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Optimizing Performance at Signalized Intersection through Signal Optimization: A Case Study at Padmodaya Chowk, Putalisadak

Arbin Amgain[1], Satkrit Silwal[2], Nikshaya Karmacharya[3], Prashant Panthi[4], Dhiraj Bohara[5]

[1]*Lalitpur Engineering College, Department of Civil Engineering, Kathmandu, Nepal, arbin.amgain567@gmail.com*
[2]*Lalitpur Engineering College, Department of Civil Engineering, Kathmandu, Nepal, ssatkrit@gmail.com*
[3]*Lalitpur Engineering College, Department of Civil Engineering, Kathmandu, Nepal, Nikshaya999@gmail.com*
[4]*Lalitpur Engineering College, Department of Civil Engineering, Kathmandu, Nepal, panthiprashant789@gmail.com*
[5]*Lalitpur Engineering College, Department of Civil Engineering, Kathmandu, Nepal, dhirajbohara@lec.edu.np*

Abstract

Putalisadak is one of the busiest places in Kathmandu which faces severe traffic congestion during peak hours leading to prolonged delays, increased air pollution and heightened accident risks. It is a crucial hub connecting major roads to important areas through the three-legged intersection of Padmodaya Chowk. Data such as traffic volume, pedestrian volume and saturation flow were collected through video-graphic survey over 3 days in the morning peak hours and the evening peak hours. Other parameters such as cruise speed, back of queue length and intersection geometry were collected through field surveying in the site. PCU values were calculated through Indo HCM values. Indo HCM is a highway capacity manual of India that provides guidelines and methods unique to the conditions and requirements of the road network. The traffic volume was found to be much higher in the morning peak hour from 9:30 to 10:30 am than the evening peak hour. So, the data of morning peak hour was inputted in SIDRA Intersection 8 software along with other parameters by creating a base model each for both the intersections. The calibration and validation of the data obtained from the SIDRA software was done to get accurate results and verify of the data The existing conditions of the intersections were found by determining the average delay, queue length and level of service of the intersections and found to be sec average delay, 159.4m queue length. The existing level of service of the Padmodaya Chowk was found to be “D” using the Indo HCM values. So, the traffic signals of the intersection was optimized which led to almost no improvement in the overall LOS of the intersections but significant reduction in the average delay and queue length in the approaches of the intersection.

Keywords: Average Delay, Back of Queue (BOQ), Indo Highway Capacity Manual (Indo HCM), Level of Service (LOS), SIDRA

1. Introduction

Kathmandu, the capital city of Nepal, has experienced rapid urbanization and a significant increase in population over the past few decades. This growth has resulted in an escalating number of vehicles on the road, contributing to severe traffic congestion, particularly at major intersections due to a mismatch between the road capacity and the growing number of vehicles (Budathoki,2024). In the context of Nepal, roundabouts are a relatively recent introduction and are considered to be suitable to handle more number of cars with less delays but are preferred less than signalized intersections (Kunwar et al., 2025). Inadequate or inefficient traffic signal systems, often designed without considering peak-hour traffic patterns, degrade the situation (Nepali et.al, 2024). Many intersections in the city lack synchronized traffic signals, which leads to long waiting times for vehicles and pedestrians (Pokhrel et.al, 2024). This inefficiency contributes to the formation of traffic jams, causing delays and frustration for commuters. Reliable and properly maintained road infrastructure is essential for ensuring the smooth and efficient movement of traffic and the transportation of goods between locations (Shrestha et al., 2024). Additionally, unregulated parking, illegal lane-changing, and the presence of informal transport modes, such as motorcycles, bicycles, and rickshaws, further complicate the traffic scenario. The lack of public transportation options forces many people to rely on private vehicles, further worsening the congestion problem (Tiwari et.al, 2023). The public transportation system in the Kathmandu Valley is characterized by the absence of a clear timetable, poor interconnectivity, a lack of designated bus terminals, and inconsistent fare structures, therefore requiring optimization of available signals for smooth operation of through traffic at the intersection (Thapa et al., 2024).

Congestion knowledge can be utilized for optimizing transport networks, saving money and boosting efficiency in commercial and private travel. Traffic congestion is accountable for air pollution due to increased emissions from idling vehicles. Congestion can also lead to an increased chance of accidents as drivers become impatient or use unsafe tactics. A number of bike and ride sharing services have further increased the congestion within the valley(Chaudhary et al., 2024). With congestion and the causes of congestion known, measures can be put in place to improve traffic flow and reduce accidents. Signal optimization is the process by which time wasted in road traffic is reduced to a minimum by having the best possible signal timings. Signal optimization seeks to reduce delay and waiting time and give economical, effective traffic flow to all road users in a safe manner.

1.1 Research objectives

The main objective of this study is to evaluate the existing conditions of the Padmodaya Chowk and to optimize the signal timing of the intersections to decrease the average delay and queue length.

1.2 Literature review

Many studies and research articles of optimizing the performance of intersections have been published in the recent years. Most of these studies have used SIDRA software for the formulation of model and analysis.

Dhakal et al. (2023) conducted evaluation and performance enhancement of the four legged intersection of Satdobato using SIDRA Intersection 8.0 software where the existing LOS of the intersection was found to be F which was not changed by optimizing the signal but there was decrease in the average delay and BOQ.

Pokhrel et al. (2023) used SIDRA intersection software for the performance assessment of signalized Jay Nepal Intersection where it was determined that the intersection was over saturated and had a poor level of service (F) in both morning and evening peak hour which was improved to D by optimizing the cycle length and improved to C after using left turn controlled optimum cycle length.

Budathoki et al. (2024) carried out the assessment of operational performance of unsignalized intersection using microsimulation at the three legged intersection of Pepsicola where the existing condition LOS was found to be C with average total delay of 18.62 sec.

Maharjan et al. (2023) conducted performance evaluation and improvement of Thapathali intersection through SIDRA software to determine the intial LOS of the intersection to be E which was improved to LOS C with optimum cycle timing.

Tiwari et al. (2023) carried out a study for optimizing performance at signalized intersections through signal coordination in Shital Niwas intersection and Kanti Children’s Hospital intersection of Nepal where the average delay per vehicle and queue length was significantly decreased from the existing conditions with the use of optimum cycle length, optimum cycle with controlled left turn and coordinatng the signal timings. In this case, coordinating the signal timings was found to be the best alternative solution.

2. Methodology

2.1 Study area

The study area includes the 3-legged intersection of Padmodaya Chowk. Padmodaya Chowk connects the busy areas of Putalisadak, Pradarshani Marg (Fun Park) and Singhadurbar as shown in the figure.

Figure 1. Study Area

The methodology is described in the following flowchart:

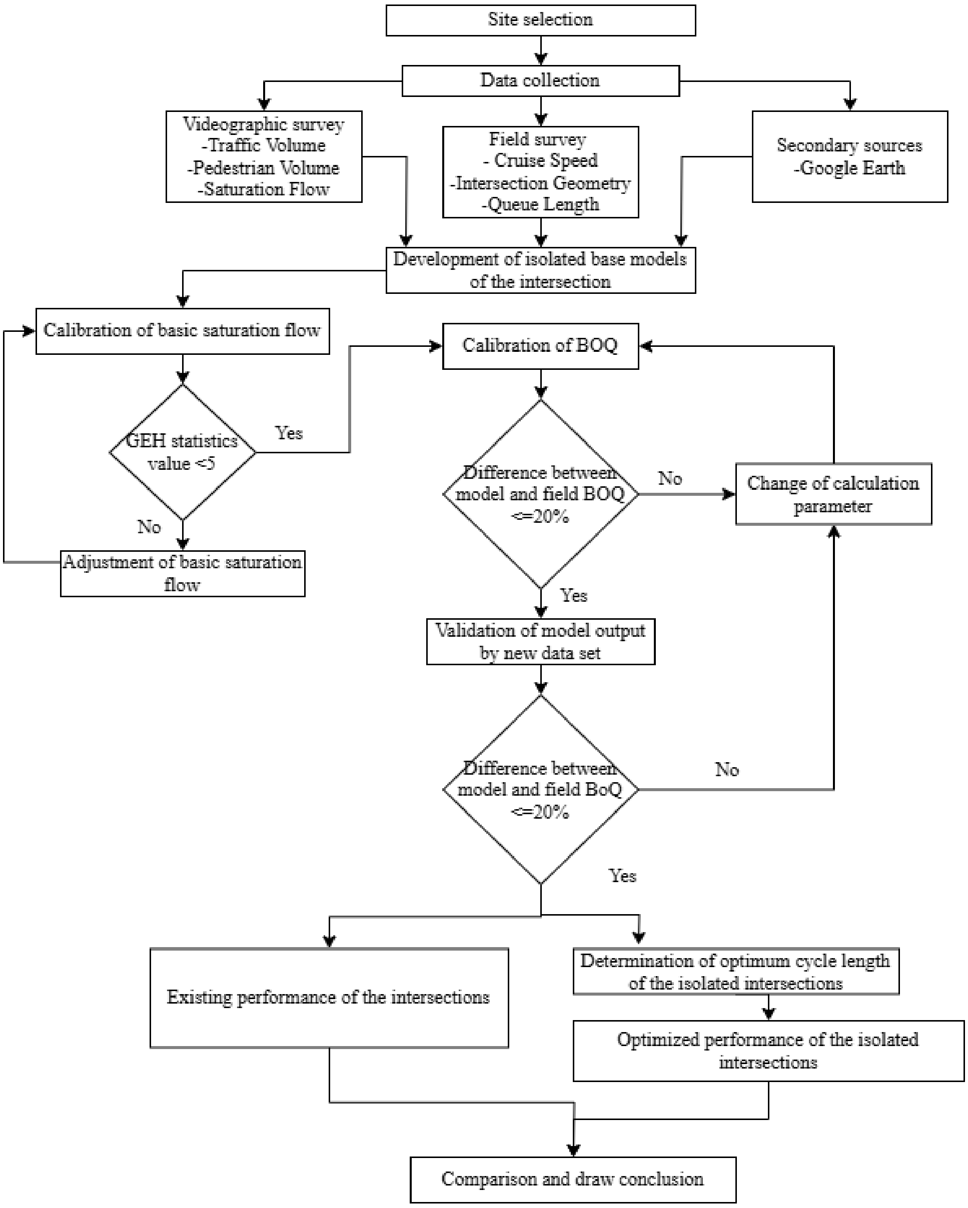

Figure 2. Methodological Framework

2.2 Data Collection

For traffic volume count, video cameras were installed to record the footage of traffic flow in the 3-legged intersection. The video was taken for morning and evening time for three days days (Tuesday, Wednesday and Thursday). The video was taken at two different times in a day – 9 AM to 11 AM in the morning and 4 PM to 6 PM in the evening. The vehicle counts were done by classifying the vehicles according to their types and finally converted into PCU values by multiplying the data with their PCU factors.

The geometry of the junctions such as width of lane, width of curb, approach width, approach distance, etc. were measured carefully with measuring tape and laser. Secondary sources like Google Maps and Google Earth were also used. The pedestrian volume count was also done through the recorded videos. The data of one day (Morning 9 am to 11 am and evening 4 pm to 6 pm) was manually collected.

The cruise speed of the approaches of the intersection were determined by conducting speed studies in the field over the course of 2 days. The speed of the vehicles approaching and exiting the Padmodaya Chowk in Putalisadak and Fun Park approaches in alternate 15 minute intervals were taken in Day 1 whereas the speed of the vehicles approaching and exiting the Padmodaya Chowk in Singhadurbar approach was taken in Day 2.

A total of 20 observations were made for the measurement of the BOQ at all three approaches in the Padmodaya Chowk in the morning peak hour period. In the context of civil and transportation engineering, particularly for field measurements related to traffic flow, intersection delay, and level of service, sample sizes ranging from 15 to 30 are commonly accepted to balance the trade-off between statistical reliability and logistical feasibility (Transportation Research Board [TRB], 2010). Previous studies have also employed similar sample sizes in empirical evaluations of intersection performance and operational characteristics, confirming the adequacy of this approach (Chien, Ding, & Wei, 2002; Board, 2010)

2.3 Construction of model in SIDRA

By inputting the parameters obtained from the data collection in the SIDRA software, the isolated base model of the intersection was prepared.

2.4 Calibration and Validation

Calibration of the data is needed to ensure that the simulation model reflects conditions in the real world. The base model was calibrated for saturation flow rate and back of queue collected for Day 1 and Day 2 through surveys and site observations. The calculated average BOQ of the model is within 20% of the field observed average BOQ, which is the range that (Florida Department of Transportation, 2021) recommends.

Validation of the model output is necessary to ensure that the modeling outputs match reality with regard to traffic condition. Outputs generated by the model for BOQ are compared with BOQ generated from the actual field, and if the difference was found to be within 20% (Florida Department of Transportation, 2021) recommends of the actual field data then the model was said to be validated; otherwise, it was recalibrated.

3. Results and Discussion

3.1 Traffic Volume

On the 21^{st}. 22^{nd} and 23^{th} July 2024 we conducted the intersection traffic study and from the recorded video we find 6 vehicle directions, and 8 types of vehicles. Traffic volume of different types of vehicles are given in the table below:

Table 1. Traffic Volume of different types of vehicles

Number of vehicles	Motorcycles	Cycle	Car	Three wheeler	Microbus	Bus	Heavy Truck	Light Truck
Putalisadak	12373	167	2725	466	30	111	4	8
Fun Park	2614	41	369	0	2	147	0	4
Singhadurbar	12873	66	2400	303	93	304	3	1

3.2 Existing Phase and Sequence

The cycle length during the morning peak hour is 92 seconds by using Indo HCM values and the corresponding phase sequence is shown in the table and figure below.

Table 2. Phase timing at Padmodaya Chowk

Phase	A	B
Phase Change Time	0	92
Green Time (sec)	86	52
Phase Time (sec)	92	58
Phase Split	61%	39%

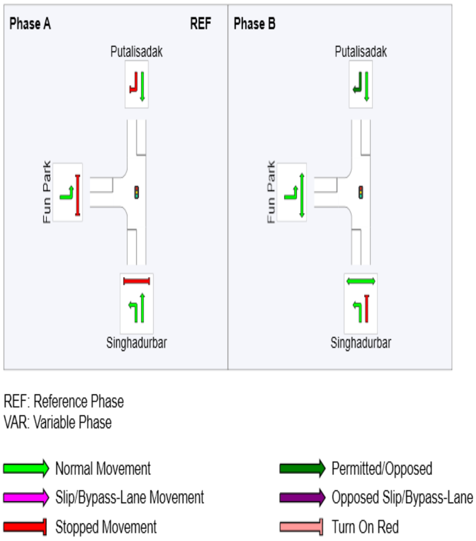

Figure 3. Phase pattern at Padmodaya Chowk

3.3 Calibration of Satutation Flow Rate

The saturation flow rate of the base model was calibrated using the calculation of GEH for the assessment of how well simulated results from a model match over and above observed traffic conditions. To better reflect the real intersection circumstances in the base models and match the saturation flow rate obtained in the field, it was calibrated locally. The results of local calibration of the basic saturation flow for various approach lanes at the intersections are compiled in Tables 3. In order to attain a result less than 5, as advised (Florida Department of Transportation, 2021) the accuracy of the calibration was evaluated using the Geoffrey E. Havers (GEH) statistic during the procedure. The SIDRA model was rerun with the basic saturation flow rate modified if the GEH statistic did not fall within the acceptable range.

Table 3: Calibration for basic saturation flow

Approach	Lane	Field Measured Saturation Flow Rate (veh/hour)	Model Estimated Saturation Flow Rate (veh/hour)	GEH Value	Adjusted Basic Saturation Flow (PCU/hour)
Fun Park	1	793	892	3.411	1575
	2	793	892	3.411	1575
Putalisadak	1	1380	1563	4.771	1890
	2	1377	1541	4.293	1890
	3	1377	1541	4.293	1890
Singhadurbar	1	1483	1594	2.829	1890
	2	1435	1583	3.809	1890

3.4 Calibration for Back of Queue

For the calibration of BOQ, the BOQ output from the model and the measured BOQ in field were compared and found to be within the difference of 20% (Florida Department of Transportation, 2021).

Table 4. Calibration of SIDRA base model for BOQ

Approach`	Average BOQ (m)		
	Model Estimated	Field Measured	Difference (%)
Putalisadak	45.2	52.48	16.11
Fun Park	0	0	0
Singhadurbar	159.4	185.22	19.34

3.5 Validation

The output of the model was tested using the third day traffic data to validated the model with a new data set. The difference between the models estimated average BoQ and the observed average BoQ of Day 3 must be within the acceptable limit of 20% range as per as FDOT (2021).

Table 5. Validation of SIDRA Base model

Approach	Average BOQ (m)		
	Model Estimated	Field Measured	Difference (%)
Putalisadak	67.8	58.52	13.68
Fun Park	0	0	0
Singhadurbar	181.73	168.52	7.27

3.6 Existing Performance

The existing performance indicates that the current level of service of Padmodaya Chowk is D. The average delay is 49.3 sec and the average queue length is 159.4 m. The detailed result is given below:

Table 6. Existing average delay and queue

Leg	Demand (veh/hour)	Avg Delay (sec)	Avg Back of Queue Distance (m)	LOS
Putalisadak	1676	48.9	45.2	D
Fun Park	326	3.4	0.7	A
Singhadurbar	1650	58.8	159.4	E

3.7 Performance evaluation after signal optimization

The signal timing was modified from the previous configuration to optimum cycle length for the improvement of operational performance of the intersection. Future studies should isolate and quantify the influence of each parameter to strengthen causal interpretations.

Table 7. Average delay and queue in optimum cycle length

Leg	Demand (veh/h)	Avg Delay (sec)	Avg Back of Queue Distance (m)	LOS
Putalisadak	1676	43.6	44.6	D
Fun Park	326	3.4	0.7	A

Leg	Demand (veh/h)	Avg Delay (sec)	Avg Back of Queue Distance (m)	LOS
Singhadurbar	1650	39.6	132.2	D

The ideal cycle timing for Padmodaya Chowk by Indo HCM is 90 seconds. The optimized performance indicates that the level of service of Padmodaya Chowk remains D. The average delay is improved to 40.1 sec and the average queue length is reduced to 132.2 m.

3.8 Comparison of the alternatives

The results obtained from analyzing SIDRA are compared for the intersection.

Table 8. Comparison of BOQ

1	Scenario	BOQ (m)
A	Existing	159.4
B	Optimized	132.2

The BoQ distance using optimized signal timing decreased from 159.4 m to 132.2 m in Padmodaya Chowk.

Table 9. Comparison of Average Delay

Option	Scenario	Average Delay (sec)
A	Existing	49.3
B	Optimized	40.1

The average delay using optimized signal timing decreased from 49.3 sec to 40.1 sec in Padmodaya Chowk.

4. Conclusion

This study is focused on the operational performance assessment of the signalized intersection of Padmodaya Chowk in Kathmandu, Nepal, by adopting Indo HCM values. The intersection model was constructed on SIDRA software with the data collected from video-graphic and field survey. The validation was conducted on queues for each approach of the intersection, comparing actual and modeled counts and the existing performance of intersection was evaluated. The existing level of service of the Padmodaya Chowk was found to be “D”.

When optimizing the signal timing in the intersections, there was no improvement in the LOS of the intersections due to its classification being based on broad threshold ranges given by Indo HCM (2017) within which the improved delay still falls under the same category. But there was significant reduction in the BOQ and average delay. Specifically, the average queue length decreased from 159.4 m to 132.2 m. Similarly, the average vehicle delay of Padmodaya Chowk decreased from 49.3 sec to 40.1 sec.

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