-48	26	97
81	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	1-17	48	56
82	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	20-17	40	38
83	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	15-28	48	50
84	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	54-28	48	56
85	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	5-4	48	47
86	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	9-8	48	14
87	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8-9	40	28
88	NETSIM	Duration of a lane-change maneuver	1	8	Seconds		2	6
89	NETSIM	Mean time for a driver to react to a sudden deceleration of the lead vehicle	1	30	Tenths of seconds		5	6
90	NETSIM	Minimum deceleration for lane changing	1	10	Feet per second square		3	4
91	NETSIM	Difference in maximum and minimum acceptable	5	15	Feet per second square		7	11

SN	Model	Parameter	Lower bound	Upper bound	Units	Links	Value before calibration	Value after calibration
		deceleration for a mandatory lane change						
92	NETSIM	Difference in maximum and minimum acceptable deceleration for a discretionary lane change	5	15	Feet per second square		5	15
93	NETSIM	Deceleration rate of lead vehicle	10	15	Feet per second square		10	11
94	NETSIM	Deceleration rate of follower vehicle	10	15	Feet per second square		10	12
95	NETSIM	Driver type factor used to compute driver aggressiveness	15	50	N/A		20	49
96	NETSIM	Urgency threshold	0	5	Tenths of a second squared per foot		1	2
97	NETSIM	Safety factor x 10	6	10	Tenths of units		6	7
98	NETSIM	Percentage of drivers who cooperate with a lane changer	10	100	Percentage		30	39
99	NETSIM	Headway below which all drivers will attempt to change lanes	1	30	Tenths of seconds		15	14
100	NETSIM	Headway above which no drivers will attempt to change lanes	30	100	Tenths of seconds		40	45
101	NETSIM	Mean longitudinal distance over which drivers decide to perform one lane change	50	2500	Feet		240	475
102	NETSIM	Acceptable Gap for Driver Type 1	15	75	Tenths of seconds		45	45
103	NETSIM	Acceptable Gap for Driver Type 2	15	75	Tenths of seconds		40	38
104	NETSIM	Acceptable Gap for Driver Type 3	15	75	Tenths of seconds		37	37
105	NETSIM	Acceptable Gap for Driver Type 4	15	75	Tenths of seconds		34	15
106	NETSIM	Acceptable Gap for Driver Type 5	15	75	Tenths of seconds		31	57
107	NETSIM	Acceptable Gap for Driver Type 6	15	75	Tenths of seconds		30	28
108	NETSIM	Acceptable Gap for Driver Type 7	15	75	Tenths of seconds		27	46
109	NETSIM	Acceptable Gap for Driver Type 8	15	75	Tenths of seconds		24	24
110	NETSIM	Acceptable Gap for Driver Type 9	15	75	Tenths of seconds		21	21
111	NETSIM	Acceptable Gap for Driver Type 10	15	75	Tenths of seconds		16	17
112	NETSIM	Additional Gap Time for Crossing 1 Lane	10	75	Tenths of seconds		10	31
113	NETSIM	Additional Gap Time for Crossing 2 Lanes	10	75	Tenths of seconds		19	55
114	NETSIM	Additional Gap Time for Crossing 3 Lanes	10	75	Tenths of seconds		23	69
115	NETSIM	Additional Gap Time for Crossing 4 Lanes	10	75	Tenths of seconds		28	29
116	NETSIM	Additional Gap Time for Crossing 5 Lanes	10	75	Tenths of seconds		31	18
117	NETSIM	Additional Gap Time for Crossing 6 Lanes	10	75	Tenths of seconds		35	37

SN	Model	Parameter	Lower bound	Upper bound	Units	Links	Value before calibration	Value after calibration
118	NETSIM	Additional Gap Time for Crossing 7 Lanes	10	75	Tenths of seconds		38	32
119	NETSIM	Additional Gap Time for Crossing 8 Lanes	10	75	Tenths of seconds		41	40
120	NETSIM	Additional Gap Time for Crossing 9 Lanes	10	75	Tenths of seconds		44	19
121	NETSIM	Additional Gap Time for Crossing 10 Lanes	10	75	Tenths of seconds		46	45
122	NETSIM	Percentage of Drivers that know only one turn movement	0	100	Percentages		5	50
123	NETSIM	Percentage of Drivers that know two turn movements	0	100	Percentages		95	50

Table B6. Calibration Parameters in the Third Experiment with McTrans Model

SN	Model	Parameter	Lower bound	Upper bound	Units	Links	Value before calibration	Value after calibration
1	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	1-4	58	80
2	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	4-1	58	20
3	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8002-4	58	53
4	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8003-3	58	42
5	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	3-1	58	33
6	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	1-3	58	70
7	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	1-2	58	15
8	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	2-1	58	48
9	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	7-2	68	21
10	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8004-7	68	48
11	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	6-2	68	19
12	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	2-6	68	22
13	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	5-2	68	16
14	NETSIM	Mean queue discharge headway	14	99	Tenths of seconds	8006-5	68	65
15	NETSIM	Percentage of Drivers that know only one turn movement	0	100	Percentages		5	29
16	NETSIM	Percentage of Drivers that know two turn movements	0	100	Percentages		95	71

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