MICROSCOPIC APPROACH TO EVALUATE THE CAPACITY OF MULTI-LANE HIGHWAYS UNDER MIXED TRAFFIC CONDITION

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ABSTRACT

This research aims to look into the effect of mixed traffic on the capacity of the intercity roadway system in Khulna metropolitan city, Bangladesh. The microscopic approach summarises the behavior of each type of vehicle by applying statistical methods. There are five types of vehicles on the road: regular cars, buses, trucks, CNG, auto-rickshaws, and motorcycles. Consequently, both complex mathematics and statistical methods are required to examine the differences in the system because of the large number of variables. Significant parameters like driving behavior patterns and safe distances are considered to simulate so that the result is more accurate than macroscopic simulation. There are different types of approaches currently available to resolve this problem. In this study, PTV VISSIM traffic simulation software has been used for the best result in terms of precision. The VISSIM program is calibrated and deployed to generate traffic processes based on field data, utilizing the software's performance measurement capability. The speed-flow curves are used to calculate the simulated capacity values for various combinations of the conventional automobile and one of the remaining four vehicle classes in the traffic stream. The capacity of this segment was calculated using three different methods: survey data, modeling, and formulas explicitly created for this study. Finally, simulated results and data from speed-flow charts are merged to present a general model predicting highway capacity for mixed traffic. Three capacity numbers are Are found to be consistent. 4.5% and 4.9% error are observed when comparing calculated capcity with simulated and field capacity respectively.

Keywords: *mixed traffic, highway capacity, traffic simulation, VISSIM*

1. INTRODUCTION

Mixed traffic condition is a widespread scenario in Bangladesh highways. Especially in the urban area, it is prevalent to see different vehicles moving in the street. Bangladesh's total roads are classified into three categories (RHD, 2010). Among these roads, there are the top five longest roads. They are N1, N2, N5, N6, N7 (Sequences are not written as per the length of the road). N7-7 Road started from Modhukhali (Int. with Z7102) and ended at WAPDA more (Int. with Z7008) with a length of 14.107 km (RHD, 2010). This is road has linked to the Khulna-Jessore highway, including the Khulna Metropolitan zone (RHD, 2010). Different types of vehicles traffic have been observed on this highway starting from heavy truck, medium truck, small truck, large bus, medium bus, micro bus, utility, private car, three wheeler, two wheeler, cycle rickshaw, bi-cycle and other motorized and non-motorized vehicles. Due to a mixed traffic flow situation, there are uncertainties of generating heavy traffic congestion with traffic accidents.

Bangladesh is still in its developing phase, including the traffic system operation. The transportation system plays a vital role to play in this development. Roads and highways connect to different regions. However, because of the mixed traffic, the roadways are not serving their intended purpose. According to Roads and Highways (RHD) of Bangladesh, the non-motorized vehicle lane's highway capacity should be 1015 pcu/hr. (Tables 6.40, 6.47, RMSS Vol. V11A) The non-motorized vehicle lane is not only used for non-motorized vehicles, despite the fact that capacity has been reduced to under a thousand for mixed traffic. From Heavy trucks to Bi-cycle is passing through that lane. Mixed traffic condition reduces the capacity of the highway along with the utilization properly. As a result, the road is not well utilized, and valuable time is wasted.

The non-motorized vehicle (NMV) lane in Bangladesh is 7m wide and contains two lanes. Due to the interaction of opposing flows, traffic operations on two-lane highways differ from those on divided carriageways. An inbound one and an outbound one. On the roads, many vehicles are always travelling in different directions. Some travel straight ahead, then veer left or right to connect with little side roads. That's why there are so many roundabouts and u-turns leading to the main highway. As a result of these connecting roads, traffic jams occur on highways.

Traffic congestion is becoming more intense day after day. The huge amount of vehicles, the deteriorating infrastructure, and the flawed administration of the development are the main factors for increased traffic congestion. Congestion causes slower speeds, longer trip durations, and increased traffic queueing. Urban traffic congestion has risen dramatically. When traffic demand is high enough, vehicle interaction slows the flow of traffic, causing congestion.

However, despite the fact that these roads were designed in accordance with national highway laws, the excess capacity might not only be hazardous to the roads but also raise the expense of re-construction, repairing, and maintenance. There is no other option for re-constructing these roads because it would cut Khulna off from the rest of the country. This has a negative economic impact on the Khulna region.

In the context of studies on mixed traffic flow behavior, (Dey, 2006) used traffic simulation modeling program to determine capacity of two-lane rural roads under mixed traffic conditions. Authors described the effect of vehicle composition on highway capacity through simulation and the model was applied for estimation of passenger car units for various types of vehicles.

For this aim, one roundabout has been selected in the N7 national highway passing through Khulna metropolitan zone. This selected road leads towards the Raligate bus stoppage to the Maniktala bus stoppage. Like in all other regions of the country, Maniktala is such a place that belongs to the N7 highway, where mixed traffic generates simultaneous congestion every day. It is tricky to examine the traffic flow here as it is not uniform but mixed. That is why the author decided to assemble the field data from this locality for a more commendatory outcome.

2. METHODOLOGY

The study's goal is to show how a highway's traffic mix affects its capacity. The construction of speed-flow curves for various traffic mix conditions would be required, and they could not be derived from field data. As a result, the application of VISSIM for microscopic traffic simulation is employed in this proposal. Since this program was designed for use in both the US and Germany, it must first be calibrated for mixed traffic circumstances before being used in desired section.

2.1 Field Data Collection and Analysis

Khulna city was selected for the study area. One of the significant national highways, N7, has crossed through this metropolitan city and is linked with Jessore and Dhaka highway. This highway is always congested as this is one of the feasible routes connected with Mongla port.

"Raligate towards Maniktola" (Figure: 1) intersection was selected for the study area to collect traffic flow and speed data. For speed determinations, a 100-meter-long longitudinal segment was created on the selected sections. Because it was a two-lane road, monitoring inbound and outgoing traffic movement necessitated a side change. The camera was placed on a tripod in a suitable location from which both lanes could be observed (Figure: 2).

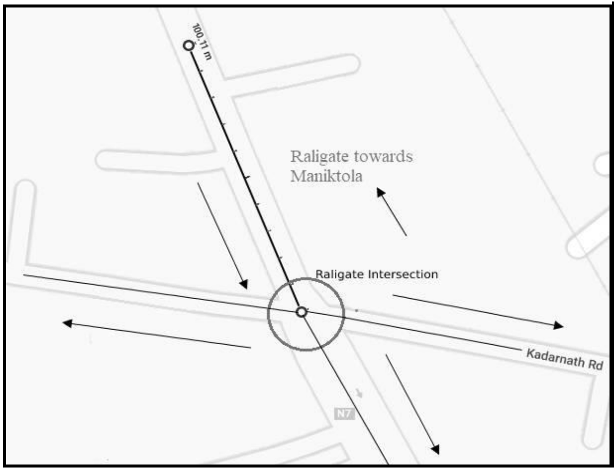

Figure 1: Raligate Intersection

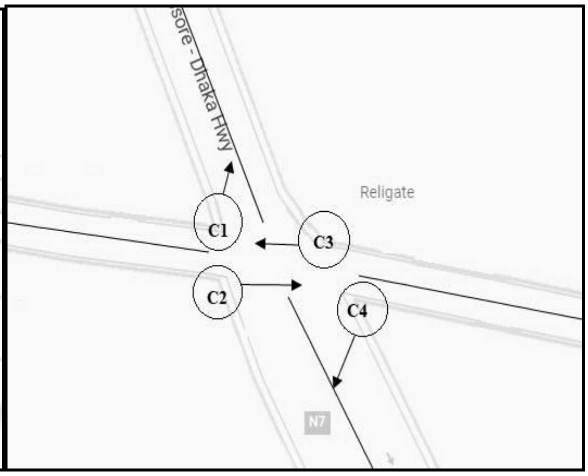

Figure 2: Camera Locations

To make the analysis more valuable and data-driven, vehicles with similar physical and operating conditions were grouped. All vehicles were divided into five groups: minibusses, cars and buses (CS), utility vehicles (CB), large and average trucks (HV), mahindra and CNG (3W), and motorcycles (2W). On Bangladeshi roads, even within the same car category, there are numerous types. As a result, vehicles are divided into small cars (regular) and large cars. Table 1 displays the speed parameters and vehicle composition in the mixed traffic recorded in the field.

Table 1: Traffic patterns and speed limits

Speed Parameters	**Type of Vehicle, Speed (km/h)**				
	CS	CV	HV	3W	2W
Maximum	67.4	90	60	60	80
Minimum	40	70	40	25	50
Average	52.7	80	45	35	55
85^{th} Percentile	46.5	80.75	55.24	41.2	50.2
Traffic Composition	7%	4%	6%	67%	16%
Speed Limit (km/hr)			80		

2.2 Peak Hour Volume and Factor

During the busiest time of the day, the peak hour volume is the number of vehicles using the route, lane, or lane subgroup in concern at that time. Passenger car units are commonly used to express peak hour traffic volume since converting all cars to passenger car units is more accurate. From the field data, we can calculate the Peak Hour Factor (PHF) as well as the actual flow rate (Table 3). PCU factors for different types of vehicles in Bangladesh is shown in Table 2.

Table 2: Passenger Car Unit (PCU) values

Vehicle Type	PCU Value
Truck	3.0
Bus	3.0
Minibus	3.0
Utility	1.0
Car	1.0
Baby taxi	0.75
Motorcycle	0.75
Bicycle	0.5
Cycle Rickshaw	2.0
Bullock Cart	4.0

Source: (RMSS, 2010)

Table 3: Actual Flow Rate Calculation

Internal Volume (pcu/h)	Peak Flow (pcu/h)	PHF	pcu/h
84	873.5	0.913702929	956
99.5			
133			
121.5			
192.75			
239			
230.75			
200.25			
203.5			
177.5			

Peak hour traffic volume is essential to determine to evaluate the capacity and other parameters because it represents the most critical time period. This study is carried out considering this key factor. Table 3 represents internal volume of traffic flow, which is determined through recording 15 minutes peak volume data.

It is mentioned earlier that to study the impact of mixed traffic, it is required to develop speed-flow curve for different types of traffic mix.

2.3 Macroscopic Analysis

The movement of one travel demand parameter concerning another is represented in a macroscopic stream model. The relationship between speed and density is the most important of these (Figure 3). Greenshield proposes the initial and most basic relationship between them in equation (1).

$$U = U_f - [\frac{U_f}{K_j}] \times K \quad (1)$$

Where, U is the mean speed at density K, U_f is the free speed and K_j is the jam density. Figure 4 shows the relation between speed and flow. This flow-density relationship has a parabolic form, as shown in Figure 4 and can be estimated from equation (2).

$$Q_{\max} = K \times V \qquad (2)$$

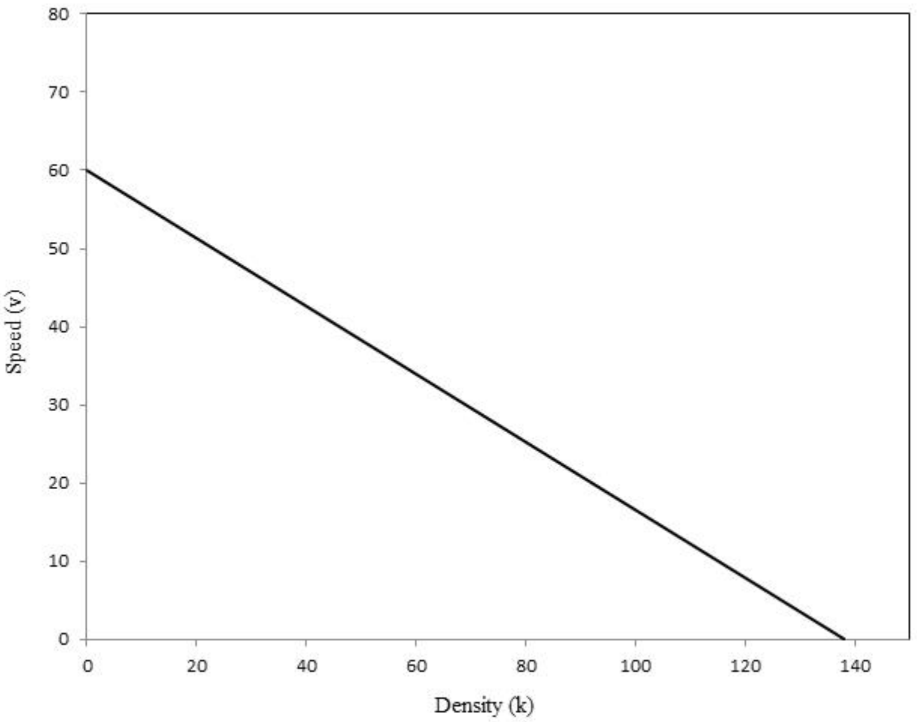

Figure 3: Relation between speed and density

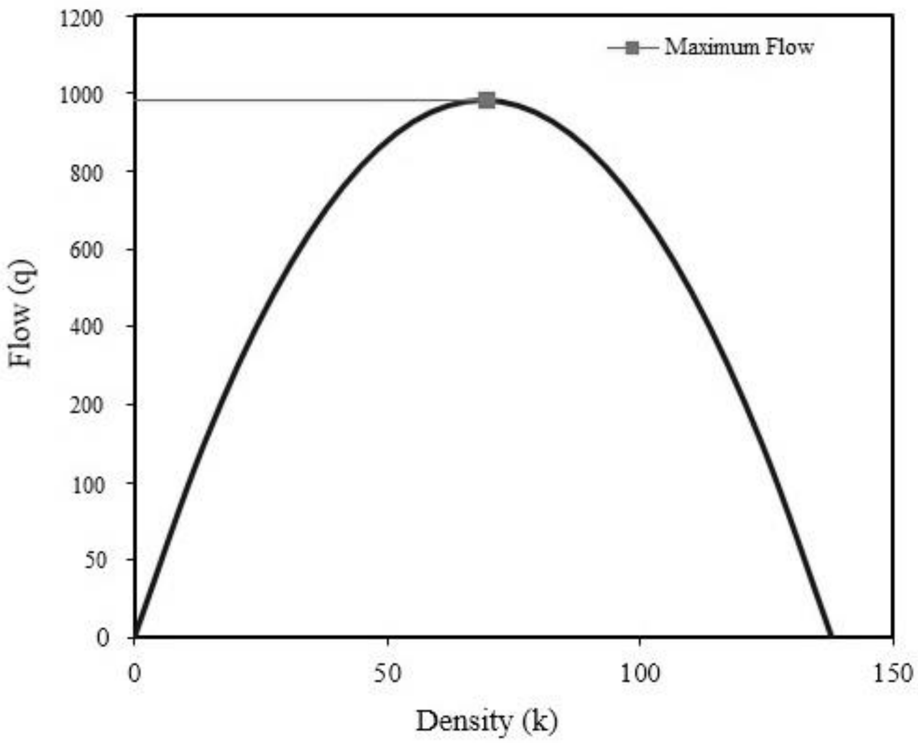

Figure 4: Relation between flow and density

Now, using equation (2), flow is estimated over the entire density and speed range. The speed-flow curve is created with the entire range, and theoretical capacity is calculated. Superimposing field data on the theoretical curve in Figure 5 illustrates that field data follows the Greenshield curve. The Greenshield model was proven to be the best suitable in a mixed traffic situation since the velocity of the stream of traffic begins to drop with volume right at the curve's inception.

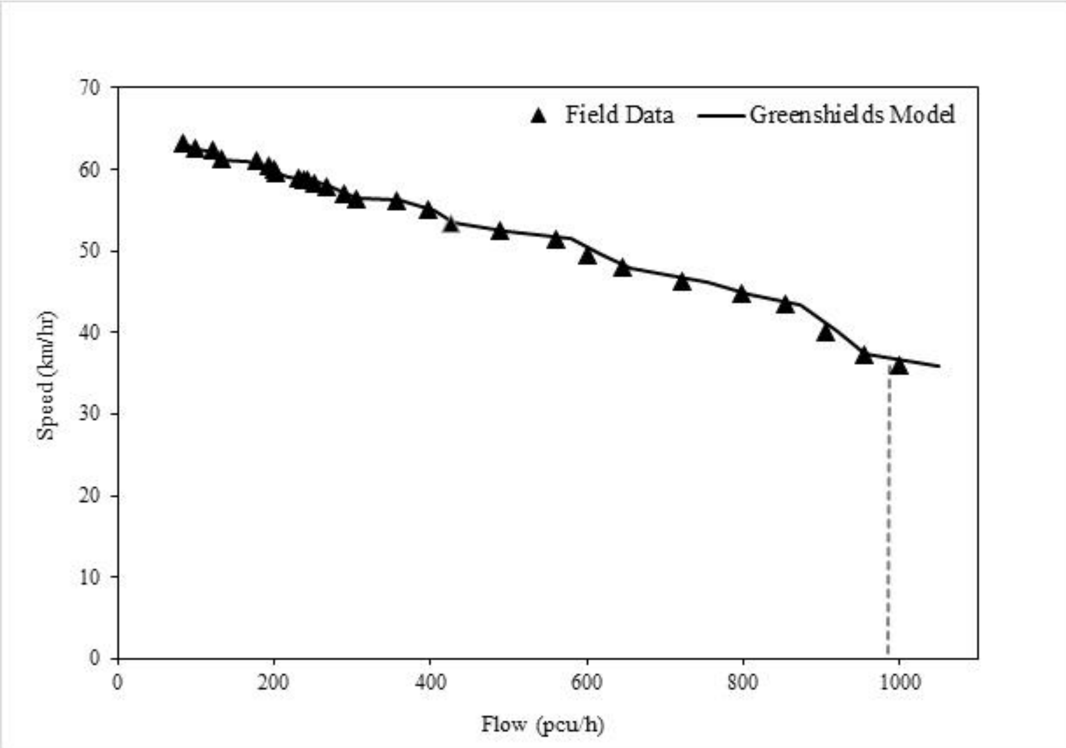

Figure 5: Speed-Flow Relationship for two-lane divided highway

2.4 VISSIM Model and Input Parameters

VISSIM is a behaviour pattern, microsimulation model for complex traffic conditions on highways, city streets, and public transportation. The VISSIM's primary input data requires particular specific road design, type of vehicle measurements, traffic mix, and expected vehicle speed parameters. VISSIM simulates networks based on their trajectory, utilizing a psycho-physical driver modelling approach established by (PTV, 2011).

This model has ten different driver behaviour characteristics, numbered CC0 to CC9, that correlate to different driving scenarios, including free-driving, approaching, pursuing, and slowing. The default values for these parameters can have a significant impact on the simulation results. The projected capacity is quite sensitive to specific parameters, such as CC0 and CC1, that influence driver behaviour in the simulation. (Chitturi & Benekohal, 2008).

2.5 Calibration of Parameters

Standstill distance (CC0) and time headway (CC1), these two variables need special consideration throughout simulation model readjustment to replicate the movement of traffic in a field correctly. The amount recorded into the model is constantly in vehicles per hour with a user-defined transport mix. One kilometre of connection length was built in VISSIM, and the properties found in the survey area were assigned. The capacity was calculated to be 1457 pcu/h/dir with standard input variables, much higher than the field capacity of 956 pcu/h/dir. It indicates that the capacity is increased when using the preset simulation parameter values. The default settings of several parameters in VISSIM's car-following model tend to enhance stream speed. As a result, the safety distance parameters for additional vehicle classes were calibrated. (Shukla & Chandra, 2011) developed a traffic simulation program to examine the properties of multilane-divided highway flow of traffic.

When more than one type of vehicle is present in a mixed traffic situation, traffic stream weighted mean can be calculated using equations 3 or 4 for CC0 and CC1 correspondingly:

$$CC0_{mixed}=CC0_{CS}\times P_{CS}+CC0_{CB}\times P_{CB}+CC0_{HV}\times P_{HV}+CC0_{3W}\times P_{3W}+CC0_{2w}\times P_{2W} \quad (3)$$

$$CC1_{mixed}=CC1_{CS}\times P_{CS}+CC1_{CB}\times P_{CB}+CC1_{HV}\times P_{HV}+CC1_{3W}\times P_{3W}+CC1_{2W}\times P_{2W} \quad (4)$$

Where CC0i and CC1i are the parameter values for the homogeneous traffic stream of the i^{th} type of vehicle, and Pi is the percent share of the i^{th} type of vehicle in the mixed traffic stream.

For modelling a two-lane road with mixed traffic, determined estimations of the CC0 and CC1 variables were produced. The data was incorporated into a driving behaviour model, and simulation tests were performed at low, medium, and high volume levels. Based on simulated data, a speed-volume relationship was established to evaluate the capacity of the street in a combined traffic stream. The simulated volume based on their driving behaviour parameters was estimated and shown in Table 4.

Table 4: Simulated capacity for similar traffic streams

Similar Vehicle	Simulated Capacity (veh/h)	CC0(m)	CC1(m)
CS	75	1.1	1.1
CB	120	1.4	1.5
HV	175	2.3	1.7
3W	405	1.3	0.8
2W	253	0.2	0.4

CC0 and CC1 factors are regarded to be reliant on the types of vehicles and their percentage participation of the traffic stream in mixed traffic. As a result, the safety distance values (CC0 and CC1) were calibrated for additional vehicle types as well. In VISSIM, a homogeneous traffic stream of single-category vehicles such as CB, HV, 3W, and 2W was simulated separately, and the CC0 and CC1 parameters were changed to find capacity values as close to the indicated values as possible. Table 4 shows the capacity values determined by VISSIM, as well as the related CC0 and CC1 values.

3. ILLUSTRATION OF MIXED TRAFFIC OVER CAPACITY

The simulation program was ran with two types of cars to see how traffic mix affected capacity: a regular car and one of the other four types of vehicles are available. Additionally, the second car category percentage in the stream was varied to determine the capacity value under various traffic patterns. There are four vehicle types: CB, HV, 3W, and 2W. This approach is carried out separately for each vehicle type. In VISSIM, a two-lane road segment with varying proportions of second category cars in a regular car traffic stream was simulated with different ratios of second category vehicles. A speed-volume curve was created from the simulated data, then used to calculate capacity values for different traffic combinations. For a two-lane split roadway with standard cars and heavy vehicles in the customary proportions, Figure 6 shows the speed-volume relationship for the highway.

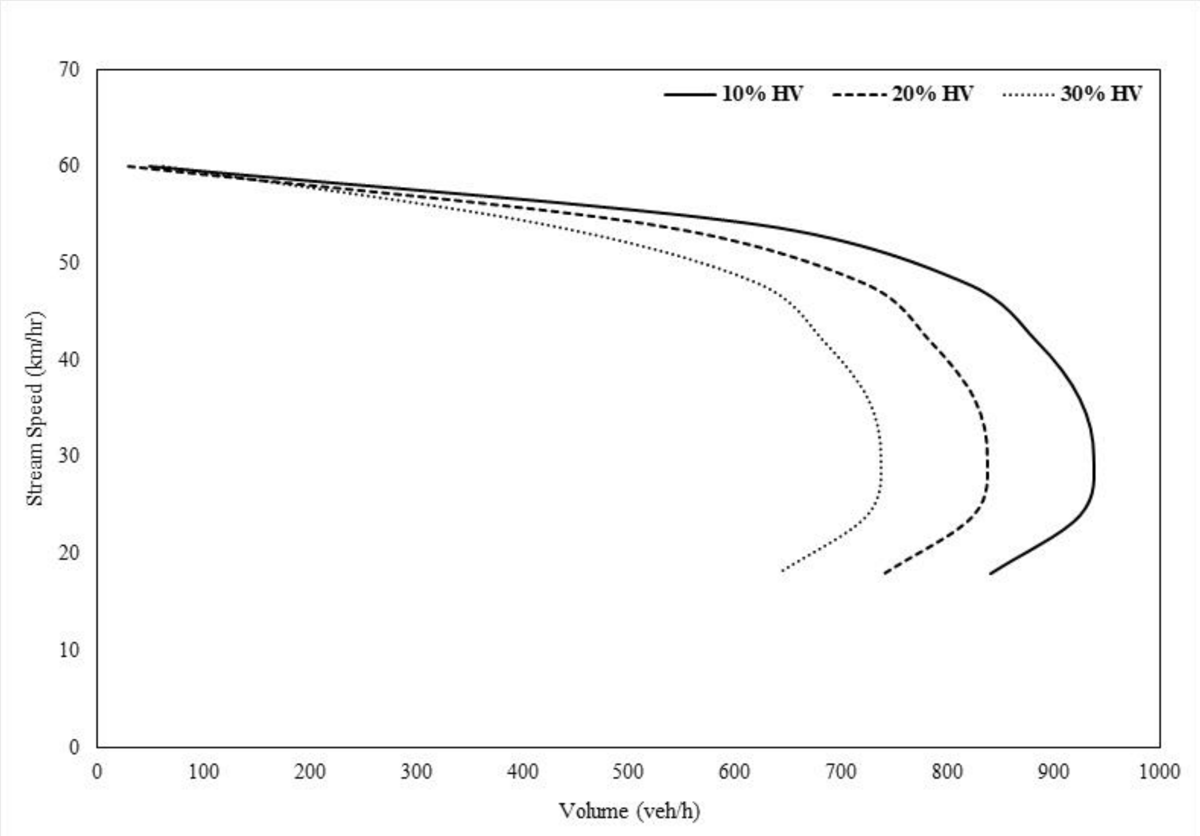

Figure 6: Impact of heavy vehicle on the stream volume from simulation data

The additional vehicle groups are represented in their usual percentages in Table 5, which shows the capacity obtained from the curves.

Table 5: Two-lane motorway capacity for two vehicle types

Type of Vehicle	**Directional capacity (veh/h) at second category share**				
	0 %	10 %	20%	30%	40%
CB	956	865	780	551	342
HV	956	735	578	414	322
3W	956	915	872	765	687
2W	956	935	856	778	654

Table 5 shows the effect of the proportion of second-category vehicles in the traffic stream on highway capacity. It represents directional volume of different vehicles on the mixed traffic stream with respect to the second-category share at 0, 10, 20, 30 and 40 percent.

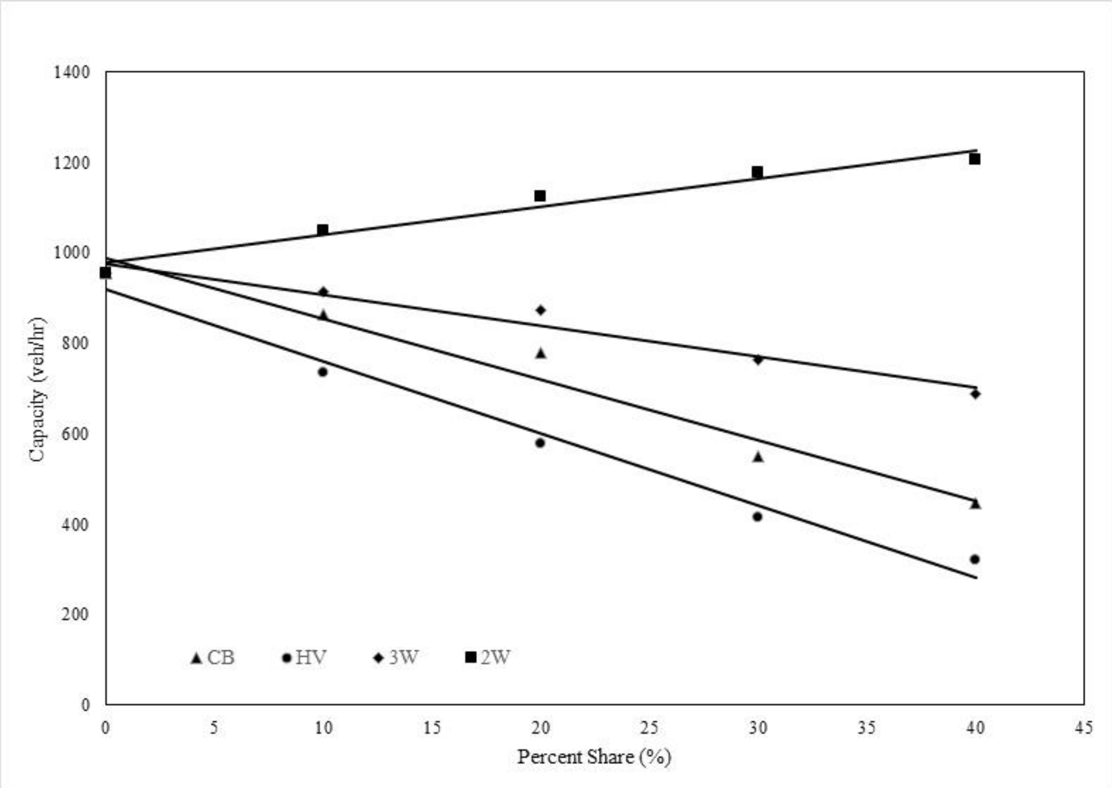

Figure 7: Capacity at different traffic composition

The relationship between directional capacity and the percentage of cars in the later category in the traffic stream is seen in Figure 7. Equation following shows the straight line relationships generated from these plots:

$$C_{mix} = 956 - 13.36 \times P_{CB} \tag{5}$$

$$C_{mix} = 956 - 15.89 \times P_{HV} \tag{6}$$

$$C_{mix} = 956 - 6.88 \times P_{3W} \tag{7}$$

$$C_{mix} = 956 + 6.26 \times P_{2W} \tag{8}$$

In the preceding calculations, the constant term is purposefully fixed at 956, which is a two-lane highway's capacity in all normal vehicle conditions Equations (5) to (8) can now be coupled to compute highway capacity in the presence of all five categories of cars at the same time.. It is provided by:

$$C_{mix} = 956 - 13.36 \times P_{CB} - 15.89 \times P_{HV} - 6.88 \times P_{3W} + 6.26 \times P_{2W} \tag{9}$$

Where C_{mix} represents the total volume of mixed traffic, and P_i represents the percentage of different vehicle types that are present in the flow of traffic.

4. CONCLUSION

The current research looks at how traffic composition affects highway capacity in mixed traffic situations. Field data from highways was utilized to build speed-flow curves to calculate capacity, resulting in 956 pcu/h/dir. The capacity models presented in this paper can be used to quickly compute the volume-to-capacity ratio on a highway, which is a surrogate for connectedness and service quality. The interference of non-motorized vehicles reduces the speed of motorized vehicles and increases the probability of accidents. Non-motorizing vehicles impair mixed traffic flow for lane dividing principle due to a much lower rate and significantly smaller size of non-motorizing vehicles than motorized vehicles, resulting in lower speed and more accidents. Non-motorized vehicles should travel exclusively in designated lanes, even if they are part of a mixed traffic flow.

This model eliminates the need for a vehicle parity factor, which is another challenging parameter in mixed traffic situations. The volume of traffic on the road is measured in vehicles per hour, and the capacity of the road may likewise be determined in vehicles per hour using the relationships presented in this study. The capacity equations reported in this research, on the other hand, are exclusively applicable to the vehicle categories investigated. If there is a change or addition of another vehicle category, new equations will be required. In addition, a multilane highway's capacity is affected by its longitudinal gradient and curvature. In this study, these geometric characteristics were not taken into account. However, they may be incorporated in future studies.

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REFERENCES

Chitturi, M. V. (2008). Calibration of VISSIM for freeway. Washington DC: 87th TRB Annual Meeting CD-ROM,TRB. doi:Paper No.-08-2317.

Dey, P. P. (2006). “Speed distribution curves under mixed traffic conditions.” . *Journal of Transportation Engineering, ASCE, Vol. 132, No. 6*, pp. 475-481. doi:10.1061/ ASCE/0733-947X/2006/132: 6(475)

PTV. (2011). VISSIM Users Manual, version 5.4. Karlsruhe, Germany: PTV.

RHD. (2010). Road Maintenance Management System, Ministry of Communications, Roads and Railways Division, Government of the People’s Republic of Bangladesh.

RMSS. (2010). Road Maintenance Management System, Ministry of LGRD & Cooperatives, Government of the People’s Republic of Bangladesh.

Shukla, S. A. (2011). Simulation of mixed traffic flow on four-lane divided highways. *Journal of the Indian Roads Congress*, Vol. 72, No. 1, 55-71.