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Performance Evaluation of Signalized Intersection- A Case study of Prithivi Chowk, Pokhara

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ABSTRACT- Prithivi Chowk, a heavily trafficked signalized intersection in Pokhara, Nepal, currently relies on manual traffic control, leading to significant issues during peak hours. This study employs the Highway Capacity Manual (HCM) methodology to evaluate the intersection's performance, aiming to address congestion and recommend improvements. Data collected from July 10-12, 2023, during peak hours, indicated traffic volumes of 6369.5 PCU/h in the morning and 6275.5 PCU/h in the evening, demonstrating over-saturation. The analysis included 12 vehicular and 4 pedestrian directions, with peak hour factors of 0.942 and 0.954, respectively. Initial assessments of three lane configurations and signal phasing plans revealed all phase plans exceeded capacity, resulting in a Level of Service (LOS) 'F'. Subsequent evaluations involved geometric enhancements, such as adding lanes. Increasing lanes in the Eastbound Through, Northbound Right Turn, and Westbound Right Turn directions significantly improved performance, achieving LOS 'D' in the third iteration of Phase Plan I. Optimal signal timings were designed using the Webster method, resulting in cycle lengths of 123 seconds for the morning peak and 116 seconds for the evening peak.The study highlights critical challenges and proposes targeted measures to enhance traffic flow at Prithivi Chowk, offering valuable contributions to transportation engineering and urban planning in Nepal. These findings emphasize the need for systematic traffic management improvements to mitigate congestion and enhance intersection performance.

KEYWORDS- Signalized Intersection, Peak Hour, Saturation Flow, Capacity, Delay, Level of Service

I. INTRODUCTION

A. Background

Traffic congestion refers to a situation in which transport networks experience slower speeds, longer travel times, and increased vehicle queues due to a higher volume of traffic. The primary cause of congestion is the physical utilization of roads by vehicles, which slows down the flow of traffic when vehicle interactions become more frequent. Many transportation engineers believe that congestion is an inevitable and persistent problem, especially in developing countries where limited financial resources and restricted right of way exacerbate the issue.

Intersections, where two or more roads meet or cross at the same or different levels, play a significant role in causing congestion. These intersections are responsible for managing traffic conflicts and merging streams of vehicles to reduce or minimize delays. Geometric parameters typically govern and regulate the path of vehicles through intersections. Additionally, assessments can be conducted to determine the traffic flow and turning movements at selected intersections, thereby determining if the traffic exceeds the intersection's capacity. If the intersection operates comfortably below its capacity without experiencing overcapacity, traffic flows smoothly. However, if overcapacity occurs, travel time and delay must be considered in assessing the intersection's performance. Intersection delays pose a major challenge in congestion analysis.

Prithivi Chowk stands as a critical juncture within Pokhara, connecting various important routes. Understanding its operational dynamics and evaluating its level of service (LOS) is essential for urban planners, traffic engineers, and policymakers to make informed decisions regarding traffic management and infrastructure development. This study aims to assess the performance of the Prithivi Chowk signalized intersection in Pokhara, Nepal, by analyzing various parameters such as traffic flow, delay, and level of service.

B. Problem Statement and Objective of the Study

In Nepal, diverse vehicles share the same road space without segregation, resulting in significant urban traffic congestion. This problem is particularly severe at closely spaced intersections, intensifying congestion during peak hours. Researchers are working to quantify and mitigate this congestion and enhance traffic operations at urban intersections. In Pokhara, the rapid increase in vehicle density due to population growth and urbanization makes intersection improvements essential. Major intersections such as Prithivi Chowk, Sabhagriha Chowk, Zero KM, and Srijana Chowk experience severe traffic jams during peak times. Prithivi Chowk, a key transit point, requires alternative solutions for efficient and safe vehicle movement.

C. Objectives of the Study

The objectives of the study are

- To evaluate the operational performance of intersection using HCM.
- To signal design the intersection using Webster method.

D. Limitations of the Study

- There may have been some fluctuations in the traffic flow pattern due to the manual counting process.
- The Passenger Car Equivalent factors used referring to Nepal Road Standard.

II. LITERATURE REVIEW

Ranjitkar et al. (2014) compares the operational efficiency of three types of intersections: priority controlled, roundabout and signalized. The efficiency is measured by intersection capacity, average delay and total emissions and uses SIDRA software to model different traffic conditions with varying volume and turning ratios and finds that each intersection type has its own strengths and weaknesses depending on the traffic demand and suggests that priority controlled intersections are best for low demand, roundabouts are best for moderate demand and signalized intersections are best for high demand [1].
Pokhrel et al. (2023) assesses Jay Nepal Intersection's performance in Kathmandu's central business district. Utilizing SIDRA Intersection 8 software, it identifies oversaturation and poor service levels, particularly during peak hours. Implementation of left-turn control significantly reduces average delays, queue lengths, and improves overall intersection efficiency, surpassing other optimization strategies [2].
Tiwari et al. (2023) addresses traffic congestion at two critical intersections, Shital Nivas and Kanti Children's Hospital, in Kathmandu Valley, Nepal. Through surveying and simulation using SIDRA software, signal coordination strategies are evaluated. Results demonstrate significant reductions in average delay time and maximum queue length at both intersections. While this study focuses on two intersections, it highlights the efficacy of signal coordination in alleviating urban congestion network-wide [3].
Dhakal et al. (2023) studies signalized intersections in Satdobato, Lalitpur, Nepal, using micro simulation software 'SIDRA Intersection 8.0'. Evaluation reveals oversaturation, with all approaches exceeding capacity, leading to severe congestion. Peak traffic occurs during office hours, worsening congestion. Despite optimization efforts, the Level of Service remains poor (F), though signal timing adjustments reduce delays and queues. Controlling left-turn movements further improves intersection performance [4].
Bajracharyaa and Dhungelb, (2022), studies the operational efficiency of Keshar Mahal and Durbar Marg intersections in Kathmandu, Nepal, plagued by lengthy queues and delays. Using SIDRA Intersection software, various signalization strategies were simulated. Results favored pre timed signal coordination with an optimal network cycle, yielding a 33.4% reduction in total travel time, a 48.8% decrease in control delay, and notable improvements in intersection performance. Comparison with the existing network showcased its potential benefits in traffic flow and delay reduction [5].
Mistry et al. (2021) focuses on improving traffic operations and safety at the Kamrej intersection in Surat, India, using a micro simulation-based approach. Traffic management measures and geometric improvements are suggested to optimize the intersection's efficiency. Simulation using PTV-VISSIM software is used to assess the effectiveness of these strategies. The study finds that delays for straight and right movements can be significantly reduced, leading to improved traffic efficiency. Among the proposed measures, the most effective one includes a modified central island, free left turns, widening of a selected road, and a four-phase signal control, resulting in a substantial enhancement from the current LOS F to LOS C, as per national guidelines [6].
Acharya (2020) studies at New Baneshwor Intersection highlights the underutilization of microsimulation environments for assessing network safety, particularly in Nepalese contexts. Crash data reliability issues, time-consuming collection processes, and delayed implementation of solutions are noted. The study utilizes VISSIM and SSAM to predict conflicts at New Baneshwor Intersection. Result shows significant correlations between simulated and observed conflicts. High rear-end crashes are attributed to congestion and limited clearance times, with potential mitigation through scenario analysis for improved safety [7] [8].

III. METHODOLOGY

To obtain the LOS for Prithivi Chowk intersection this study will follow the methodology that describe in HCM [9]. Figure 1 shows the main steps that must be follow to obtain the LOS which is the primary output.

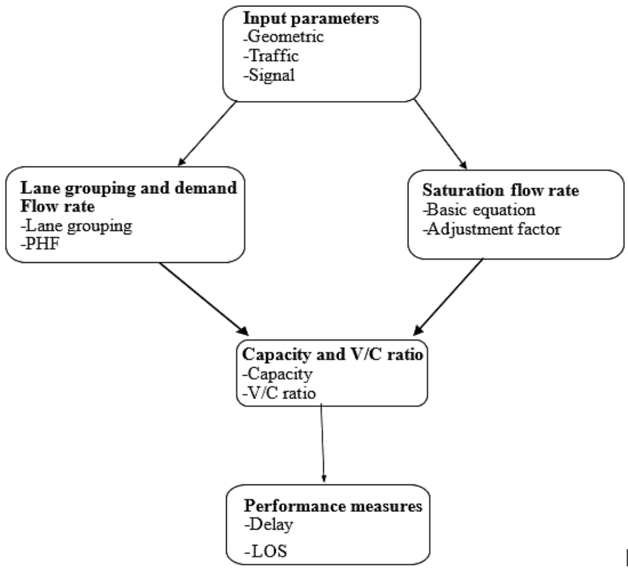

Figure 1: Flow Chart of Research Methodology

A. Study Location

Prithivi Chowk intersection, a busy signalized intersection located in the heart of Pokhara, Nepal is taken as the study area in this research study. It is a four legged intersection and the transit point of major destinations, interlinking of highways along with local routes. The current traffic management system at the intersection relies on manual control by traffic police personnel during peak hours. The intersection legs formed are:

- North-road towards Nayabazar (Nayabazar Leg, 13.5m)
- South-road towards Airport (Airport Leg, 18m)
- East-road towards Chinapul (Chinapul Leg, 23.5m)
- West-road towards Sabhagriha (Sabhagriha Leg, 18m)

The north, south and west legs are of four lanes and east leg is of six lane The location of the study intersection is shown in figure 2.

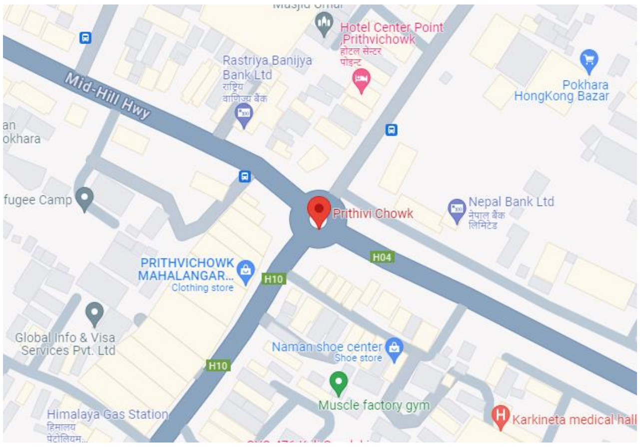

Figure 2: Prithivi Chowk Intersection

B. Data Collection

Data collection was done by installing video camera for 3 days in Prithivi Chowk intersection at each leg .Traffic data input includes classified traffic volume counts for various movements of intersection .Following data were collected in the field:

- Intersection geometry, including lane usage and link distances
- Existing Intersection Turning Movement Counts
- AM and PM peak hour observation (2 hours @ 15 minute interval) for three days
- Classified count of vehicles.
- Additional data (as required)

C. Passenger Car Unit (PCU)

The traffic in Nepal is heterogeneous with many different types of vehicles taking up different amounts of road space and having different operating capabilities. It is, therefore, necessary to adopt a standard traffic unit to which other types of vehicles may be related. Table 1 shows the PCU factors used for the observed vehicles in this research as per Nepal Road Standard [10].

Table 1: Passenger Car Unit (PCU) equivalent factor

Vehicle Classification	PCU
Heavy Vehicle	3
Truck/Tanker	3
Bus	3
Micro/Van	1
Car/Jeep/Taxi	1
Motorcycle/Bicycle	0.5

(Source: DOR,2070)

D. Analysis and Results

- ***Peak Hour Volume***

Classified traffic studies were conducted from 9:00 to 11:00 in the morning and from 4:00 to 6:00 in the evening for three days from Monday, July 10 to Wednesday, July 12, 2023 with the recorded traffic video footage of the intersection. A total of 12 vehicular movement directions with different types of vehicles including bicycle were observed at the intersection. In order to find out the total volume in PCU, the volume of each type of vehicles were multiplied with their respective PCU factors. The morning and evening peak hours were found out to be 9:45 - 10:45 and 4:00 - 5:00 respectively. The morning peak hour volumes of the intersection was 6361 PCU/h. Similarly, the evening peak hour volume of the intersection was 6275.5 PCU/h. Both the morning and evening peak hours was selected for the analysis of the performance evaluation of the intersection.

- ***Peak Hour factor***

The peak fifteen minute within the peak hour was identified in order to get the peak hour factor (PHF). The peak hour factor for morning is 0.949 and for evening is 0.954.

- ***Lane Grouping***

Lane grouping is the practice of dividing a road into separate lanes for different types of vehicles or directions of travel. In this study, we have separated road section into different types of lane group and left turn is always permitted. Table 2 shows the lane grouping of intersection.

Table 2: Lane Grouping

EBTH	East Bound Through	Sabhagriha to Chinapul
EBRT	East Bound Right Turn	Sabhagriha to Airport
WBTH	West Bound Through	Chinapul to Sabhagriha
WBRT	West Bound Right Turn	Chinapul to Nayabazar
NBTH	North Bound Through	Airport to Nayabazar
NBRT	North Bound Right Turn	Airport to Chinapul
SBTH	South Bound Through	Nayabazar to Airport
SBRT	South Bound Right Turn	Nayabazar to Sabhagriha

Saturation Flow rate

Saturation flow rate is considered as the flow in vehicles per hour that can be accommodated by the lane group assuming that the green phase were displayed 100% of the time.

Saturation flows are calculated using:

$$Su = \ SNfw\,fHfgfbfafLufLfRfLpfRp \quad \text{(Eq. 1)}$$

Where,

S = Base saturation flow rate per lane (pc/h/ln);
N = number of lanes in lane group;
fw = Adjustment factor for lane width;
fH = Adjustment factor for heavy vehicles in traffic stream;
fg = Adjustment factor for approach grade;
fb = Adjustment factor for blocking effect of local buses that stop within intersection area;
fa = Adjustment factor for area type;
$fL\,u$ = Adjustment factor for lane utilization;
fL = Adjustment factor for left turns in lane group;
fR = Adjustment factor for right turns in lane group;
fLp = Pedestrian adjustment factor for left-turn movements; &
fRp = pedestrian-bicycle adjustment factor for right-turn movements

Table 3: shows the saturation flow calculated using HCM.

Table 3: Saturation Flow

Movement	Morning Saturation Flow	Evening Saturation Flow
EBTH	3507.04	3513.904
WBTH	4583.22	4594.232
NBTH	3557.99	3550.015
SBTH	3220.38	3174.38
EBRT	1827.32	1811.333
WBRT	1709.36	1668.746
NBRT	1822.93	1860.543
SBRT	1572.86	1573.412

Lanewise Level of Service

For Morning Peak Hour (see the table 4)

Table 4: Sum of Critical Flow Ratio Morning (Phase Plan I)

Morning				
Phase Plan I				
Movement	Analysis Volume	Saturation Flow	V/S	(V/S) c
EBTH	1228.77	3507.04	0.350	0.350
WBTH	1116.77	4583.22	0.243	
NBTH	506.37	3557.99	0.142	
SBTH	421.44	3220.38	0.130	0.142
EBRT	287.69	1827.32	0.157	
WBRT	457.54	1709.36	0.267	0.268
NBRT	558.92	1822.93	0.306	
SBRT	343.42	1572.86	0.218	0.307
(V/S)c	**1.067**			
				1.067

While considering above mentioned phase plan, the sum of critical flow ratio is found to be greater than one i.e. the cycle length is obtained as negative value. Therefore, so as to obtain the sum of critical flow ratio less than one, we devise the phasing and consider another phase plan in Table 5 i.e. phase plan II as below:

Table 5: Sum of Critical Flow Ratio Morning (Phase Plan II)

Morning				
Phase Plan II				
Movement	Analysis Volume	Saturation Flow	V/S	(V/S) c
EBTH	1228.77	3507.04	0.35	0.35
EBRT	287.69	1827.32	0.157	
WBTH	1116.77	4583.22	0.243	0.267
WBRT	457.54	1709.36	0.267	
NBTH	506.37	3557.99	0.142	0.306
NBRT	558.92	1822.93	0.306	
SBTH	421.44	3220.38	0.13	0.218
SBRT	343.42	1572.86	0.218	
(V/S)c				**1.141**

While considering above mentioned phase plan, the sumof critical flow ratio is found to be greater than one i.e.the cycle length is obtained as negative value. Therefore, so as to obtain the sum of critical flow ratio less than one, we devise the phasing and consider another phase plan in Table 6 i.e. phase plan III as below:

Table 6: Sum of Critical Flow Ratio Morning (Phase Plan III)

Morning				
Phase Plan III				
Movement	Analysis Volume	Saturation Flow	V/S	(V/S) c
EBTH	1228.77	3507.04	0.35	0.35
NBRT	558.92	1822.93	0.306	
NBTH	506.37	3557.99	0.142	0.267
WBRT	457.54	1709.36	0.267	
WBTH	1116.77	4583.22	0.243	0.243
SBRT	343.42	1572.86	0.218	
SBTH	421.44	3220.38	0.13	0.157
EBRT	287.69	1827.32	0.157	
(V/S)c				**1.017**

In either combination of phase movements, the sum of critical flow ratio exceeds unit value i.e. vehicle in the road are greater than its capacity. For existing condition neither of the phase plan gets succeeded and LOS for all leg is 'F'.

So, now the phase plan is devised to get desired level of service D, this can be achieved hypothetically by increasing no of lanes in EBTH.

1ST ITERATION

Table 7 shows the LOS value after increment of lane (+1 lane) in EBTH

Table 7: LOS value after increment of lane

PHASE PLAN	**(V/S)c**	**Cycle length**	**Intersection Delay**	**LOS**
PHASE PLAN I	0.96	400	176.631	F
PHASE PLAN II	1.035	negative	-	F
PHASE PLAN III	0.973	593	253.77	F

Result: level of service becomes F. Now again new saturation flow rates are calculated for NBRT lane movement by increasing no of lane (+1 increment)

2nd ITERATION

Table 8 shows the LOS value after increment of lane (+1 lane) in EBTH and NBRT

Table 8: Results of 2nd Iteration

PHASE PLAN	**(V/S)c**	**Cycle length**	**Intersection Delay**	**LOS**
PHASE PLAN I	0.873	126	71.125	E
PHASE PLAN II	0.888	143	76.437	E
PHASE PLAN III	0.911	180	91.827	E

Result: level of service becomes E. So, to get a desired level of service D. Now again new saturation flow rates are calculated for WBRT lane movement by increasing no of lane (+1 increment).

3rd ITERATION

Table 9 shows the LOS value after increment of lane (+1 lane) in EBTH, NBRT and WBRT.

Table 9: Results of 3rd Iteration

PHASE PLAN	(V/S)c	Cycle length	Intersection Delay	LOS
PHASE PLAN I	0.763	68	48.416	D
PHASE PLAN II	0.864	118	66.95	E
PHASE PLAN III	0.786	75	50.296	D

Here desired level of service is achieved in Phase Plan I and Phase Plan III, when comparing there is low cycle length and intersection delay in Phase Plan I.

For Evening Peak Hour

For Phase Plan I

Sum of Critical Flow Ratio is found to be 0.991.We put this value in above phase plan. Table 9 contains the result of above phase plan. See below table 10.

Table 10: Result of Phase Plan I

(V/S)c	Cycle length	Intersection Delay	LOS
0.991	1778	714.553	F

While considering above mentioned phase plan, the sum of critical flow ratio is found to be near to one and cycle length and intersection delay is very high and level of service is F, we devise the phasing and consider another phase plan i.e. phase plan II as below:

For Phase Plan II

While considering above mentioned phase plan, the sum of critical flow ratio is found to be 1.048 which greater than one i.e. the cycle length is obtained as negative value. Therefore, so as to obtain the sum of critical flow ratio less than one, we devise the phasing and consider another phase plan i.e. phase plan III as below:

For Phase Plan III

Sum of Critical Flow Ratio is found to be 0.997. Table 11 is showing the result of above phase plan.

Table 11: Result of Phase Plan II

(V/S)c	Cycle length	Intersection Delay	LOS
0.997	5334	2686.693	F

In either combination of phase movements, the sum of critical flow ratio exceeds unit value or near to unit value i.e. vehicle in the road are greater than its capacity. For existing condition neither of the phase plan gets succeeded and LOS for all leg is ‘F’. So, now the phase plan is devised to get desired level of service D, this can be achieved hypothetically by increasing no of lanes.

In morning case we already increased lane of EBTH NBRT and WBRT .So, new saturation flow rates are calculated for EBTH NBRT and WBRT by increasing number of lane:

1ST ITERATION

We put this value in above phase plan and the result is (see table 12):

Table 12: Results for 1st Iteration (Evening)

PHASE PLAN	(V/S) c	Cycle length	Intersection Delay	LOS
PHASE PLAN I	0.750	64	47.42	D
PHASE PLAN II	0.817	87	63.396	F
PHASE PLAN III	0.777	314	144.506	F

IV. SIGNAL DESIGN

In both morning and evening cases, level of service D is achieved and low cycle length and intersection delay is achieved in phase plan I. Now, we design signal timing for this devised phasing using Webster method

For morning flow

Y= Sum of Y of all phases = 0.763
Loss per cycle (L) = (2+2)*4 = 16 sec
Cycle length (Co) = (1.5*L+5)/ (1-Y) = 123 sec
Green time per cycle= Co-L= 107 sec

For evening flow

Y= Sum of Y of all phases = 0.750
Loss per cycle (L) = (2+2)*4 = 16 sec
Cycle length (Co) = (1.5*L+5)/(1-Y)= 116 sec
Green time per cycle= Co-L= 100 sec

V. CONCLUSION AND RECOMMENDATION

The research evaluated the operational performance of the Prithivi Chowk intersection during peak hours and proposed improvements to enhance capacity and performance. Traffic studies, conducted from July 10 to July 12, 2023, recorded vehicular and pedestrian movements in 12 and 4 directions, respectively. Morning and evening peak volumes were 6369.5 PCU/h and 6275.5 PCU/h, indicating oversaturation. The Highway Capacity Manual (HCM) methodology showed that all initial lane configurations resulted in a Level of Service (LOS) of 'F'. Geometric improvements, including lane additions, ultimately achieved a desirable LOS of 'D' with optimal signal timings using the Webster method, reducing cycle lengths to 123 seconds (morning) and 116 seconds (evening).

A. Recommendation

It is recommended to improve the performance of intersection by increasing the number of lanes in the sabhagriha section and for the right turning of Airport and Chinapul. Parking and stopping of public vehicles should not be allowed within 75-100 meters from the stop line in the approach and exit lanes of each leg of the intersection to ensure efficient departures of vehicles from the intersection.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest

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