International Journal on Engineering Technology and Infrastructure Development (InJET-InDev)
Volume 1, Issue No.1, Page 111-121
Received Date: 12/25/2023
Revised Date: 1/15/2024
Accepted Date: 1/22/2024
ISSN:

Calibration of VISSIM Model for Urban Multilane Highways using Highway Capacity in Mixed Traffic Condition- A Case Study

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ABSTRACT

The present study illustrates the effectiveness of utilizing VISSIM software in evaluating the capacity of urban multi-lane highways under varied traffic conditions. Traffic flow and speed data from a section of Ratna Rajmarga's four-lane divided highway were used to establish a speed-flow relationship. This relationship was utilized to ascertain the field capacity. Subsequently, this data was inputted into VISSIM to generate a simulated speed-flow curve, which was then compared with the actual field curve. Results revealed that the original VISSIM model tends to overestimate both speed and capacity of the highway using default parameters. Previous research has highlighted standstill distance (CC0) and headway time (CC1) as significant influencing parameters in establishing the relationship between speed and volume. Therefore, in this study, these parameters were calibrated for an urban four-lane divided road. Initial assessments of CC0 and CC1 were carried out under homogeneous traffic conditions, focusing solely on one of the five vehicle types present for all vehicles. These findings were amalgamated to determine these parameters for a more representative mixed traffic scenario. Upon recalibrating the field data using the adjusted CC0 and CC1 values, the simulation-generated curve approached closer to the reliable limit for comparison with the field data curve. Consequently, it was utilized to determine the capacity, which was found to be less than 1 percent in comparison with the capacity determined by field data.

1. Introduction

Highway capacity refers to the maximum number of vehicles or people that a road or highway can accommodate within a specific time period under prevailing conditions. It is a crucial measure in transportation planning and engineering, helping assess the efficiency and performance of road networks (Anon., 2000). Highway capacity is important for optimizing traffic flow, reducing congestion, and planning for future infrastructure improvements. It gives a quantitative measure of traffic (Salam & Majid, 2022) Also, Understanding the relationship between speed, flow, and density is crucial for predicting highway Capacity (Gautam, et al., 2023).

Micro-Simulation is a useful tool to effectively analyze and evaluate proposed improvements and alternatives. The goal of the microscopic modeling approach is the accurate description of traffic Dynamic (Tettamanti & Varga, 2012). Traffic flow in Nepal is heterogeneous. Uncontrolled mix of traffic makes it even more difficult for capacity analysis. Hence, Simulation of traffic flow has been a very effective tool for such problems (Mehar, et al., 2013). The involvement of various vehicle types and an uneven distribution significantly influences the dynamics of unmanaged traffic. The diversity in size and speed not only affects the fluidity of traffic but also results in distinct driving behaviors (Prajapati, et al., 2022).

Various conventional methods for traffic flow models were previously used in different sections of multilane roads in Nepal. Various conventional macroscopic speed-density models namely Greenshields, Greenberg, Underwood, Drake, Pipes – Munjal, Polynomial and modified Drake and Underwood models were first calibrated and validated for Jadibuti - Suryabinayak road section in Nepal (Tiwari & Marsani, 2014).

VISSIM is a microscopic, behavior-based multi-purpose traffic simulation to analyze and optimize traffic flow (Dey, et al., 2018). It was developed in Germany based on the continuous work of Wiedemann (1999) on car following behavior. The method used for calibration is comparison of field based and simulated speed flow curve as it provides information about all the three regions, could replicate the whole range of traffic behavior and not just peak period (Menneni, et al., 2008). The applicability of VISSIM for mixed traffic flow condition in a multilane highway has been conducted in this study, calibrating for speed flow curve.

Capacity assessment on the field is a very tedious and hectic work to do. Hence, this study focuses on the calibration-based approach to find the capacity of any road section, which can be continued in various other sections in coming future. The objectives of the current study include:

- Analyze the potential of VISSIM simulation techniques in calibrating parameters.
- To evaluate the effective calibrated CC0 and CC1 for mixed traffic conditions.
- To determine the capacity of a 4-lane divided highway from the calibrated parameters.

2. Literature Review

Many studies have been conducted to measure the capacity using speed flow relationship. A recent study in Telangana, India, examined heterogeneous traffic on four-lane inter-urban highways. Data on spot speed, traffic composition, vehicle categories, and road geometry specifics were collected via videography. The study aimed to estimate the capacity of two-lane two-way inter-urban roads based on field data, incorporating road geometry, pavement conditions, and traffic composition. (Verma, et al., 2024) Similarly, In Sri Lanka as well for a four-lane highway with heterogenous traffic, capacity was estimated and a model was developed from speed flow curve in a traditional approach. (Jayaratne, et al., 2018). No simulation software was used to determine the capacity of the highway on those above-mentioned papers but the field data collection is tedious. Hence in many recent studies VISSIM was used as a simulating software to develop the model.

A study validated microscopic traffic flow model VISSIM in different real-world situations in German and US freeway. They suggested that the VISSIM after its calibration shows most realistic driving behavior (Fellendorf & Vortisch, 2001). A study established speed-flow relations based on their extensive field survey of traffic flow on multilane highways in Beijing using statistical test. They estimated the capacity for four-lane, six-lane and eight-lane divided carriageways as 2104, 1973 and 1848 pcu/hr./ lane respectively (YANG & ZHANG, 2005).

A study in Cox's Bazar in south-eastern Bangladesh was conducted to demonstrate the relevancy of VISSIM software to work out the capacity of two-lane two-way highways under mixed traffic flow conditions. Speed flow curve was developed by field traffic flow data and then the same set of field data is used in VISSIM and the simulated speed-flow curve was compared with the field curve. Analysis of field data with calibrated values parameters of Wiedemann74 indicated a decent match between field and simulated capacity. The result of the capacity was estimated to be 3840 veh/hr in both directions (Islam, et al., 2020).

In this paper, Spot speed was used as calibrating parameter in a suburban corridor of about 12 km located in Greater Cairo Region using video data collected for 9 hours. Spot speeds of over 2,000 vehicles were measured, and VISSIM was used for modeling. Statistical tests ensured accuracy, and corridor travel time served as a validation parameter (Tawfeek, et al., 2018). A study was conducted where Traffic volume and travel speed was used for model calibration, while average travel time was used for validation for a microscopic model during peak hours in Madinah City, Saudi Arabia using VISSIM. GEH statistics established the relationship between observed and simulated traffic flow, demonstrating a strong correlation based on calibration and validation results (Abdeen, et al., 2023).

A study was conducted to demonstrate the capacity of four-lane divided highway with paved shoulders using VISSIM. Spot speed data was collected on field and speed flow curve was developed can compared with the simulated Speed flow curve obtained from the software. It was found that VISSIM in its original form overestimates both speed and capacity of the highway. The simulated capacity was 5329 pcu/hr against the field capacity of 5277 pcu/hr (Mehar, et al., 2013). On four-lane divided national highway at kumbalgodu, Bangalore, classified traffic volume and composition was found and same data was used to obtain simulated speed flow curve using VISSIM for heterogenous traffic flow. conclusions. The microsimulation model VISSIM was found to be suitable to simulating and hence studying heterogeneous traffic flow in a national highway to a satisfactory extent. The capacity of the highway was found to be 5334 PCU/hr/dir. (BS, 2021)

A paper was published on 2020 based on the study of four lane divided highway and 6 lane divided highway for heterogenous traffic in India. They calibrated five out of ten correlation parameters including CC0 and CC1. The ±5% variation in traditional and simulated capacity values is justified by the results of the estimated capacity in this study. The two simulation models for capacity estimation, differing only in five parameters of the car following model, demonstrate proper calibration and validation of the CC parameters (CC0, CC1, CC2, CC7, and CC8) of the Wiedemann 99 car following model used in the microscopic traffic simulation. (Ghosh, et al., 2020)

3. Study Road Section

The 500-meter-long, 4-lane divided highway is incredibly important for the infrastructure of Birendranagar Municipality. It acts like a main pathway, allowing easy transportation and connection between different areas. Specifically, it links two significant spots in the municipality: Yari Chowk and Mangalgadhi Chowk, as depicted in Figure 1. This road isn't just a simple connection between two places; it's strategically positioned to play a vital role in shaping how the region grows economically and socially. By linking these two crucial junctions, the highway enhances accessibility and fosters interactions among people and businesses. It serves as a lifeline for the municipality, enabling goods and services to flow smoothly and facilitating social connections that are essential for a thriving community. In essence, it's a catalyst for progress and development in Birendranagar Municipality.

This particular stretch of road has a Right of Way (ROW) of 30 meters, with total width of the road is 15 meters. It is divided into four lanes, and there's a divider between them of 3 meters wide. The designated speed limit for this section of the road is set at 40 kilometers per hour (km/hr.), which is meant to ensure safety for all road users. However, despite this established limit, it's observed that a majority of vehicles are not adhering to it. Besides the main lanes, there are also service lanes on both sides of the road. These are like extra lanes, usually meant for slower traffic or for vehicles to pull over. Right now, many vehicles are parked in these service lanes, which might cause a bit of congestion. However, the good thing is that in the future, these lanes can be used to help manage heavy traffic. They provide a sort of buffer space that can be adapted to accommodate more vehicles when needed. So, while they might seem crowded now, they actually offer a solution for potential traffic issues down the line.

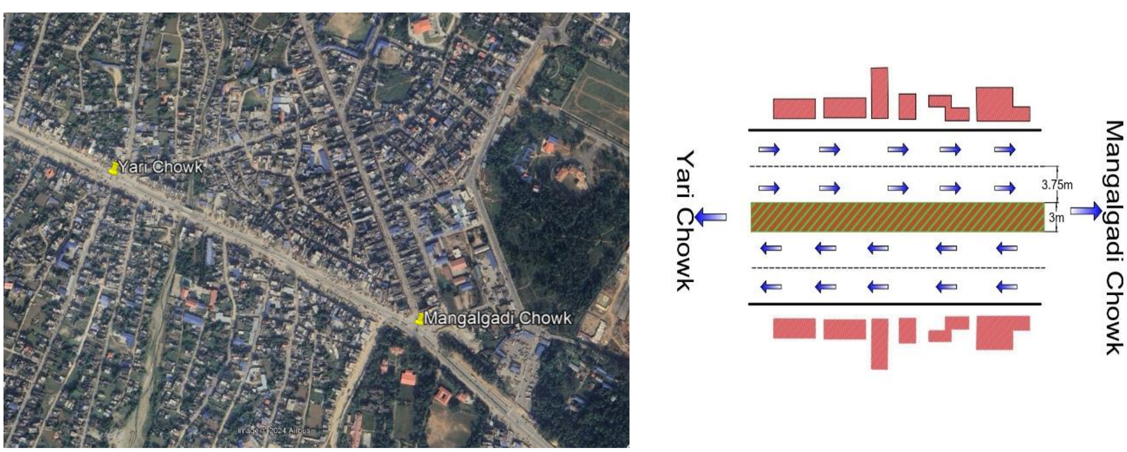


Figure 1 Study Area (Link Road between Yari chowk and Mangalgadhi chowk)

4. Properties of Data

Vehicle properties and speed-related data were collected during field visits. The data properties utilized for further analysis are described in the following sections.

4.1. Traffic Volume Properties

A traffic volume count survey was conducted in the study road section during a twelve-hour time period from 7:00 AM to 7:00 PM. Traffic volume was recorded by CCTV cameras at one section of the road, and the recordings were reviewed manually during the counting process. The volume count intervals were set at 30-minute increments. Based on the results of the traffic volume count, the categorized vehicles were divided into five broader categories—Cars, Micro Buses, Two-Wheelers, Buses, and Trucks. The dimensions and 95th percentile proportions of these vehicles in the study road sections are presented in Table 1.

Table 1 Vehicle Dimension and proportions

Vehicle Type	Length (m)	Width (m)	Projected Area	Proportion
Car	4.4	1.8	7.92	27.00%
Micro Bus	4.9	2	9.8	5.00%
Two-Wheeler	2.2	0.8	1.76	43.00%
Bus	7.8	2.2	17.16	15.00%
Truck	8.3	2.5	20.75	10.00%

4.2. Speed Data

Speed data were collected through a one-day speed survey conducted over a 12-hour time period from 7:00 AM to 7:00 PM. The radar gun was employed to measure speeds with an accuracy of 0.5 km/hr. The collected speed data were categorized, and percentile speeds were calculated, as shown in Table 2.

Table 2 Percentile speed

Vehicle Type	Spot Speed Parameters (Km/hr.)						
	15th Percentile	50th Percentile	85the Percentile	98th Percentile	Average	Minimum	Maximum
Car	50.1	60	69.9	87	59.90	37.5	90
Micro Bus	39.6	51	60	71.24	51.17	27	82.5
Two-Wheeler	48	61.5	75	84	61.39	34	90
Bus	42.6	52.5	63	72.12	52.42	28.5	76.5
Truck	37.5	46.5	59.4	66.12	46.80	24	72

5. Determination of Passenger Car Unit (PCU)

In further analysis, volume and capacity are expressed in terms of Passenger Car Unit (PCU). PCU is defined as a measure of the relative interaction developed by a categorized vehicle compared to a passenger car in traffic flow. This interaction primarily depends on the dimensions of vehicles, speed parameters, and roadway conditions. Various methods, documented in the literature, exist to determine PCU for different vehicle types. In the case of the study area, characterized by highly heterogeneous traffic conditions, the physical dimensions and speed of vehicles are considered. Equation 1 proposed by Chandra and Kumar in 2003 for determining PCU has been utilized in this study (Chandra & Kumar, 2003).

$$PCU_i = \frac{Vc/_{Vi}}{Ac/_{Ai}} \tag{1}$$

Where, PCU_i = Passenger car unit of i^{th} type of vehicle

V_c/V_i = Speed ratio of car to i^{th} type of vehicle

A_c/A_i = Physical area ratio of car to i^{th} type of vehicle

After applying Equation 1, the PCU for each individual categorized vehicle is determined. The PCU for a car is set as 1, and for a micro, two-wheeler, bus, and truck, the obtained PCU values are 1.25, 0.33, 2.45, and 3.35, respectively. These PCU values are utilized in the subsequent sections for further analysis when calculating volume and determining capacity.

6. Speed -Flow Relation from Field Data

The total 12-hour traffic volume is divided into 24 datasets in 30-minute time intervals. Subsequently, the number of vehicles is multiplied by the corresponding PCU to determine the volume in PCU for each respective 30-minute interval. Additionally, the volume is multiplied by 2 to determine the hourly volume. Similarly, speed data were averaged in 30-minute intervals. The speed-flow curve is prepared based on these field-collected data, as shown in Figure 2. According to the field survey, the two-lane road in one direction yields a capacity value of 4240 PCU/hr per direction or 2120 PCU/hr per lane.

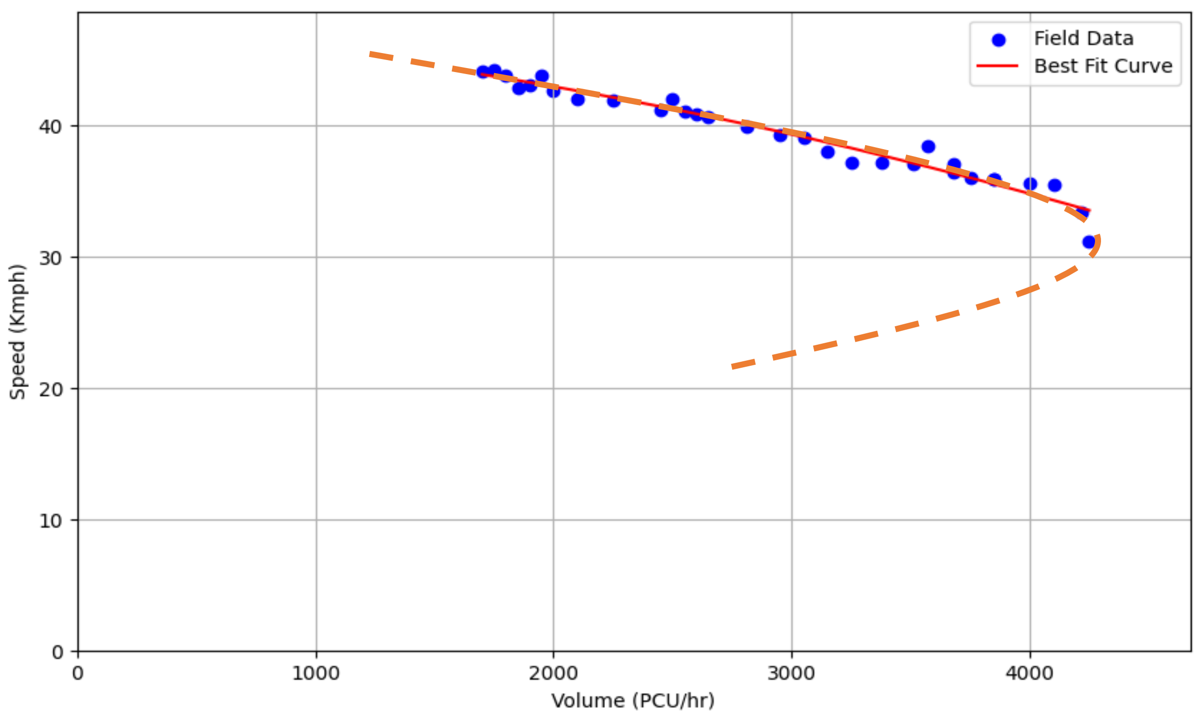


Figure 2: Speed- Flow Curve using field data

7. Development of Simulation Model using VISSIM

VISSIM, a microscopic simulation model developed to simulate traffic characteristics for freeways, urban traffic, and public transit operations (PTV, 2011). The geometry data of the road were used to create a 500-meter section of the urban highway. Additionally, vehicle attributes in the real field were assigned to the vehicle types in the simulation model. Free-flow speed distributions collected in the field were used to assign the desired speed for each vehicle type. The composition of categorized vehicles was also assigned in the vehicle composition. The minimum and desired acceleration and deceleration were set to the default values of the vehicle types. The Wiedemann (1999) car following behavior was utilized, consisting of ten different driver-related parameters from CC0 to CC9. The initial assessment was conducted using the default values of these parameters. Many researchers in the past have comprehensively evaluated and assessed the sensitivity of these parameters and their impact on the speed-flow curve. According to the literature review, standstill distance in meters (CC0) and time headway in seconds (CC1) between two vehicles at speed are highly sensitive (Gomes, et al., 2004). Hence, this study only intends to calibrate these parameters for heterogeneous traffic conditions on a four-lane divided urban highway.

Various scenarios were input into the developed simulation model, and the results were evaluated and recorded. The results included the volume of categorized vehicles and average speeds during a 1-hour simulation period. Subsequently, a speed-flow graph was developed, as shown in the Figure 3. The graph indicates that at the default parameters of CC0 and CC1, the speed is overestimated for the respective traffic volume, and the capacity of road sections during the simulation is 4681 PCU/hr, which is 10.40% higher than the actual field capacity of 4240 PCU/hr

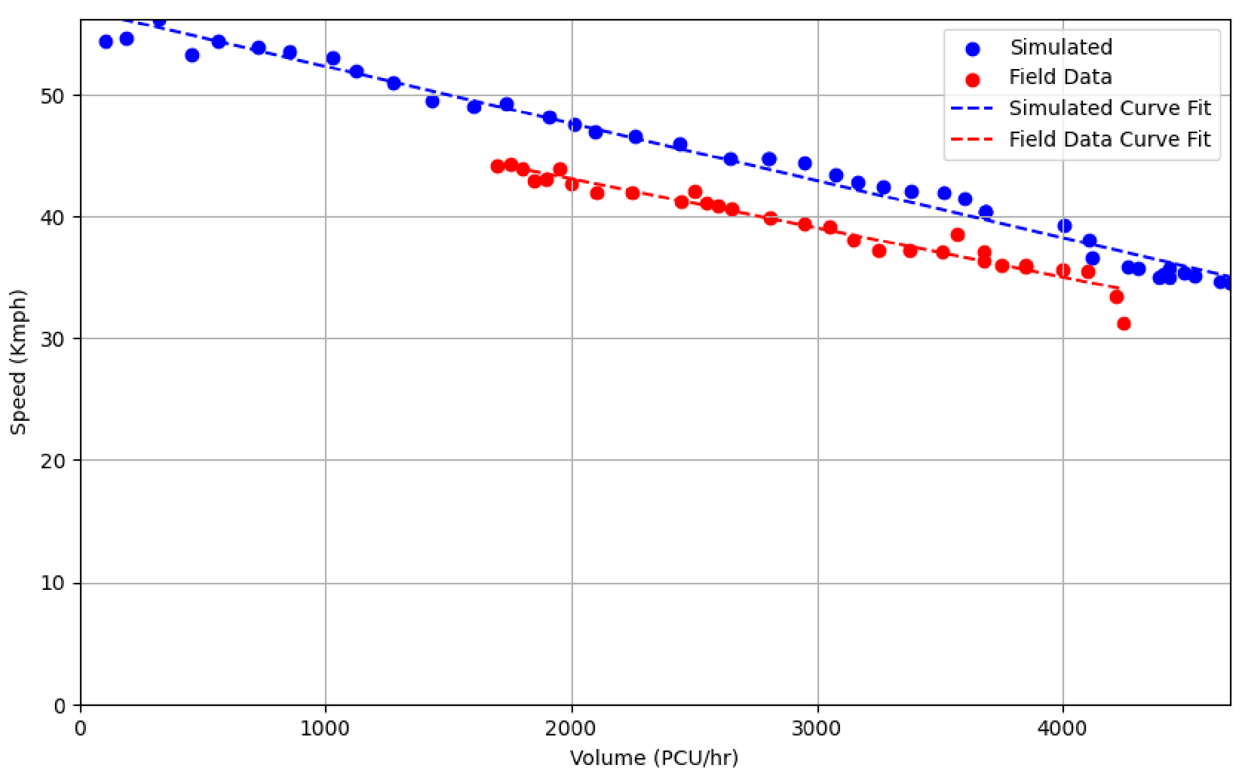


Figure 3: Speed- Flow Relation from Simulation Data and Field Data before Calibration

8. Calibration of CCO and CC1

Standstill Distance (CC0) represents the desired average distance between two vehicles or the preferred rear-bumper to front-bumper distance when the vehicles are stationary. Headway Time (CC1) is the time gap (in seconds) a driver aims to maintain at a specific speed. A higher value indicates a more cautious driver. These parameters are combined to calculate the desired safety distance in the simulation model using Equation 2, where V is the desired velocity (PTV, 2011).

$$\text{Desired Safety Distance} = CC0 + CC1 * V \quad (2)$$

The CC0 and CC1 parameters are highly related to the vehicle type and its share in the traffic, especially in heterogeneous traffic conditions. Calibrating these parameters in mixed traffic conditions is quite challenging. Therefore, considering homogeneous scenarios and determining specific CC0 and CC1 values for each vehicle type proves to be an optimal solution. Subsequently, the individually calibrated CC0 and CC1 values are then multiplied by the proportion of each vehicle type in the traffic stream to evaluate the effective CC0 and CC1 for mixed traffic conditions.

The capacity, determined from the field survey and PCU factor, is utilized to assess the capacity of the four-lane divided highway in terms of the number of vehicles during homogeneous traffic conditions. The results indicate capacities of 4240 vehicles per hour per direction for cars, 3390 for micro buses, 12850 for two-wheelers, 1730 for buses, and 1260 for trucks. These data are used to determine the values of CC0 and CC1 for each vehicle type during homogeneous traffic conditions. The simulation model was run for a one-hour simulation period with all cars, varying the values of CC0 and CC1. Figure 4 shows the results in capacity for cars at different values of CC0 and CC1. It is found that the combination of CC0 and CC1 is highly sensitive to capacity, and it is observed that a capacity of 4240 cars per hour per direction can be obtained with different combinations of CC0 and CC1.

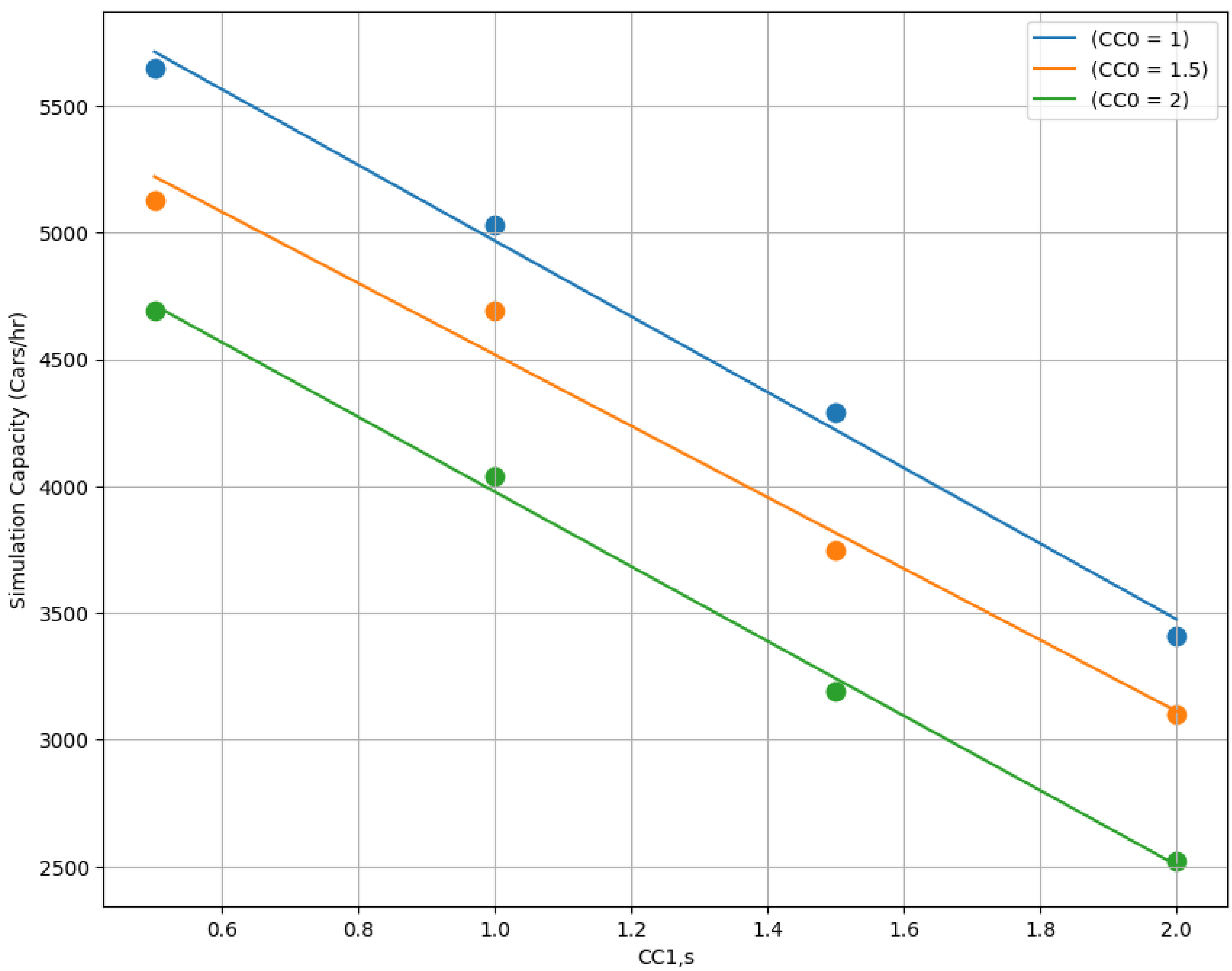


Figure 4: Relation of CC0 and CC1 Parameters in Simulated Capacity

Furthermore, the equal capacity line, representing 4240 cars in one direction, was determined and is shown in Figure 5. Any combination of CC0 and CC1 that falls on this equal capacity line provides the desired capacity for all car conditions. Assumptions were made to determine specific values for these parameters. Considering various literature mentioned above and accounting for the aggressive behavior of drivers on Nepal's roads, the value of CC1 is assumed to be higher than the default value. Hence, the value of CC1 is set at 1.11 seconds, with the corresponding value of CC0 being 1.21 meters.

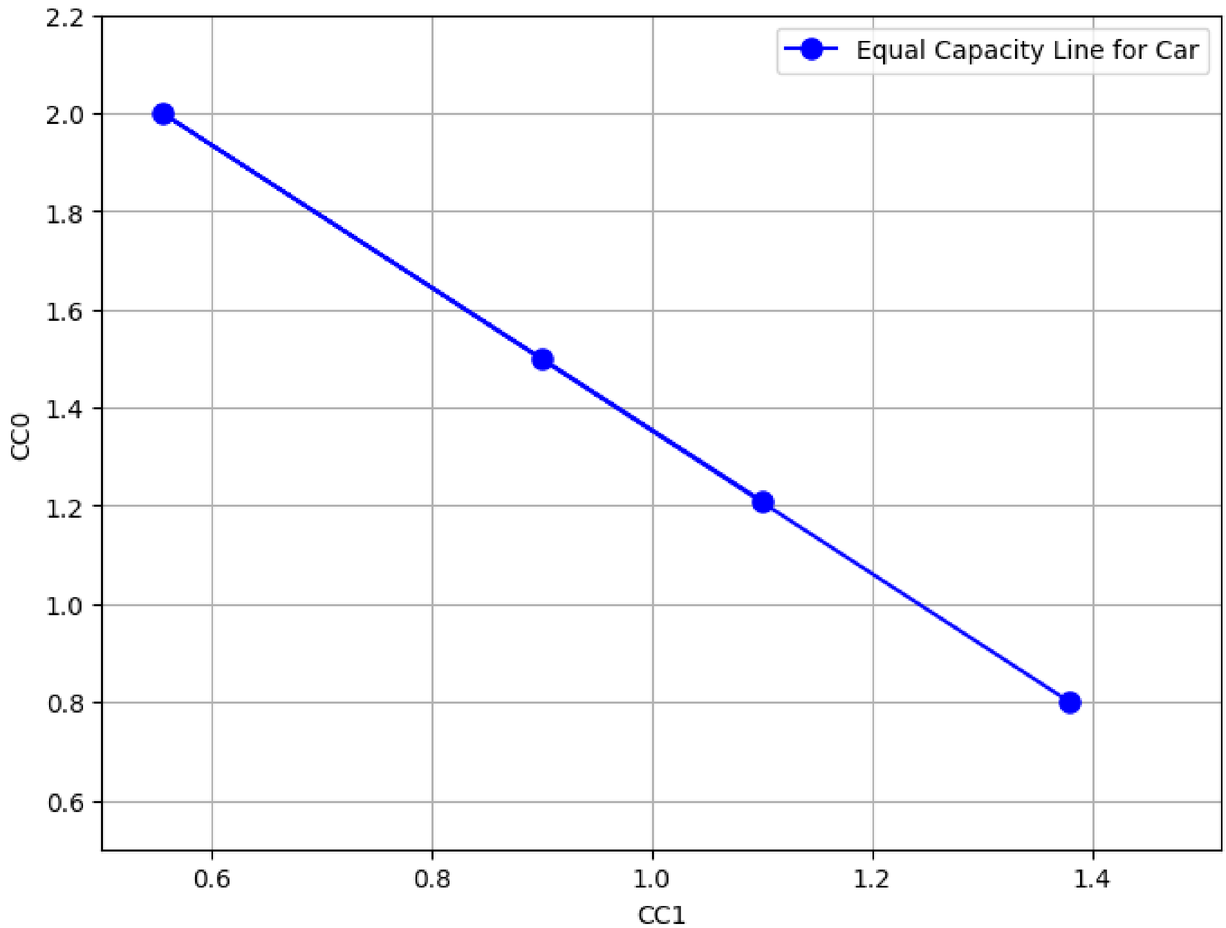


Figure 5: Equal Capacity Line for Desired Capacity with Relation between CC0 and CC1 for All Car Conditions

Similar methods have been adopted of scenarios of for all micro buses, two wheelers, buses and trucks and also the parameters were determined based on desired equal capacity line. The results of desired capacity in terms of vehicle per hours and corresponding CC0 and CC1 is shown in Table 3.

Table 3: Calibrated Parameters in Homogeneous Traffic Condition

Vehicle Type	Simulated Capacity (Vehicle per Hour)	CC0 (Meter)	CC1 (Second)
Car	4240	1.21	1.11
Micro	3390	1.26	1.29
Two-Wheeler	12850	0.39	0.4
Bus	1730	1.72	1.65
Truck	1260	2.56	1.78

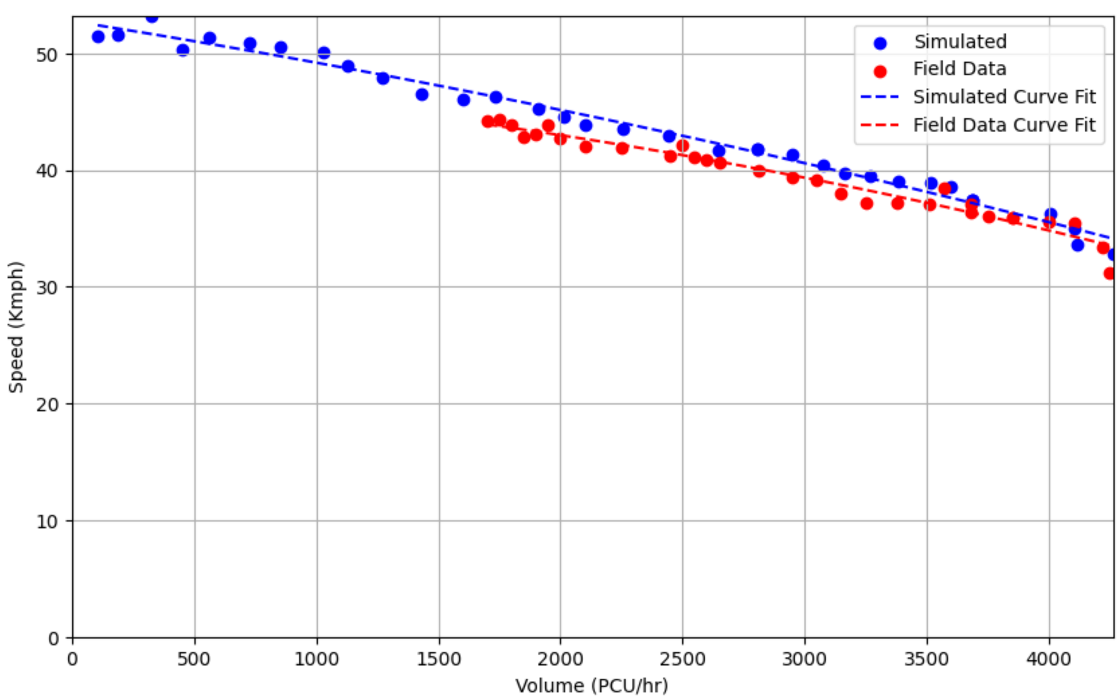
In the realm of parameters CC0 and CC1, a lower numerical value signifies enhanced maneuverability and a diminished requisite safety distance. This is particularly relevant when considering two-wheeler vehicles, characterized by their smaller size. For these vehicles, having lower values for the calibrated parameters is deemed reasonable, given their compact dimensions and typically more agile nature. Conversely, when it comes to buses and trucks, vehicles of larger size and potentially lesser maneuverability, higher values for CC0 and CC1 are often warranted. This higher numerical calibration reflects the imperative for a more substantial safety distance, acknowledging the challenges posed by the sheer size and potentially slower maneuvering capabilities of buses and trucks. The contrast in these calibrated parameters underscores the nuanced dynamics and safety considerations associated with different vehicle types within the traffic system.

The calibrated parameters, specifically CC0 and CC1, obtained under homogeneous traffic conditions, are extrapolated to a mixed traffic scenario involving five different vehicle types. These parameters are distributed proportionally according to the prevalence of each vehicle type in the traffic stream. Given that the proportion of two-wheelers and cars is notably higher compared to other vehicle types, the impact of these vehicles is more pronounced in influencing the calibrated values of CC0 and CC1 in the mixed traffic condition. Equations 3 and 4 are the equations that have been used to determine calibrated value of CC0 and CC1 for mixed traffic conditions.

$$CC0_{mixed} = CC0_{car}*P_{car} + CC0_{micro}*P_{micro} + CC0_{two\text{-}wheeler}*P_{two\text{-}wheeler} + CC0_{bus}*P_{bus} + CC0_{truck}*P_{truck} \quad (3)$$

$$CC1_{mixed} = CC1_{car}*P_{car} + CC1_{micro}*P_{micro} + CC1_{two\text{-}wheeler}*P_{two\text{-}wheeler} + CC1_{bus}*P_{bus} + CC1_{truck}*P_{truck} \quad (4)$$

Where, $CC0_{mixed}$ and $CC1_{mixed}$ represent the final calibrated values of CC0 and CC1 in heterogeneous traffic conditions, with P representing the proportion of each vehicle type. Using Table and Equations 3 and 4, the value of CC0 and CC1 for heterogeneous traffic condition is found to be 1.07 and 0.96 respectively. Using these final calibrated parameters, the simulation model was run again, and a speed-flow curve was developed, which was then compared to the speed-flow curve derived from field data. The figure illustrates the speed-flow curves of both simulation and field data. Notably, the updated values for CC0 and CC1 bring the simulation data closer to the field data. The simulation



capacity is determined to be 4263 PCU/hr per direction, closely aligning with the field data capacity of 4240 PCU/hr per direction. The variability of capacity between simulation data and field data, initially at 10.40% with default values of CC0 and CC1, is significantly reduced to 0.56% with the calibrated values of these parameters.

Figure 6: Speed- Flow Relation from Simulation Data and Field Data after Calibration

9. Conclusion

This study demonstrates the potential of VISSIM simulation techniques in calibrating parameters such as standstill distance (CC0) and time headway (CC1). These parameters have a significant impact on capacity, as they need to be precisely determined due to their application in ensuring safety, efficiency, and the overall functionality of transportation systems. Determining these parameters becomes challenging in mixed traffic conditions. VISSIM software has limitations and does not simulate mixed traffic conditions using various values of these parameters based on vehicle types. Therefore, a comprehensive literature review was conducted to develop a methodology for calibrating CC0 and CC1. This methodology uses data collected from a field survey and simulation techniques for a four-lane divided highway in an urban area, specifically under mixed traffic conditions. Speed flow curve is used to determine capacity using field data as well as using simulation results. With the default parameters in the developed simulation model, the variation between the field capacity (4240 PCU/hr/direction) and the simulation capacity (4681 PCU/hr/direction) was 10.40%. Subsequently, using homogeneous criteria, individual calibrated CC0 and CC1 values for the five vehicle types were determined. These calibrated parameters were multiplied by the proportion of each vehicle type in mixed traffic conditions to determine CC0 (1.07m) and CC1 (0.96s) for mixed traffic conditions. The simulation model was then run again using these calibrated parameters, resulting in a simulated capacity of 4263 PCU/hr/direction. The new simulated capacity closely aligns with the field capacity, reducing the variation to 0.56%.

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