

# Impact of PCU Values on Performance Assessment of Unsignalized Intersection: Case Study of Airport Chowk, Surkhet

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## Abstract

*Airport Chowk Intersection is an unsignalized intersection which is one of the main intersections of Birendranagar, Surkhet which faces heavy traffic flow during peak hours. This study aims to find the Volume-to-Capacity ratio and level of services at the intersection using the passenger car unit ( PCU) value based on the Indo Highway Capacity Manual ( Indo-HCM) 2017, Nepal Road Standard 2070( NRS) and Department Of Road (DOR) and to compare the results obtained from all three standards. Classified traffic volume count is conducted to determine the peak hour volume. Peak hour traffic volume is converted into PCU based on all three standards. The intersection is assessed using the methodology recommended by Indo-HCM for the assessment of unsignalized intersections. Conflicting flow rates and critical gap values are determined for each movement in priority rank. Thereafter intersection's capacity and Level of Service (LOS). The result indicates that the intersection operates at an overall LOS of 'A' in the morning peak hour for movement 1 (Pipira to Airport) but 'B' in the morning and 'C' in the evening for movement 3(Airport to Bulbule). Remarkably, movement 3 experiences higher congestion because of the greater proportion of heavy vehicles resulting in an increase in critical gaps and V/C ratios. By comparing the value of LOS obtained from PCU based on all three standards found almost similar except value of LOS obtained from NRS for movement in the evening peak hour. The study highlights the necessity of strategic interventions to enhance intersection performance and mitigate congestion during peak hours.*

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## Introduction

A road intersection is an area, shared by two or more roads, whose function is to provide for the change of route direction at the same level. Traffic conflict is a major problem at intersections which increases delay time [1]. Intersections are crucial points in any road network because they are where conflicting streams of vehicle movements share space and time, causing traffic congestion. Depending on the kind of control employed, at the intersection, it can be categorized hierarchically as an uncontrolled, stop-controlled roundabout, signalized, or grade-separated (i.e. flyover and interchange). An unsignalized intersection is one of the more complicated locations in urban networks. With the increase in traffic volume, it had an impact on the decline of the operational quality of the urban network. At an unsignalized intersection, each driver needs to identify a safe opportunity to proceed while taking into account the existing traffic conditions, relevant traffic signs (such as stop or yield), and applicable regulations (including the "right before left" rule). Consequently, the analysis of operations at an

unsignalized intersection focuses on the interactions among vehicles, considering the geometric characteristics of the intersection [2]. Each year, a significant number of road traffic fatalities and injuries is caused by poorly designed infrastructure, inadequate safety measures, and lack of enforcement [3].

Emerging cities like Birendranagar is experiencing rapid urbanization, which poses a challenge to the current urban infrastructure and congestion. Vehicles registration has exponential expanding due to the higher increase of population in this city [4]. In particular, it causes mental tension and interferes with people's everyday routine, leading to high blood pressure, increased negative mood stress states, and lowered tolerance for frustration. Additionally, traffic jams have a negative effect on the economy. High vehicle traffic density, incidents, behavioral factors, environmental factors, public transportation issues, and infrastructural limits are the main causes of traffic congestion [5]. Surkhet Valley's road traffic is extremely diverse with a wide range of static and dynamic features. These vehicles include cars, buses, trucks, auto rickshaws, bikes/scooters, cycle rickshaws, etc. It is challenging to measure such heterogeneous traffic because of the different physical dimensions, speeds of vehicles, and behavior of drivers [6]. In order to solve this issue, various vehicle types are converted into equivalent passenger cars, and the volume is expressed in terms of passenger car units (PCU) per hour [7].

### **Objectives**

The main objectives of this study is to measure the Volume-to-Capacity ratio (V/C) and Level Of Service (LOS) of unsignalized intersections under the current conditions and study further aims to compare the results obtained using PCU values from Nepal Road Standard (NRS 2070) and Indo HCM (2017) and Department of Road (DOR).

### **Literature Review**

Different strategies and approaches are typically applied to traffic congestion, in urban areas. Many researchers have employed enough time & effort for the evaluations of intersections in terms of delay and level of service and to identify the measures of improvement. A study of an uncontrolled 3-legged signalized intersection at Pepsicola, Kathmandu conducted to assess the operational performance of unsignalized intersections using Microsimulation. The intersection is an uncontrolled 3-legged signalized intersection. The 3 days traffic volume was counted using the video graphics survey on May 9, 10, and 11 from 8:00 AM and 4:00 PM- 6:30 PM. The operational performance of the intersection at Pepsicola is evaluated with the help of simulation software VISSIM and the level of service [LOS] of the intersection is C with an average delay of 18.62 sec. The traffic flow from Jadibuti to Sanothimi has better service quality and could have an enhancement in the design and coordination of the signal phase [8].

A study was conducted to optimize the performance at signalized intersections through signal coordination in two intersections in Nepal. This study aims to improve traffic flow at two busy intersections (Kanti Children's Hospital and Sital Niwas) in Kathmandu Valley, Nepal. Traffic volume of morning peak hour was collected with the geometrical features of the two intersections and a signalized intersection model was developed for using "SIDRA Intersection 8.0. The results showed that dealing with the signal system significantly reduced both the average delay time and maximum

queue length at both intersections. This study found that dealing with the signal between intersections can be a cost-effective and efficient solution to reduce congestion. [1]

Various researchers have analyzed the signalized and unsignalized intersections throughout Nepal using different values of Passenger Car Unit (PCU) suggested by Indo-HCM and NRS. A study of the New Baneshwor intersection was conducted adopting PCU values from both NRS and Indo HCM with the aim of measurement delay, determining the level of service (LOS), and comparison of the result of LOS obtained from both methods Indo-HCM and NRS. Three days of traffic data were counted through the peak hour in the morning and evening. The performance of the intersection has been assessed and the result indicates the Level of Service [LOS] remains unchanged in both methods [5]. A group of researchers performed the assessment of a signalized intersection at the Jay Nepal Intersection using the PCU based on Indo-HCM. This study gives an overview of the current situation of signalized intersections in Jay Nepal Hall, Kathmandu, Nepal which faces congestion & busy approaches using the software "SIDRA Intersection 8.0", the environmental and traffic flow model was developed. The assessment of the performance of the intersection is based on the Label of Service, average delay time, and queue length. The results show that the intersection was over-saturated [DOS>1] and had a poor Level of Service [F] in both morning and evening peak hours. The flow is still an oversaturated intersection signal and it is concluded that for the better performance of intersection signal timing was optimized by changing the cycle length and the continuous left turning movement was controlled under signal time. [9]

A study of the determination of dynamic Passenger Car Equivalent in Pokhara Metropolitan City is carried out. The study found that variation of dynamic PCU values with the change in traffic composition, flow speed, and number of lanes [10]. It is concluded that PCU differs from place to place. Their Researchers have found that they are using different values of PCU for the analysis.

Also, the assessment of the Intersection is carried out in the Kathmandu valley. A study of the Buspark intersection in Birganj Metropolitan City aims to assess the recent traffic situation at the Buspark Junction in Birgunj, Nepal to identify the measure of its solution. 72 hours of traffic volume data and geometrical characteristics of the road intersection were collected and an existing model of the intersection was made with the help of the software "SIDRA Intersection 8.0". The results show that the current scenario of the intersection is unsatisfactory and it is concluded that to improve the performance of the intersection, signal timing was optimized by changing the cycle length, and the continuous left-turning movement was controlled under signal time [11].

## **Methodology**

### **Study Area**

Airport Chowk intersection is located in the capital of Karnali province of Nepal, Birendranagar Surkhet. It is an unsignalized intersection that faces heavy traffic flow during peak hours. This intersection connects the route of the Airport, Pipira, and Bulbule. The graphical location of the intersection is 28°34'51.87''/81°37'55.71''E. The substantial rise in traffic is due to a rapid increase in the population as people from other districts of Karnali province migrate here for better opportunities which causes an increase in urbanization and has resulted in extensive traffic congestion within Birendranagar, Surkhet. Bulbule - Pipira Road section is also part of Karnali Highway [H12]. It is one

of the busiest junctions since it connects the route to the Airport and the Bulbule - Pipira Road section is also part of Karnali Highway [H12]. This crossing is one of the busiest in the scenario of Surkhet Valley since it has substantial hospitals, business centers, government offices, banks, and educational institutions, and the fact that major tourist area of Surkhet, Bulbule Lake is situated near the intersection.



*Figure 1: Satellite image of Airport Chowk Intersection*

The capacity and Level of Service (LOS) of unsignalized intersections was calculated using the methodology used in Indo HCM – 2017 [12]. The process to be achieved during the study is shown in the flow chart below.

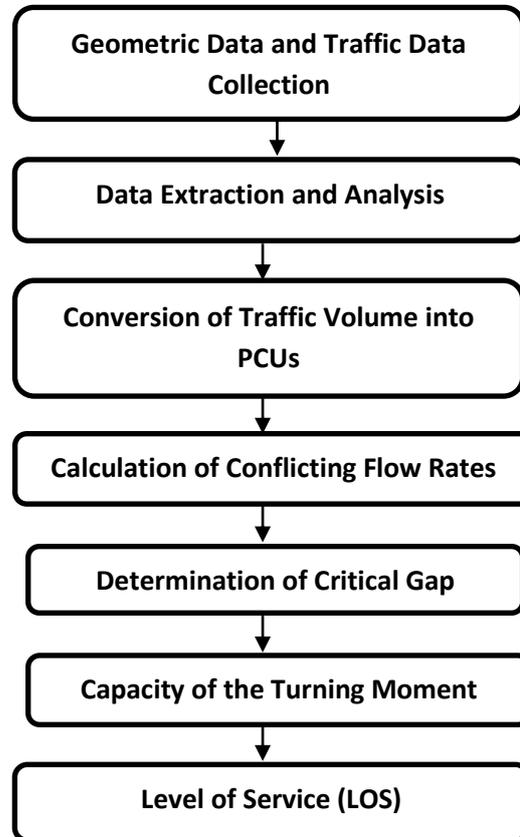


Figure 2: Methodology for calculation of capacity of turning moment and LOS.

Traffic volume for three days at this intersection was collected with the help of recorded video. The geometrical parameters of the intersection such as lane width, divider width, curb width, etc were precisely measured using the taps. Peak hour traffic volumes of the morning [9:15 am to 10:15 am] and evening [4:00 pm to 5:00 pm] were determined. A secondary source like Indo HCM-2017 is used to extract secondary data.

Traffic volumes in six directions were counted. For the analysis, a standard Passenger Car Unit (PCU) is used to standardize the flow of vehicles. The data of the Passenger Car Units for unsignalized intersections were extracted from NRS, Indo HCM – 2017 and DOR to calculate the peak hour volume in PCU/hr as shown in below Table.

Table 1: Passenger Car Unit for Unsignalized Intersection

Vehicle Modes		PCU Factor		
		As Per Indo-HCM	As Per NRS	As Per DOR
Truck	Multi-axle	3.06	3	4
	Heavy	2.38	3	3
	Light	1.1	1.5	1.5
Bus	Big	2.29	3	3
	Mini	2.29	3	2.5
	Micro	2.29	1.5	1.5
Car/Taxi		1	1	1
Motorcycle		0.48	0.5	0.5
Utility vehicles		1.7	1	1
Tractor		1.62	1.5	1.5
Three-Wheeler		0.5	1	0.75
Four-wheel drive		1.29	1.5	1.5
Power Trailer		3.13	3	1.5
Rickshaw		1.29	0.5	0.5
Bicycle		0.42	1.5	1

Base critical values in seconds of four-lane undivided intersections were taken from Indo-HCM as shown below table;

Table 2: Base Critical Gap Value for Four-Lane Divided Intersection

Movement	Standard Car
Movement 1	2.7
Movement 2	3.8

The adjustment factors for a proportion of large vehicles in conflicting traffic streams were also taken from Indo-HCM as shown in the table below;

Table 3: Adjustment Factor for Proportion of Large Vehicles in Conflicting Traffic Streams

Movement	Standard Car
Movement 1	0.46
Movement 2	0.88

The adjustment factors relevant to the capacity model are outlined below.

Adjustment Factors	Movements	
	Movement 1	Movement 2
a	0.8	1
b	1.3	2.16

Peak-hour traffic volumes are converted into an equivalent number of passenger cars using the PCU value suggested by Indo HCM and NRS [13] to standardize the flow of vehicles.

The conflicting flow rates of Movement 1 of priority rank 2 and Movement 3 of priority rank 3 were determined using the below equation given by Indo HCM – 2017.

For two-lane major streets;

$$V_{c,1} = v_5 \dots\dots\dots(1)$$

$$V_{c,3} = v_5 + v_1 + 0.5v_2 \dots\dots\dots(2)$$

where,

$V_1$  = Peak hour traffic volume in PCU/hr for movement 1.

$V_2$  = Peak hour traffic volume in PCU/hr for movement 2.

$V_5$  = Peak hour traffic volume in PCU/hr for movement 5.

Critical gaps for different movements using the base values and adjustment factors for the proportion of large vehicles in conflicting traffic streams using the below equation given by Indo HCM – 2017.

$$t_{c,x} = t_{c,base} + f_{LV} \times \ln(P_{LV}) \dots\dots\dots(3)$$

where,

$t_{c,base}$  = Base critical gap value for corresponding vehicle type executing the same movement

$f_{LV}$  = Adjustment factors for different vehicles in the conflicting traffic stream.

$P_{LV}$  = Proportion of large vehicles in the conflicting traffic stream.

### Capacity of the Turning Moment And Level of Service (LOS)

The capacity of any movement in an unsignalized intersection can be calculated by using the gap acceptance model presented in the equation given by Indo HCM – 2017.

$$C_x = a \cdot V_{cx} \frac{e^{-V_{cx}(t_{cx} - b)/3600}}{1 - e^{-V_{cx}t_{fx}/3600}} \dots\dots\dots(4)$$

Where,

$C_x$  = capacity of movement 'x' (in PCU/h),

$V_{c,x}$  = conflicting flow rate corresponding to movement x (PCU/h),

$t_{c,x}$  = critical g [9]ap of standard passenger cars for movement 'x' (s),

$t_{f,x}$  = follow-up time for movement 'x' (s), and

'a' and 'b' = adjustment factors based on intersection geometry.

Level of Service is graded from A to F based on the ratio between volume and capacity for each moment.

### Data Analysis And Result

The diagram presented below illustrates the peak hour traffic volume in the morning from 9:15 AM to 10:15 AM and evening from 4:00 PM to 5:00 PM across the Airport Chowk intersection. There is a substantial rise in traffic volume at indicated morning peak hour. The following diagram shows the representation of the traffic volume trends and highlights the critical areas of congestion. The result of traffic volume counts is shown in Fig. 3 below.

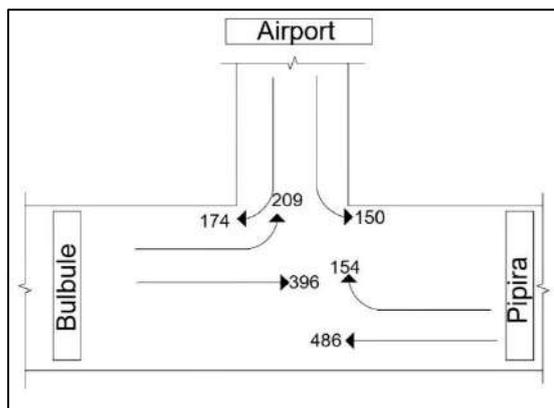


Figure 2: Peak hour volume in the morning.

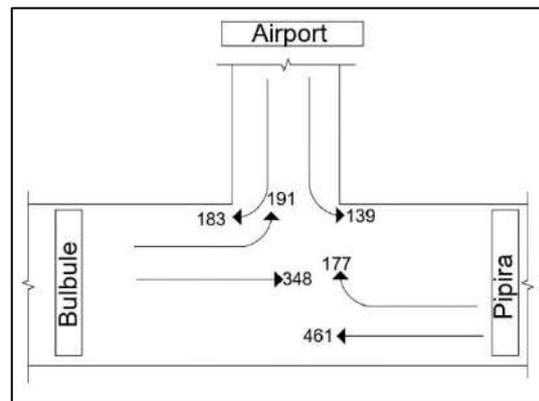


Figure 3: Peak hour volume in the evening

### Peak-hour traffic volume

It has the heaviest traffic flow rates between 9:15 AM to 10:15 AM in the morning and 4:00 PM to 6:00 PM in the evening. The data is analyzed for different movements of vehicles and presented below table;

Table 4: Classified Traffic Volume (peak 1 hour) for different movements

At Morning						
Vehicle Type	Movements					
	1	2	3	4	5	6
Multi-axle truck	1	10	5	0	9	4
Heavy truck	0	7	2	2	8	2
Light truck	0	4	3	0	3	2
Big Bus	1	4	0	2	2	3
Mini Bus	4	9	3	5	9	7
Micro Bus	1	27	3	7	22	3
Car	5	8	3	3	12	6
Motorcycle	60	201	70	88	157	120
Utility Vehicles	5	17	3	4	16	1
Four Wheel Vehicles	12	35	6	9	13	4
Tractor	3	8	1	3	1	1

Three Wheelers	62	105	37	33	101	23
Power Triller	0	5	2	0	0	0
Bicycle	11	42	14	14	21	7
Rickshaw	3	4	2	2	3	1
Total	168	486	154	172	377	184
<b>At Evening</b>						
Vehicle Type	Movements					
	1	2	3	4	5	6
Multi-axle truck	1	4	1	1	2	1
Heavy truck	0	2	0	2	6	8
Light truck	1	2	4	1	2	5
Big Bus	0	1	2	0	10	2
Mini Bus	7	14	8	6	14	11
Micro Bus	6	18	8	3	16	12
Car	3	13	5	1	8	9
Motorcycle	56	209	97	73	189	99
Utility Vehicles	2	13	5	7	7	6
Four Wheel Vehicles	16	18	1	9	16	3
Tractor	3	6	26	4	3	2
Three Wheelers	55	131	2	23	77	31
Power Triller	4	2	11	0	1	2
Bicycle	17	23	12	10	26	13
Rickshaw	7	7	6	0	4	4
Total	178	463	188	140	381	208

The peak hour volume of Traffic executing in each movement at the intersection is converted into Passenger car unit based on Indo-HCM, NRS, and DOR and presented in the following table;

Table 5: Traffic Volume Converted into PCU

	<b>At Morning</b>					
	<b>V1</b>	<b>V2</b>	<b>V3</b>	<b>V4</b>	<b>V5</b>	<b>V6</b>
As per Indo-HCM	119	477	121	132	377	145
AS per DOR	137	446	136	150	346	153
AS per NRS	154	475	145	151	368	158
	<b>At Evening</b>					
	<b>V1</b>	<b>V2</b>	<b>V3</b>	<b>V4</b>	<b>V5</b>	<b>V6</b>
As per Indo-HCM	150	353	200	112	309	191
AS per DOR	147	349	167	113	308	180
AS per NRS	182	418	202	126	359	215

The conflicting flow is any movement of the higher priority with which the subject movement shares the right way. Also, the movement of lower priority might affect the movement of higher priority.

Therefore, the lower priority movement is also considered while calculating conflicting flow rates. After the conversion of peak hour traffic volume into PCU Using the equations (A) and (B) recommended by the Indo-HCM, conflicting flow rates is determined as follows;

Table 6: Calculation of Conflicting Flow Rates

At Morning					
Priority Rank	Movement	Conflicting Flow Equation	Conflicting Flow		
			As per Indo-HCM	As per DOR	As per NRS
1	Movement 2				
	Movement 5				
	Movement 6				
2	Movement 1	$V_5$	377	346	368
3	Movement 3	$V_5+V_1+0.5V_2$	755	706	760
4	Movement 4				
At Evening					
Priority Rank	Movement	Conflicting Flow Equation	Conflicting Flow		
			As per Indo-HCM	As per DOR	As per NRS
1	Movement 2				
	Movement 5				
	Movement 6				
2	Movement 1	$V_5$	309	332	359
3	Movement 3	$V_5+V_1+0.5V_2$	636	676	750
4	Movement 4				

The Critical Gap value of Movement 1 and Movement 3 based on PCU value as per Indo-HCM, DOR [14], and NRS are calculated based on equation (iii) as recommended by Indo-HCM.

Table 7: Calculation of Critical Gap Values

Category	At Morning			
	Movement	Base Critical Gap (tc,base)	Proportion of heavy vehicles in the conflicting traffic stream(Plv)	Critical gap $tc,x$ $= tc,base$ $+ fLV$ $\times$ $ln (PLV)$
As per Indo-HCM	Movement 1	2.7	8.4	3.97
	Movement 3	3.8	25.62	6.76
As per DOR	Movement 1	2.7	8.76	3.7
	Movement 3	3.8	26.97	6.69
As per NRS	Movement 1	2.7	7.14	3.6
	Movement 3	3.8	21.38	6.5

		At Evening		
As per Indo-HCM	Movement 1	2.7	14.67	3.94
	Movement 3	3.8	44	7.13
As per DOR	Movement 1	2.7	10.89	3.8
	Movement 3	3.8	40.22	7.05
As per NRS	Movement 1	2.7	12.09	3.84
	Movement 3	3.8	43.56	7.14

The capacity of any movement of an unsignalized intersection is calculated based on the gap acceptance model recommended by Indo-HCM using the equation (iv) as mentioned above.  $v/c$  ratio is determined by dividing volume by capacity along the respective movement and finally, Level of Service (LOS) is found with the help of the  $V/C$  ratio as shown in the table below.

Table 8: Calculation of volume-to-capacity ratio and LOS

At Morning							
Category	Movement	Critical gap $t_{c,x}$ (s)	Follow-up time $t_{f,x}$ $=0.6*t_{c,x}$	Conflicting flow $v_{c,x}$	Capacity	Volume to Capacity ratio	LOS
AS per Indo-HCM	Movement 1	3.97	2.38	377	1034	0.12	A
	Movement 3	6.76	4.05	755	503	0.24	B
AS per DOR	Movement 1	3.7	2.22	346	1144	0.12	A
	Movement 3	6.69	4.01	706	533	0.25	B
As per NRS	Movement 1	3.6	2.16	368	1174	0.13	A
	Movement 3	6.5	3.9	760	542	0.26	B
At Evening							
AS per Indo-HCM	Movement 1	3.94	2.36	309	1075	0.14	A
	Movement 3	7.13	4.28	636	499	0.4	C
AS per DOR	Movement 1	3.8	2.28	332	1112	0.14	A
	Movement 3	7.05	4.23	676	492	0.36	C
As per NRS	Movement 1	3.84	2.32	359	1079	0.17	B
	Movement 3	7.17	4.3	750	446	0.45	C

## Discussion

The comparison of the v/c ratio at the airport intersection using PCU values based on Indo-HCM, NRS, and DOR shows the different intersection's performance during different parts of the day. In the morning, the V/C ratio using PCU based on Indo-HCM, DOR and NRS is found similar for both the movement of vehicle from Pipira to Airport ( Movement 1) and vehicle movement from Airport to Bulbule ( Movement 3) but the V/C ratio using PCU based on NRS is found to be higher than V/C ratio using PCU based on Indo-HCM and DOR in the Evening while V/C ratio using PCU based on Indo-HCM and DOR is found similar in the movement. This suggests that the intersection is more congested when evaluated with NRS standards. For movement 3, the V/C ratio is found different for three different standards based on NRS is found higher than the two values of the v/c ratio based on Indo-HCM and DOR standards. Since the peak hour traffic flow is almost similar in both movement 1 and 3 is found higher than movement 1. This is because of the higher proportion of heavy vehicles in movement 3 which increases the critical gap values and V/C ratio.

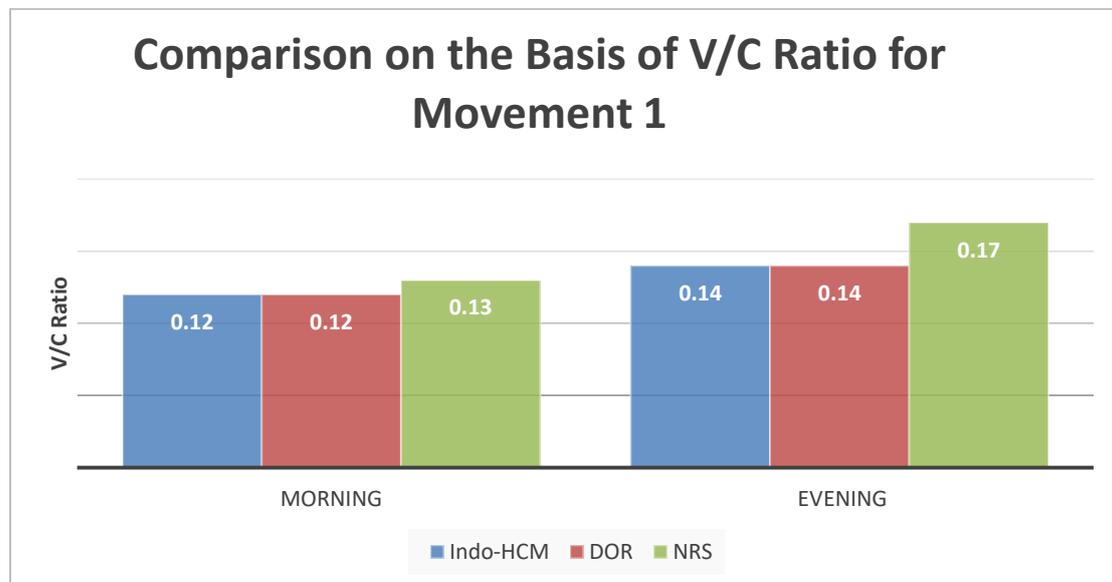


Figure 4: V/C ratio (Morning and Evening) comparison chart.

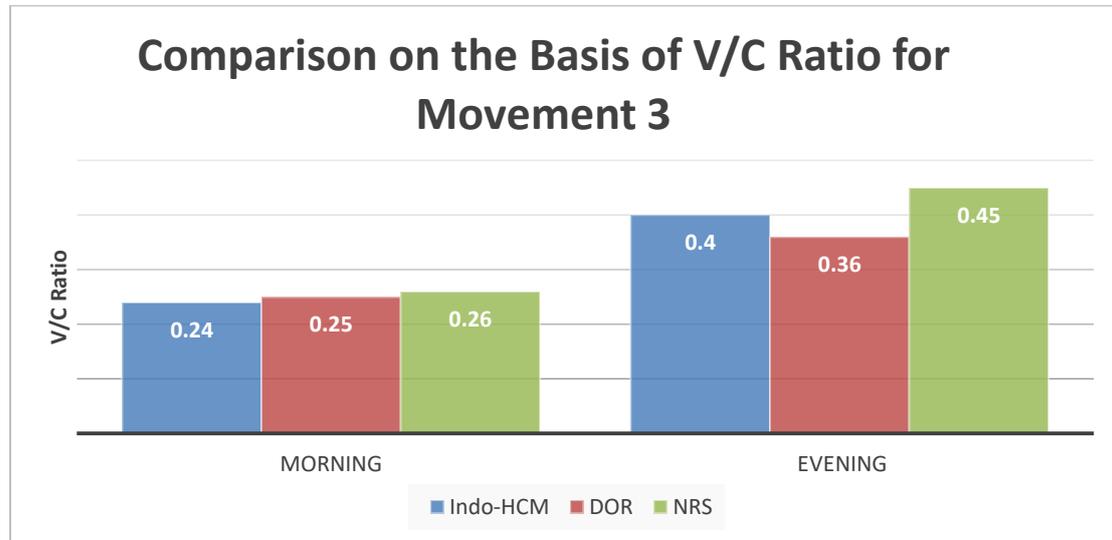


Figure 5: V/C ratio (Morning and Evening) comparison chart

## Conclusion

This study focused on the operational performance assessment of the unsignalized Airport intersection in Surkhet Valley by using the methodology recommended by Indo-HCM 2017. The survey is carried out to collect the peak hour traffic volume from 9:15-10:15 AM in the morning to 4:00- 5:00 PM in the evening and geometrical features of the intersection. The study shows that the overall Level of Service (LOS) of the intersection is found to be 'C'. Therefore, it is concluded that the road intersection is needed to avoid conflicts during the peak hour.

Furthermore, the intersection's performance has been assessed and compared the LOS values of the intersection for different movements (movement1 and movement3). The LOS values for movement 1 using PCU values from all three Indo HCM, DOR, and NRS standard is found to be 'A' in the morning but the LOS value from the NRS standard is found to be 'B' in the evening. Similarly, the LOS value for movement 3 is found to be 'B' and 'C' in the morning and evening respectively for all three standards. Besides, having almost similar traffic flow, Movement 3 (vehicles from the Airport to Bulbule) is more congested than Movement 1 (vehicles from Pipira to the Airport) which is due to more proportion of heavy vehicles in Movement 3 at peak hour. It is concluded that Movement 3 is more critical in the evening than in the morning.

The results show that LOS remains unchanged with all three methods (except the evening value for Movement-1 of the NRS standard). This comparative analysis gives a clear perception of the intersection performance, enhancing the importance selection of appropriate PCU values for accurate traffic evaluation.

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