KEC Conference 2025

ISSN: 3021-940X (Print) DOI: https://doi.org/10.3126/injet.v2i2.78600

Enhancing Traffic Efficiency of Unsignalized Intersections Through Signal Coordination: A Case Study of Pulchowk and Sahidchowk in Bharatpur

Sandesh Acharya[1, *], Asmita Pokhrel[2], Hemant Tiwari[3]

[1]*Research Scholar, Society of Transport Engineers Nepal (SOTEN), acharyasandesh987@gmail.com*
[2]*Civil Engineer, Traffic & Transportation Unlimited Solution (TATUS), ashupokhrel02@gmail.com*
[3]*General Secretary, Society of Transport Engineers Nepal (SOTEN), hemu.ioe@gmail.com*

Abstract

The aim of this study is to improve the traffic flow at Pulchowk and Sahidchowk intersections in Bharatpur, Nepal through signal coordination and two alternatives were adopted optimizing the cycle time and optimised signal timing with left-turn control. Traffic counts during peak hours and geometric data were measured, and intersection performance was evaluated on the basis of Level of Service (LOS), average delay, and Back of Queue (BOQ) length. Among the two alternatives analyzed, left turn control showed the highest improvement. The average delays during the morning peak hour were cut from 113.8 seconds to 54.2 seconds in Pulchowk and from 76.6 seconds to 35.6 seconds in Sahidchowk, while the back-of-queue lengths shortened from 821.5 meters to 414.5 meters and from 364.9 meters to 178.5 meters, respectively. During the peak evening times, delays decreased from 507.2 seconds to 62.4 seconds in Pulchowk and from 318.1 seconds to 32.7 seconds in Sahidchowk, with corresponding drops in BOQ from 1345.9 meters to 328.3 meters and from 861.3 meters to 277 meters, respectively. These findings showcase the efficiency of the integrated approach in averting delays and congestion in the study intersections.

Keywords: Average delay, SIDRA, Back of queue, Signal Coordination, Unsignalized Intersection

1. Introduction

Road safety is a significant issue in Nepal, caused mainly by growing traffic congestion, poor infrastructure, and inadequate traffic control. The soaring rate of vehicle ownership has put tremendous pressure on the available road network, especially at intersections where several traffic streams meet. Urban intersections are particularly hotspots of congestion and crashes owing to overwhelming traffic volumes, insufficient signalization, and aggressive behavior of road users.

An intersection is a location where two or more roads cross or meet at the same level, providing for movement of pedestrians and vehicles from one road to another. One of the leading problems in any intersection is congestion, an additional time of delay. Delay time is the difference in travel time with and without traffic interference, and it has a direct effect on queue length (Brilon, 2008). Unnecessary delays can anger road users, cause loss of time, and reduce productivity. Traffic signals are extensively used at intersections with high traffic volume and are intended to manage traffic, reduce accidents, reduce delays, optimize road capacity, and calm traffic (Ali, et al., 2018).

In Nepal, most unsignalized intersections rely on traffic police officers to manage vehicle movement, especially during peak hours. Officers manage the traffic based on real-time conditions such as vehicle volume, congestion levels, and pedestrian flow. While this manual control can prevent long delays, often it is inconsistent, inefficient and prone to human error, factors such as fatigue, misjudgment and external conditions such as weather and emergencies can lead to uneven traffic flow and unpredictable delays. Additionally, solely reliance on traffic police limits the scalability of traffic management, as controlling multiple busy intersections simultaneously becomes challenging especially during the peak hours.

In most areas of Bharatpur, traffic in busy intersections is controlled manually by traffic police since signalized systems do not exist. Signal optimization is a scientific and systematic method of intersection

**Corresponding Author*

control. Traffic lights at signalized intersections regulate the sequence and timing of traffic movements to ensure smoother flow for both pedestrians and vehicles (Demir & Demir, 2020). A well-designed traffic signal system can control traffic dynamically according to real demand, with equitable distribution of green time to various approaches. In contrast to manual control, optimized signals run with precision and consistency, lessening stop-and-go situations, lowering delays, and improving overall traffic efficiency.

The primary goal of this study is to optimize signal coordination at two key intersections in Bharatpur, Shahid Chowk and Pulchowk to improve traffic flow and reduce delays. At present, these intersections are managed manually by traffic police, relying on real-time judgment to control vehicle movement. However, manual control often leads to inconsistent traffic flow, longer wait times, and inefficiencies during peak hours. This study aims to develop a coordinated signal system that ensures smoother traffic movement, minimizes delays, and enhances overall intersection performance.

This study has a few limitations. Traffic information was collected on specific days, which may not capture daily or seasonal variations. Additionally, pedestrians and non-motorized vehicles were not represented, as the analysis assumed consistent driver behavior. The absence of real-time signaling systems also limited the ability to simulate adaptive traffic control policies.

2. Literature Review

Various sources were consulted to understand the impact of signal optimization on intersection performance. Previous studies have explored traffic congestion issues, Level of Service (LOS) evaluation, and the effectiveness of SIDRA software in optimizing signal timings. These studies highlight how traffic delays, queue lengths, and service levels can be significantly improved through data-driven signal adjustments, leading to better traffic flow and reduced congestion in urban intersections. The following literature provides insights into past research and findings related to signal optimization and intersection efficiency.

In Nepal, a significant road safety concern arises from unregulated minor junctions along highways (Department of Roads, n.d.). In many developing countries, poorly designed road networks create small critical zones that frequently become congestion hotspots, where ineffective traffic management leads to prolonged traffic jams (Jain, et al., 2012). At intersections, heavy congestion during peak hours results in a substantial loss of productive time (Timalsena, et al., 2017). In urban areas, traffic management becomes challenging due to the presence of various categories of vehicles, each operating at different speeds and maneuvering capabilities. The variation in speed and vehicle behavior creates inconsistencies in traffic flow, making it difficult to maintain smooth movement and efficient signal coordination (Bista & Tiwari, 2024). A study conducted in India explored methods to mitigate traffic congestion and concluded that effective traffic management and control are among the most efficient solutions (Thakre & Pawade, 2024).

In Kathmandu Valley, Nepal, a study was conducted on signal coordination to improve traffic flow at Kanti Children's Hospital and Shital Niwas intersections using SIDRA software. Traffic data and geometric features were collected to develop and validate a signalized intersection model. The results showed that signal coordination significantly reduced delays and queues, with the average delay time dropping from 106s to 26.5s at Shital Niwas and 43.1s to 21.7s at Kanti Children's Hospital. Similarly, maximum queue lengths were reduced from 744.7m to 122m and 456.2m to 147.7m, respectively, highlighting the effectiveness of signal optimization (Tiwari, et al., 2023).

Another study was conducted to evaluate the impact of traffic signal coordination on the level of service (LOS) at four intersections—two with four legs and two with three legs—along with two roundabouts in Kuala Lumpur and Petaling Jaya using SIDRA software version 4.0. The study analyzed traffic performance parameters such as delay, queue, journey time, and speed, comparing results between morning and evening peak hours. The findings revealed that delay was significantly reduced after optimization, with an average reduction from 3489 sec to 1571 sec in the morning and from 5093 sec to 1663 sec in the evening, achieving a 45% and 33% reduction, respectively (Ali, et al., 2015).

Signalized intersections play a crucial role in managing urban traffic by regulating vehicle flow and pedestrian movement. In Konya, Turkey, the Kule and Nalçacı–Sille intersections were analyzed using SIDRA

Intersection 5.1 to optimize cycle times and enhance traffic efficiency. The study applied both Australian methods and American HCM (Highway Capacity Manual) methods, comparing existing and optimized signal timings. The findings revealed that both methods yielded similar results, with optimized cycle times significantly reducing delays and increasing capacity, demonstrating the impact of effective signal timing adjustments (Akmaz & Çelik, 2016).

At the Gaa-Akanbi intersection in Ilorin, Nigeria, researchers aimed to improve traffic conditions by conducting a comprehensive traffic volume survey along with an intersection geometry assessment. The collected data was analyzed using SIDRA Intersection software, leading to the development of a three-phase signal system designed to achieve a Level of Service (LOS) D. The recommended cycle length was 150 seconds, with green light durations set at 48 seconds for phase 1, 46 seconds for phase 2, and 38 seconds for phase 3, while each phase included a 2-second amber time (Adelek, et al., 2023).

A study in Al-Bayda assessed four signalized intersections using SIDRA software to analyze traffic flow and Level of Service (LOS) during peak hours. The findings revealed high delays and poor LOS (F to D), highlighting the need for improvements. After implementing optimized signal timings, LOS improved to B and D, significantly reducing average delay times by 32.3% to 44.3% in the morning and 45.8% to 69.5% in the evening, demonstrating the effectiveness of signal optimization in mitigating congestion (Ahmida, et al., 2023).

In Satdobato, a research was conducted to analyze the performance of a signalized intersection using SIDRA Intersection 8.0 to assess congestion and traffic flow parameters. The model was calibrated and validated using field data, and intersection performance was evaluated based on LOS, delay, and queue length. Various signal optimization strategies, including cycle length adjustments, timing splits, and left-turn control, were implemented to improve efficiency. The study provided recommendations based on system performance after optimization, highlighting the benefits of data-driven signal adjustments in reducing congestion (Dhakal, et al., 2023). Similarly, another study in Birgunj focused on improving traffic flow at Buspark Junction, a key intersection connecting the Indian border to the East-West Highway was conducted. Using SIDRA Intersection 8.0, researchers developed and validated a traffic model based on 72-hour volume data and geometric characteristics. The study explored two optimization strategies: adjusting cycle lengths and controlling left-turn movements under signal timing. As a result, the LOS improved from E to D, with reductions in average delay (34.7% and 38.8%) and back of queue length (34.7% and 40%), demonstrating the effectiveness of signal optimization in reducing congestion (Luitel, et al., 2023).

3. Study Area

Pulchowk Intersection

The Pulchowk intersection, a critical junction along the East-West (E-W) Highway, features four lanes with bus stops, a 9-meter-wide footpath, motorcycle parking, and green buffer zones. Two-meter-wide medians divide the lanes, but unmanaged taxi and three-wheeler parking contribute to congestion. Serving as a key link to Gaindakot (NW), the Main Road (NE), Sahid Chowk (SE), and New Road (SW), it faces bottlenecks due to the E-W Highway converging onto the narrow Narayani Bridge and access from two smaller roads, creating multiple conflict points. Managed manually by traffic police, the intersection experiences heavy through and right-turning traffic, leading to delays and operational challenges.

Sahidchowk Intersection

Sahidchowk is a key intersection with access through medians and designated lanes, linking the East-West (E-W) Highway, Pragati Path (a major trade center), and Belchowk (another commercial hub). During peak hours, it experiences heavy traffic, with the E-W Highway links carrying the highest volumes. Frequent roadside parking along the north-south link and on the wide footpaths near the E-W Highway further impact traffic flow, making it a crucial node for both vehicular movement and commercial activities in Bharatpur. The location of the two intersections is shown in Figure 1.

Figure 1. Study Area

4. Methodology

The methodological framework followed for the study is shown in Figure 2.

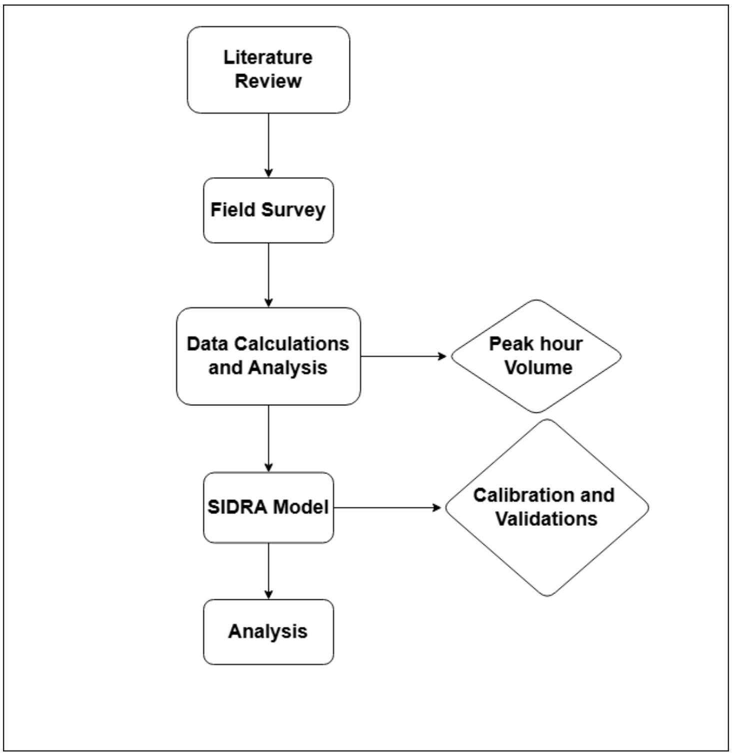

Figure 2. Methodological framework

Literature Review

We reviewed various studies on traffic congestion, intersection design and signal optimization, especially from Nepal. The review demonstrated the common causes of traffic congestion and the effective measures which we can take to minimize the problem. The objective was to develop the methodology and to collect necessary field data and to calibrate the data and create the SIDRA model to optimize the traffic flow.

Field Survey

Directional traffic volume statistics were collected over a period of 72 hours, measured at 15-minute intervals. Cameras were placed at intersections to record vehicular movement, while four trained persons manually analyzed the recorded video to classify traffic volumes. Data were averaged over three days and calibrated through the use of vehicle-type equivalency factors (Table 1) to determine peak hour volumes and directional flows. Additionally, field observations recorded the lane geometry,approach features, and queue lengths during peak hours for validation of the models.

Table 1. PCU equivalency factor

S. No.	Vehicle Type	PCU Equivalency Factor
1	Multi-axle Truck	4
2	Heavy Truck	3
3	Light Truck	1.5
4	Big Bus	3
5	Mini Bus	2.5
6	Microbus	1.5
7	Car	1
8	Motorcycle	0.5
9	Utility Vehicles	1
10	4 Wheel Drive	1
11	Tractor	1.5
12	3 Wheeler	1
13	Power Tiller	1.5

(Source: (Government of Nepal, n.d.))

Data Calculations and Analysis

Field data were initially arranged to satisfy the input demands of SIDRA Intersection 8, thereby enhancing the precision and uniformity of the modeling procedure. A detailed model was subsequently established from field measurements, with the inclusion of required parameters like lane geometry, approach types, and traffic control devices. In order to evaluate traffic differences, vehicles were classified into various types according to their PCU equivalency rates. Peak periods were defined separately for morning (6 AM – 12 PM) and evening (3 PM – 10 PM) time frames according to traffic volume patterns to accurately reflect the times of greatest congestion. For each peak period, traffic volumes, vehicle compositions, and movement distributions (through, left-turn, right-turn) were analyzed to determine critical traffic conditions and evaluate capacity, delay, and Level of Service (LOS) metrics in SIDRA.

SIDRA Model

Following data formatting, each intersection was first optimized separately in the SIDRA system to establish its then-current efficiency of operation. Then, a network-based optimization method was applied to consider the joint performance of the two intersections to enable coordination of traffic more effectively. By considering the interaction of traffic streams between intersections, this technique sought to maximize overall efficiency, reduce delays, and provide a more even distribution of traffic volumes throughout the network.

Calibrations and Validations

The field data were checked for validation to ensure accuracy in the simulation model. Calibration involved selecting appropriate model parameters to closely replicate local traffic conditions observed in the field. The calibration was done based on the Table 2. This process aimed to minimize discrepancies between real-world traffic behavior and model predictions (Hollander & Liu, 2008).

The calibration and validation of the model were performed using queue length data. The queue lengths obtained from the field were compared with those generated by the SIDRA model to assess accuracy. To maintain reliability, the error margin between the observed and simulated queue lengths was required to be within 20%, which is shown in Table 3.

Table 2. Calibrating Parameters

Parameter	Value/Condition	Notes
Base Saturation Flow	2500 veh/hr	Determined from on-site measurements
Lane Utilization Ratio	Program calculated	Based on software computation
Saturation Speed	Program calculated	Computed within the program
Capacity Adjustment	0%	No adjustments applied
Buses Stopping	0 veh/hr	No bus bays within 75 meters
Parking Maneuvers	0 veh/hr	No parking lane present

Table 3. Validation result for SIDRA model

Time	Model	Observed	Difference
Morning	364.9	431	18.11%
Evening	861.3	719	16.52%

5. Performance of Network at Morning Peak hour

Alternative I: Optimizing the Cycle Time

The cycle time was optimized by optimizing the phase split and cycle time while keeping other conditions constant. The cycle time is 110 seconds for the morning peak time. The performance analysis using the optimum cycle lengths for morning peak hour for both intersections is shown in Table 4.

Table 4. Performance of Intersection at Morning peak hour after Alternative-I

Pulchowk Intersection	Demand Flows Total veh/h	Average Delay sec	Level of Service	Dist m	Sahid Chowk Intersection	Demand Flows Total veh/h	Average Delay sec	Level of Service	Dist m
SouthEast: Sahid Gate					SouthEast: Chaubiskothi				
Lane 1	455	40.7	LOS D	156.9	Lane 1	169	63.7	LOS E	52
Lane 2	445	59.8	LOS E	162	Lane 2	674	48.5	LOS D	226.2
Lane 3	237	71.3	LOS E	127.5	Lane 3	120	55.1	LOS E	31.9
Approach	1137	54.6	LOS D	162	Approach	963	52	LOS D	226.2
NorthEast: Narayangadh Muglin Highway					NorthEast: Milan Road				
Lane 1	883	214.9	LOS F	821.5	Lane 1	755	116.4	LOS F	364.9
Approach	883	214.9	LOS F	821.5	Approach	755	116.4	LOS F	364.9
NorthWest: Mahendra Highway (Narayani River Bridge)					NorthWest: Pulchowk				
Lane 1	687	52.8	LOS D	236.9	Lane 1	644	30	LOS C	151.4
Lane 2	639	53.5	LOS D	212.5	Lane 2	554	20.8	LOS C	118.7
Lane 3	229	51.8	LOS D	70.4	Lane 3	283	162.4	LOS F	177.4
Approach	1556	52.9	LOS D	236.9	Approach	1481	51.9	LOS D	177.4
SouthWest: New Road					SouthWest: Belchowk				
Lane 1	866	196.8	LOS F	655.4	Lane 1	638	120.8	LOS F	331.6
Approach	866	196.8	LOS F	655.4	Approach	638	120.8	LOS F	331.6

Intersection	**4442**	**113.8**	**LOS F**	**821.5**	**Intersection**	**3837**	**76.6**	**LOS E**	**364.9**

Alternative II: Optimizing Signal Timing with Left Control

After optimizing with left control, the LOS of both Intersections improved, LOS F to LOS D for Pulchowk intersection and LOS E to LOS D for Sahid Chowk. Similarly, Average Delay was also decreased. The network optimum cycle time with minimum delay was 100 seconds for morning peak with left control. The detail performance analysis after left controlled for morning peak hour is shown in Table 5. The phase timing for the intersections is shown in Table 6 and phase diagram are shown in Figure 3 and Figure 4 for Pulchowk and Sahidchowk respectively.

Table 5. Performance of Network at morning peak hour after Alternative-II

Pulchowk Intersection	Demand Flows Total veh/h	Average Delay sec	Level of Service	Dist m	**Sahid Chowk Intersection**	Demand Flows Total veh/h	Average Delay sec	Level of Service	Dist m
SouthEast: Sahid Gate					SouthEast: Chaubiskothi				
Lane 1	455	46.8	LOS D	146.9	Lane 1	166	51.7	LOS D	43.7
Lane 2	445	50.6	LOS D	143.4	Lane 2	677	34.5	LOS C	178.5
Lane 3	237	73.3	LOS E	118.3	Lane 3	120	41.5	LOS D	25.8
Approach	1137	53.8	LOS D	146.9	Approach	963	38.3	LOS D	178.5
NorthEast: Narayangadh Muglin Highway					NorthEast: Milan Road				
Lane 1	883	49.1	LOS D	414.5	Lane 1	755	39.6	LOS D	175.6
Approach	883	49.1	LOS D	414.5	Approach	755	39.6	LOS D	175.6
NorthWest: Mahendra Highway (Narayani River Bridge)					NorthWest: Pulchowk				
Lane 1	687	41.8	LOS D	195.7	Lane 1	644	32.6	LOS C	152.4
Lane 2	639	42.6	LOS D	177.8	Lane 2	554	15.3	LOS B	94.3
Lane 3	229	45.9	LOS D	62.4	Lane 3	283	38.7	LOS D	86.7
Approach	1556	42.7	LOS D	195.7	Approach	1481	27.3	LOS C	152.4
SouthWest: New Road					SouthWest: Belchowk				
Lane 1	866	80.7	LOS F	388.9	Lane 1	638	46.2	LOS D	169.4
Approach	866	80.7	LOS F	388.9	Approach	638	46.2	LOS D	169.4
Intersection	**4442**	**54.2**	**LOS D**	**414.5**	**Intersection**	**3837**	**35.6**	**LOS D**	**178.5**

Table 6. Phase Timing for morning peak hour after Alternative-II

Pulchowk Intersection					**Sahid Chowk Intersection**				
Phase	**A**	**B**	**C**	**D**	Phase	**A**	**B**	**C**	**D**
Phase Change Time (sec)	35	58	83	5	Phase Change Time (sec)	0	26	44	69
Green Time (sec)	20	22	19	27	Green Time (sec)	23	15	22	28
Phase Time (sec)	23	25	22	30	Phase Time (sec)	26	18	25	31
Phase Split	23%	25%	22%	30%	Phase Split	26%	18%	25%	31%

Figure 3:Phase diagram for morning peak hour for Pulchowk after Alternative-II

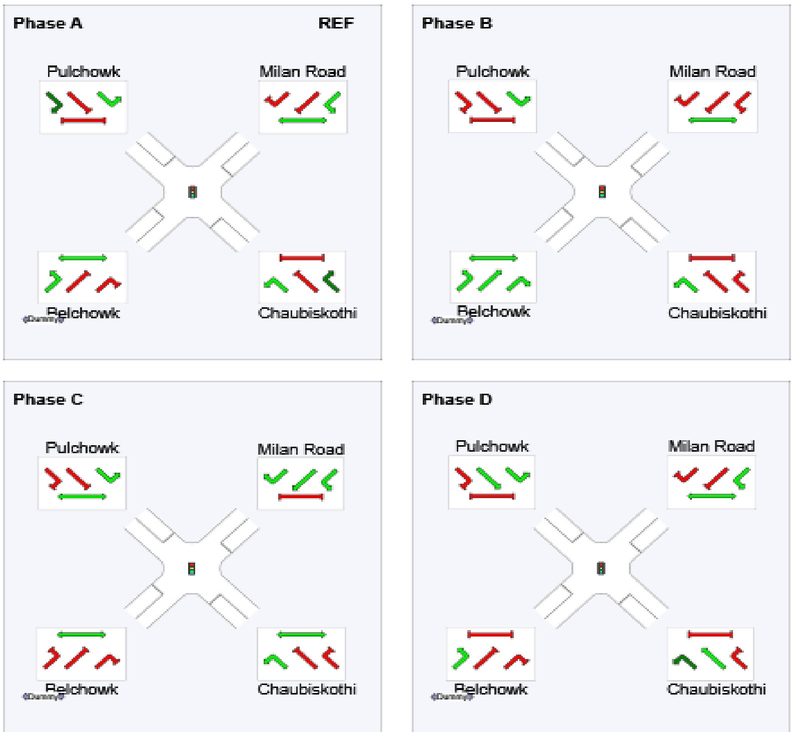

Figure 4:Phase diagram for morning peak hour for Sahidchowk after Alternative-II

6. Performance of Network at Evening Peak time

Alternative I: Optimizing the Cycle Time

After optimizing for optimum cycle time, the cycle length was 120 seconds for evening peak time for both intersections. Also, Level of Service for both intersections was obtained at Level F even after optimizing the cycle time, so another alternative i.e optimization with left control was carried out to improve the LOS. The detailed performance analysis after optimization for both intersections is shown in Table 7.

Table 7. Performance of Intersection at Evening Peak hour after Alternative-I

Pulchowk Intersection	Demand Flows Total veh/h	Average Delay sec	Level of Service	Dist m	**Sahid Chowk Intersection**	Demand Flows Total veh/h	Average Delay sec	Level of Service	Dist m
SouthEast: Sahid Gate					SouthEast: Chaubiskothi				
Lane 1	639	51.9	LOS D	149.1	Lane 1	918	396.7	LOS F	856.5
Lane 2	621	61.2	LOS E	154.1	Lane 2	718	398.1	LOS F	739.6
Lane 3	180	66.7	LOS E	42.3	Lane 3	244	134.2	LOS F	117.9
Approach	1440	57.8	LOS E	154.1	Approach	1880	363.1	LOS F	856.5
NorthEast: Narayangadh Muglin Highway					NorthEast: Milan Road				
Lane 1	1348	882.3	LOS F	1179.3	Lane 1	1032	311.8	LOS F	861.3
Approach	1348	882.3	LOS F	2179.3	Approach	1032	311.8	LOS F	861.3
NorthWest: Mahendra Highway (Narayani River Bridge)					NorthWest: Pulchowk				
Lane 1	835	797.2	LOS F	1345.9	Lane 1	1244	343.9	LOS F	500
Lane 2	592	797.5	LOS F	877.8	Lane 2	947	329	LOS F	500
Lane 3	232	226.1	LOS F	203	Lane 3	637	19.2	LOS B	65.1
Approach	1659	717.6	LOS F	1345.9	Approach	2827	262.3	LOS F	500
SouthWest: New Road					SouthWest: Belchowk				
Lane 1	918	52	LOS D	287.6	Lane 1	907	365.8	LOS F	790
Approach	918	52	LOS D	287.6	Approach	907	365.8	LOS F	790
Intersection	**5365**	**507.2**	**LOS F**	**1345.9**	**Intersection**	**6646**	**318.1**	**LOS F**	**861.3**

Alternative II: Optimizing Signal Timing with Left Control

After implementing left-turn control, the Level of Service (LOS) at both intersections improved for evening peak hour, with Pulchowk Intersection improving from LOS F to LOS E and Sahid Chowk from LOS F to LOS C. Likewise, the average delay was also reduced. The optimal network cycle time with minimal delay for the evening peak hour, considering left-turn control, was determined to be 90 seconds. A detailed performance analysis after applying left-turn control during the evening peak hour is presented in Table 8. The phase timings for the intersections are provided in Table 9.

Table 8. Performance of Intersection at evening peak hour after Alternative-II

Pulchowk Intersection	Demand Flows Total veh/h	Average Delay sec	Level of Service	Dist m	Sahid Chowk Intersection	Demand Flows Total veh/h	Average Delay sec	Level of Service	Dist m
SouthEast: Sahid Gate					SouthEast: Chaubiskothi				
Lane 1	654	43.5	LOS D	176.3	Lane 1	911	28.8	LOS C	172.8
Lane 2	606	44.2	LOS D	166	Lane 2	725	29.3	LOS C	159.4
Lane 3	180	54.9	LOS D	49.3	Lane 3	244	44.3	LOS D	53.7
Approach	1440	45.2	LOS D	176.3	Approach	1880	31	LOS C	172.8
NorthEast: Narayangadh Muglin Highway					NorthEast: Milan Road				
Lane 1	1348	105.3	LOS F	328.3	Lane 1	1032	42.4	LOS D	241
Approach	1348	105.3	LOS F	628.3	Approach	1032	42.4	LOS D	241
NorthWest: Mahendra Highway (Narayani River Bridge)					NorthWest: Pulchowk				
Lane 1	718	36.9	LOS D	195.3	Lane 1	1237	33.5	LOS C	277

Lane 2	709	37.7	LOS D	182.8	Lane 2	954	21.3	LOS C	220.4
Lane 3	232	169.2	LOS F	153.8	Lane 3	637	20	LOS C	69.7
Approach	1659	55.7	LOS E	195.3	Approach	2827	26.3	LOS C	277
SouthWest: New Road					SouthWest: Belchowk				
Lane 1	918	38.4	LOS D	208.6	Lane 1	907	44.8	LOS D	212.2
Approach	918	38.4	LOS D	208.6	Approach	907	44.8	LOS D	212.2
Intersection	**5365**	**62.4**	**LOS E**	**328.3**	**Intersection**	**6646**	**32.7**	**LOS C**	**277**

Table 9. Phase timing at evening peak hour after Alternative-II

Pulchowk Intersection					**Sahid Chowk Intersection**				
Phase	**A**	**B**	**C**	**D**	Phase	**A**	**B**	**C**	**D**
Phase Change Time (sec)	57	80	13	44	Phase Change Time (sec)	0	30	51	69
Green Time (sec)	20	20	28	10	Green Time (sec)	27	18	15	18
Phase Time (sec)	23	23	31	13	Phase Time (sec)	30	21	18	21
Phase Split	26%	26%	34%	14%	Phase Split	33%	23%	20%	23%

7. Comparison of Alternative Measures Performances

The performance changes were accessed by comparing the Level of Service(LOS), delay time (Figure 5) and Back of Queue(BOQ) length (Figure 6). During the morning peak hours, the average delay was 113.8 sec for Pulchowk and 76.6 sec for Sahidchowk for optimum cycle time, which drastically decreased to 54.2 sec for Pulchowk and 35.6 sec for Sahidchowk after left control. Similarly, 95% BOQ length for optimum cycle was 821.5m for Pulchowk and 364.9m for Sahidchowk and after left control it decreased to 414.5m for Pulchowk and 178.5m for Sahidchowk.

During evening peak hours, average delay for Pulchowk was reduced from 507.2 sec to 62.4 sec after left control and similarly from 318.1 sec to 32.7 sec for Sahidchowk. Regarding BOQ, it also decreased dramatically from 1345.9m to 328.3m for Pulchowk and 861.3m to 277m for Sahidchowk.

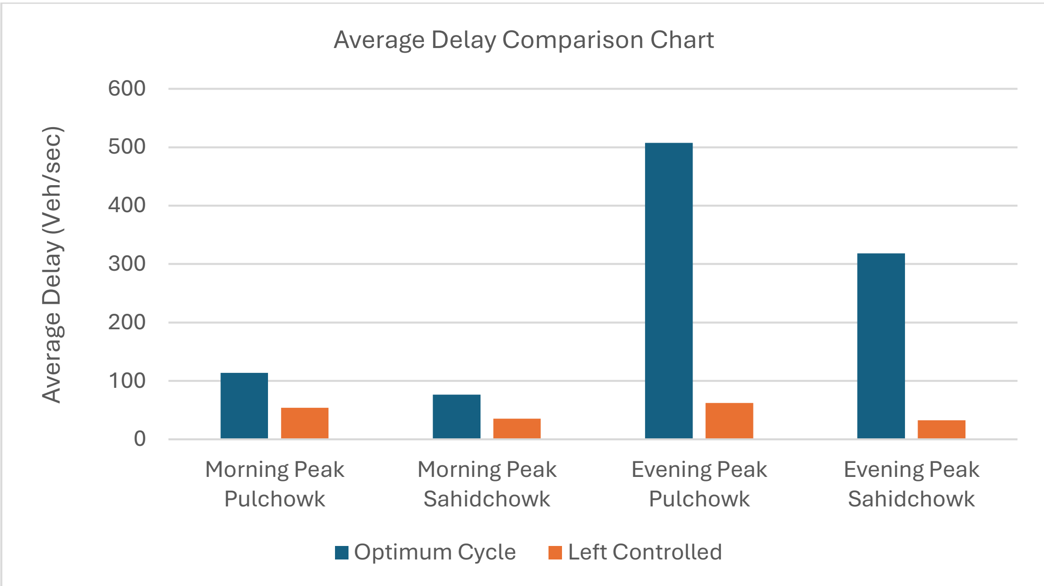

Figure 5. Average Delay Comparison Chart

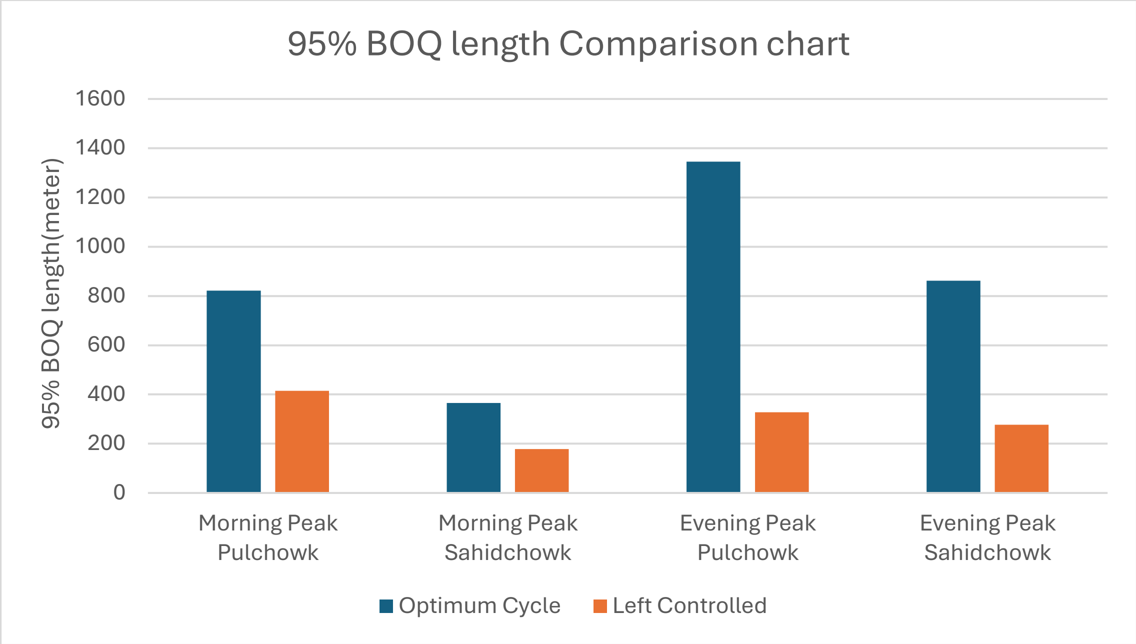

Figure 6. 95% BOQ Comparison Chart

8. Conclusion

Both Intersections, Pulchowk and Sahidchowk are an unsignalized intersections operated solely manually by traffic police. This study evaluated two improvement alternatives: optimizing the signal cycle length and implementing the left turn control. Both approaches contributed to reducing delays and queue lengths, with the alternative II being more effective. The findings emphasize that operational improvements can significantly enhance intersection efficiency without requiring costly infrastructure investments.

Given the widespread inefficiencies at many intersections in Nepal, exploring such operational alternatives is crucial. Implementing these improvements can help reduce delays, queues, fuel consumption and pollution while enhancing overall traffic safety and economic benefits.

Acknowledgement

The authors sincerely acknowledge Traffic & Transport Unlimited Solution (TATUS) for providing secondary data, including traffic counts and geometric measurements collected during peak hours, which were essential for the successful completion of this study. Additionally, we extend our heartfelt appreciation to Subash Dhungel, Chairman of TATUS for his guidance and support.

References

Adelek, O. O. et al. (2023). Improving Traffic Flow in Emerging Cities: A SIDRAIntersection Based Traffic Signal Design. *Periodica Polytechnica Transportation Engineering*, 51(2), pp. 166-171.

Ahmida, W. et al. (2023). Performance Evaluation and Improvement of Main Road Intersections in Al-Bayda City Using Sidra Software. *American Journal of Engineering and Applied Sciences*, 16(1), pp. 23-28.

Akmaz, M. M. and Çelik, O. N. (2016). Examination of Signalized Intersections According to Australian and HCM (Highway Capacity Manual) Methods Using Sidra Intersection Software. *Journal of Civil Engineering and Architecture*, 10(2), pp. 246-259.

Ali, S. I. a. et al. (2015). Evaluating the Performance of Traffic Flow in Four Intersections and Two Roundabouts in Petaling Jaya and Kuala Lumpur Using Sidra 4.0 Software. *Jurnal Teknologi*, 72(4), pp. 1-5.

Ali, S. I. A., Reşatoğlua, R. and Tozan, H. (2018). Evaluation and Analysis of Traffic Flow at Signalized Intersections in Nicosia Usingof SIDRA 5 Software. *Jurnal Kejuruteraan*, 30(2), pp. 171-178.

Bista, T. C. and Tiwari, H. (2024). Assessment of Stratified Speed Characteristics and Compliance with Posted Speed Limit in an Urban Area: A Case Study of Section of Karnali Highway, Nepal. *International Journal on Engineering Technology,* 2(1), pp. 187-194.

Brilon, W. (2008). Delay at Unsignalized Intersections. *Journal of the Transportation Research Board,* Issue 2071, pp. 98-108.

Demir, H. G.and Demir, Y. K. (2020). A Comparison of Traffic Flow Performance of Roundabouts and Signalized Intersections: A Case Study in Nigde. *The Open Transportation Journal,* 14(1), pp. 120-132.

Department of Roads, n.d. *Nepal Road Standard 2070.* [Online]
[Accessed 2070].

Dhakal, K., Tiwari, H. and Luitel, S. (2023). Evaluation and Performance Enhancement of four Legged Intersection: Satdobato, Nepal. *Journal of Advanced Research in Construction and Urban Architecture,* 8(1), pp. 23-30.

Government of Nepal, n.d. *Highway Management Information System (HMIS) UNIT.* [Online]
Hollander, Y. and Liu, R. (2008). The principles of calibrating traffic microsimulation models. *Transportation*, Volume 35, pp. 347-362.

Jain, V., Sharma, A. and Subramanian, L. (2012). *Road traffic congestion in the developing world.* Atlanta, s.n.

Luitel, S. et al (2023). Evaluation of Operational Performance of Intersection and Optimizing Signal Timing: A Case Study of the Buspark Intersection in Birgunj Metropolitan. *Journal of Advanced Research in Civil and Environmental Engineering,* 10(2), pp. 22-33.

Thakre, Y. K. and Pawade, P. Y. (2024). Traffic Congestion at Urban Road - Review. *IOP Conference Series: Earth andEnvironmental Science.*

Timalsena, A. P., Marsani, A. and Tiwari, H. (2017). *Impact of Traffic Bottleneck on Urban Road: A Case Study of Maitighar-Tinkune Road Section.* kathmandu, s.n.

Tiwari, H., Luitel, S. and Pokhrel, A. (2023). Optimizing Performance at Signalized Intersections through Signal Coordination in Two Intersections of Nepal. *Journal of Transportation Systems,* 8(1), pp. 22-32.

.