Traffic Performance Evaluation of a Four-Lane Section of Prithvi Highway Using Indo-HCM

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Abstract

The recently upgraded four-lane Prithvi Highway in Nepal requires performance-based evaluation to assure sustained operational efficiency under rapidly increasing traffic demand. This study analyzes the traffic performance of two representative highway segments, Kamalbari and Gunadi, using the Indian Highway Capacity Manual (Indo-HCM) framework. Videographic traffic surveys had been conducted for three successive days to obtain classified traffic volumes and individual vehicle speeds under heterogeneous traffic conditions. Major traffic performance parameters such as space mean speed, operating speed, capacity, traffic density, and level of service were evaluated. The analysis revealed that two-wheelers dominated the traffic stream at both locations, contributing nearly 45% of total traffic, followed by standard cars at approximately 15%. After adjusting for shoulder width, the estimated capacities were 3,787 PCU/h/dir on the Kamalbari segment and 3,677 PCU/h/dir on the Gunadi segment. Kamalbari performed under LOS A, representing free-flow conditions, while Gunadi maintained LOS B, indicating stable flow with slightly greater vehicle interactions. These findings indicate that the upgraded four-lane highway is currently operating efficiently; yet, regular monitoring and timely maintenance will be necessary to accommodate future traffic growth and maintain acceptable service levels.

Keywords: Capacity analysis, Four-lane highway, Heterogeneous traffic, Indo-HCM, Level of service

1. Introduction

The Prithvi Highway is 174 km long highway section connecting Naubise to Pokhara. It carries substantial vehicular traffic including commercial and tourist vehicles. To respond to the rising traffic and congestion, the Abukhaireni-Pokhara section of Prithvi Highway has recently undergone four-lane upgrade. Though the upgrade is expected to improve traffic flow, evaluation and operating conditions, a performance-based evaluation is required to find if the upgraded facility performs well under the mixed traffic. The commonly used highway performance metrics are roadway capacity and level of service (LOS). Capacity represents the maximum hourly flow that can be sustained, while LOS reflects traffic conditions in terms of speed, density, and vehicle interactions (Transportation Research Board, 2000). In developing countries, the use of standard Highway Capacity Manual (HCM) procedure is restricted due to heterogeneous traffic, limited lane discipline, and variable road geometry. Studies on multilane highways have shown that the conventional HCM methods often overestimate capacity when applied under mixed traffic conditions (Velmurugan et al., 2010; Arun et al., 2013). The Indian Highway Capacity Manual (Indo-HCM, 2017) provides adjustments for heterogeneous traffic and geometric features and is commonly applied in South Asia. While its use has been examined on multilane highways in India (Kumar & Sinha, 2023; Verma et al., 2024), empirical evidence from Nepal, particularly for upgraded four-lane highways, remains limited, as most existing studies focus on two-lane facilities. With traffic on the Prithvi Highway projected to grow at 5–7% annually and Nepal Road Standards recommending operation at LOS “B” without a performance-based evaluation framework, the applicability of Indo-HCM under Nepalese mixed traffic characteristics requires systematic assessment. Accordingly, this study examines the traffic performance of selected four-lane segments of the Prithvi Highway using the Indo-HCM framework, based on videography-derived traffic data to evaluate speed, capacity, density, and Level of Service.

2. Methodology

The study was performed on two representative four-lane highway sections, Kamalbari and Gunadi, located along the Abukhaireni–Pokhara section of the Prithvi Highway (NH17). These segments were selected to reflect typical interurban operating conditions, with emphasis on the uniform roadway geometry and uninterrupted traffic flow. At each location, a 60-m trap length was selected as per the site selection procedures advised in the Indian Highway Capacity Manual (Indo-HCM, 2017). Traffic data were collected using videography-based surveys carried out over three successive days during morning, daytime, and evening periods. This captures the short-term variations in traffic conditions. Seasonal and monthly variations were not captured and are the limitation of the study

Video recordings were used to extract classified traffic volumes and individual vehicle travel times. Vehicles were grouped into standard categories such as two-wheelers, cars, light commercial vehicles, buses, and trucks. Passenger car units were not adopted as fixed values; instead, observed traffic volumes were converted to PCU using stream equivalency factors as recommended in the Indian Highway Capacity Manual (Indo-HCM, 2017). The stream equivalency approach accounts for local traffic composition, speed, and interaction effects, making it more suitable than fixed or dynamic PCU values for standardized capacity and level-of-service analysis on multilane highways. This method ensures consistency with Indo-HCM–based performance evaluation while reflecting prevailing heterogeneous traffic conditions on the study segments. The following equation provided in Indo-HCM was used to calculate S_e as:

$$Se = 1 + 0.6PBC - 1.5PTW + 2.6PLCV + 3.6PTAT + 6.4PMAT + 1.2PAUTO + 4.8PBUS + 59.8 * \frac{1}{N} \quad (1)$$

Traffic volumes were collected in 5-minute intervals to determine the design hourly flow. The peak 5-minute count was taken from the peak hour, and then it was converted to Design Hourly Volume (DHV) by multiplying it with 12 and Stream Equivalency Factor.

Space mean speed (SMS) was computed from observed travel times in the trap length, and operating speed was measured as the 85th percentile speed of cars under low-traffic conditions. The SMS (u_s) is calculated as:

$$SMS = \frac{N.D}{\sum_i^N t_i} \quad (2)$$

Capacity was calculated using Indo-HCM base models with adjustments for shoulder widths as provided in equation 3 and equation 4. The adjusted capacity was then converted to PCU using equation 5. Traffic density and Level of Service (LOS) were estimated using density-based criteria recommended for four-lane interurban highways.

$$C_{base} = 30 \times V_{OS,\,base} + 1540 \quad (3)$$

$$Capacity = C_{adj} = C_{base} + 188 \times PSW + 170 \times UPSW \quad (4)$$

$$Capacity = C_{adj} \times Se \quad (5)$$

3. Results and Discussion

3.1 Traffic Composition

Traffic on both study locations showed some mixed pattern, with two-wheelers accounting for the largest share of the traffic stream. At Kamalbari and Gunadi, motorcycles contributed nearly to 45% of the total observed volume, while standard cars comprised for roughly 15%. The rest of the traffic mostly consisted of light commercial vehicles, buses, and trucks. Gunadi had slightly higher proportion of heavy vehicles, which boosted interaction among vehicles and influenced operating conditions along the segment.

Table 1: Vehicle Composition at Kamalbari Segment

Vehicle Category	Percentage Composition			
	Day-1	Day-2	Day-3	Average
Two-Wheeler (TW)	46.05	44.82	44.62	45.17
Standard Car (SC)	14.56	15.24	15.57	15.12
Big Cars (BC)	11.45	8.14	8.66	9.42
Light-Commercial Vehicles (LCV)	13.48	14.47	12.99	13.65
Two/Three Axle Truck (TAT)	7.52	9.40	11.38	9.41
Multi-Axle Truck (MAT)	0.09	0.22	0.40	0.23
Auto Rickshaw (AR)	0.13	0.09	0.13	0.12
Bus (B)	6.74	7.62	6.25	6.88

Table 2: Vehicle Composition at Gunadi Segment

Vehicle Category	Percentage Composition			
	Day-1	Day-2	Day-3	Average
Two-Wheeler (TW)	45.34	46.58	42.63	44.85
Standard Car (SC)	16.42	14.81	14.91	15.38
Big Cars (BC)	8.78	7.26	8.14	8.06
Light-Commercial Vehicles (LCV)	14.75	13.24	13.96	13.98
Two/Three Axle Truck (TAT)	6.42	9.08	11.48	8.99
Multi-Axle Truck (MAT)	0.11	0.45	0.37	0.31
Auto Rickshaw (AR)	0.34	0.12	0.29	0.25
Bus (B)	7.83	8.46	8.22	8.17

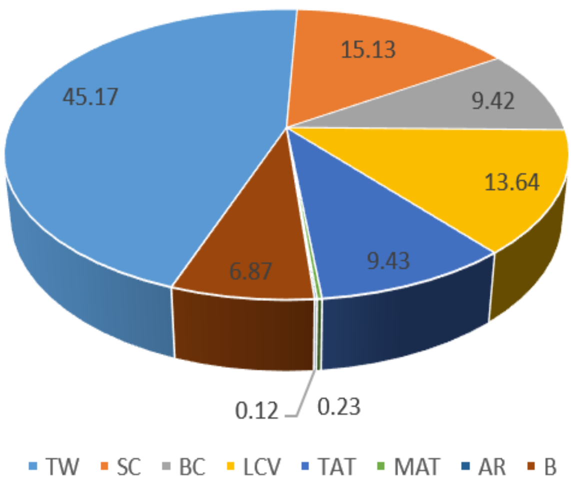

Fig. 1: Traffic Composition at Kamalbari Segment

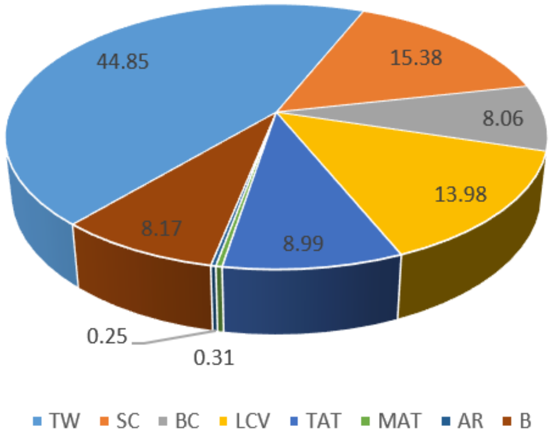

Fig. 2: Traffic Composition at Gunadi Segment

3.2 Stream Equivalency Factor

The stream equivalency factor was estimated as 1.42 for Kamalbari and 1.61 for Gunadi. The higher value in Gunadi reflects a stronger impact of heavy vehicles on the mixed traffic stream, resulting in greater obstructions to traffic flow. This difference highlights the role of local traffic composition in PCU-based capacity estimation.

3.3 Design Hourly Vehicle

The total design hourly vehicle was calculated to be 858 PCU/h/dir at Kamalbari segment, while 1072 PCU/h/dir was observed at Gunadi segment. Gunadi segment reported higher vehicle interaction.

Table 3: Design Hourly Vehicle counts at Kamalbari segment

Vehicle Category	Peak 5-min count	DHV (Veh/hr)	DHV (PCU/h/dir.)
TW	23	280	397
SC	7	88	125
BC	5	64	91
LCV	7	84	119
TAT	5	56	80
MAT	0	0	0
AR	0	0	0
B	3	32	46
Total	50	604	858

Table 4: Design hourly vehicle counts of Gunadi segment

Vehicle Category	Peak 5-min count	DHV (Veh/hr)	DHV (PCU/h/dir.)
TW	25	296	478
SC	5	64	103
BC	8	92	149
LCV	7	84	136
TAT	7	80	129
MAT	0	0	0
AR	0	0	0
B	4	48	77
Total	55	664	1072

3.4 Speed Characteristics

The weighted space mean speed was computed as 59.70 km/h at Kamalbari and 57.08 km/h at Gunadi. Even though the roadway geometry at both locations was similar, the lower speed observed at Gunadi appears to be associated to differences in traffic composition, particularly the higher presence of heavy vehicles.

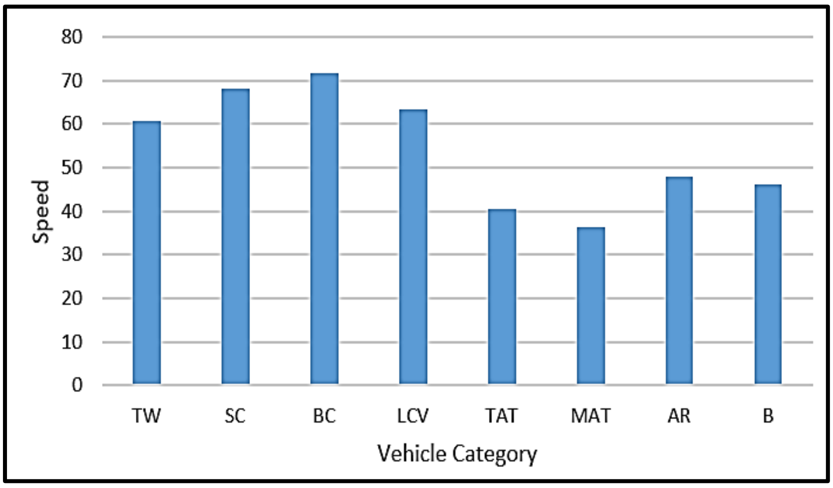

Fig. 3: Weighted SMS of individual vehicle type at Kamalbari segment

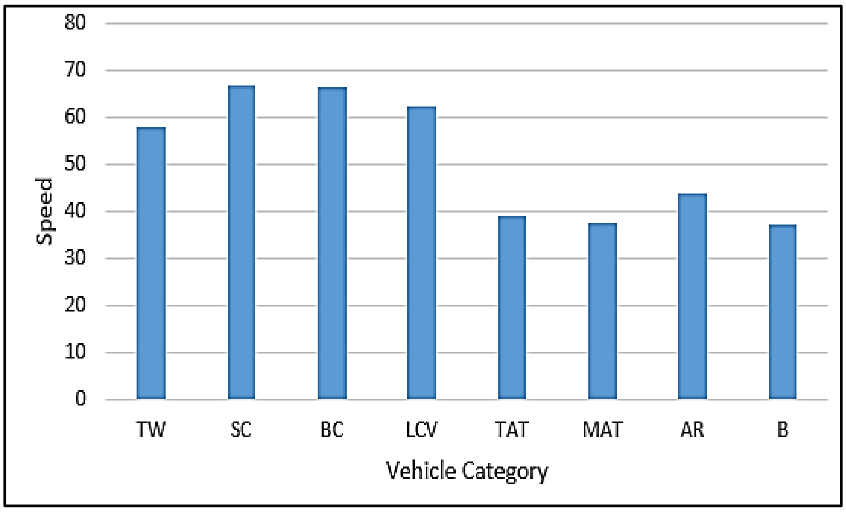

Fig. 4: Weighted SMS of individual vehicle type at Gunadi segment

Operating speed, defined using the 85th percentile speed of standard cars, was found to be 78.67 km/h at Kamalbari and 74.99 km/h at Gunadi. These values suggest that traffic generally moved under near free-flow conditions, with localized variations caused by vehicle mix rather than geometric constraints.

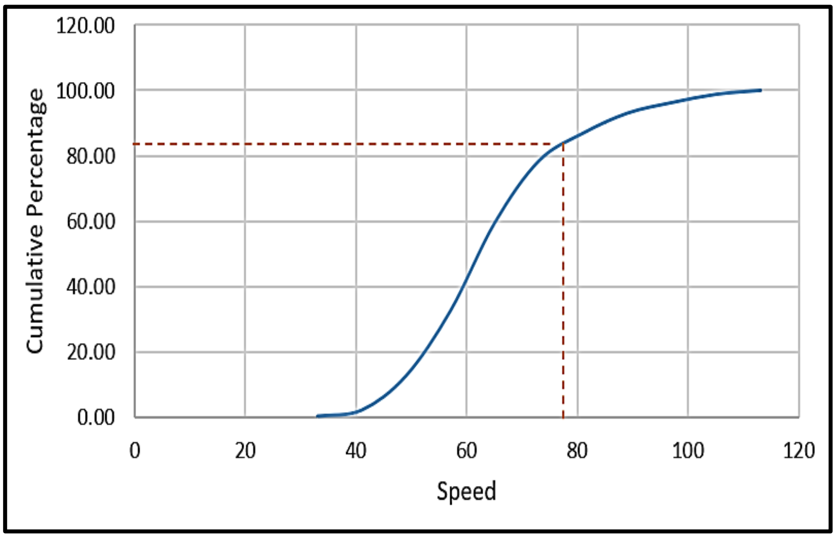

Fig. 5: Operating speed at Kamalbari segment

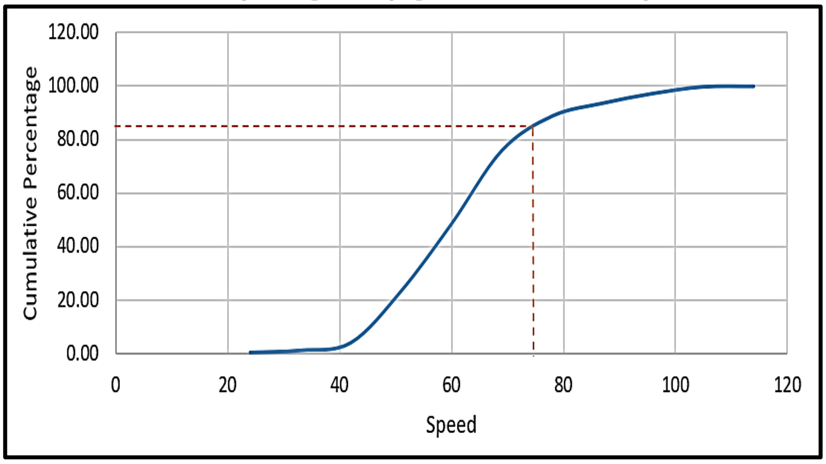

Fig. 6: Operating speed at Gunadi segment

3.5 Capacity, Density, and Level of Service

The analysis shows that both study segments are currently operating comfortably within their capacity limits. Based on observed operating speeds and roadway geometry, the base capacity was calculated to be 3900 PCU/h/dir. for the kamalbari segment and 3790 PCU/h/dir. for Gunadi segment. The capacity was adjusted using paved and unpaved shoulder width as adjustment factors and was estimated at 3787 PCU/h/dir for the Kamalbari segment and 3677 PCU/h/dir for the Gunadi segment. The capacity was reduced by 113 PCU/h/dir. in both segments while adjusting it with adjustment factors. When compared with the corresponding design-hour traffic volumes expressed in PCU, neither location approaches capacity, indicating stable operating conditions.

Traffic density was relatively low at Kamalbari (14 PCU/km/dir), resulting in LOS A and reflecting free-flow conditions with minimal interaction among vehicles. In contrast, Gunadi recorded a higher density of 19 PCU/km/dir, corresponding to LOS B, which suggests stable flow but with noticeable interaction between vehicles. This difference in service level can be linked to the higher share of heavy vehicles at Gunadi and its larger stream equivalency factor, which increases effective density even when speeds remain comparable.

The results indicate that the upgraded four-lane facility is performing efficiently under present traffic demand, although the emerging differences between segments highlight the importance of traffic composition in shaping operational performance.

4. Conclusion

The study aimed to use the Indo-HCM framework to evaluate the operational performance of a recently upgraded four-lane section of the Prithvi Highway under heterogeneous traffic conditions. With Kamalbari showing free-flow conditions and Gunadi showing stable flow that were impacted by traffic composition, the results verify that the sections under study are presently functioning within acceptable service levels. The results shows that mixed traffic affects speed, density, and Level of Service in a quantitative way, especially when two-wheelers and heavy trucks are present. Even while the current scenario is still excellent, performance could ultimately shift due to continuous traffic growth. To improve the suitability of Indo-HCM for Nepalese highways, further research should look at seasonal fluctuations, longer road segments, and local calibration of capacity characteristics.

Conflicts of Interest

The authors declare no conflict of interest.

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