Journal of Advanced College of Engineering and Management

Evaluation of Operational Performance of Intersection And Optimization of Signal Timing: A Case Study of Mangalgadhi Chowk, Surkhet

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DOI: 10.3126/jacem.v11i1.84538

Abstract
Surkhet is one of the growing cities in Nepal. The growth in urbanization often results in the growth of traffic congestion along the city. This paper presents a comprehensive evaluation of the operational performance of the Mangalgadhi intersection, Surkhet through SIDRA Intersection 8 software. The analysis focuses on comparing existing traffic conditions with proposed improvements under a left-controlled scenario and signal optimization. Key performance indicators such as Back of Queue (BOQ), level of Service (LOS), and average vehicle delay were analysed across four critical time intervals. The analysis showed that the intersection was functioning with significant delays, queue lengths and poor LOS. Out of two alternatives, left-turn controlled reduced the BOQ up to 39% making it effective measure for improvement of intersection.

Keywords— *SIDRA Intersection, Traffic Delay, Back of Queue, Intersection Performance*

1. INTRODUCTION

Traffic congestion is often observed on the growing city with the increased number of vehicular traffic. After the introduction of federalism in Nepal, Birendranagar (Surkhet), which is the capital city of Karnali province, is facing rapid urbanization in recent years [1]. The rapid urbanization suggests that there might be growth in the number of vehicles and this study compares the existing situation of the major intersection of Surkhet. Long queue, causes travel delays and drives frustration. Such type long of congestion not only reduces mobility but also increase safety concerns. This also reduces the productivity of people travelling [2].

In any road network, intersections are the critical nodes where traffic streams converge and limited space is available for smooth flow of traffic. Effective intersection management includes better signal timing to avoid travel delays due to longer queue. The "stop and go" phenomenon of traffic burns more fuel and emit more Co2 then during smooth traffic flow [3]. Inappropriate signal timing can also reduce safety by increasing the accident rates. When intersections are not planned well, they often lead to more traffic jams and a higher chance of accidents. In short, poorly timed traffic signals can cause longer delays, increase pollution and make crowded intersections more dangerous.

SIDRA intersection 8.0 software is used in this study to analyze and improve intersection performance. SIDRA is a micro-analytical tool widely used in traffic engineering which stimulates intersection operations and computes key performance metrics such as Level of Service (LOS), average delay per vehicle, queue lengths and intersection capacity [4]. SIDRA can predict current delays and identify optimum timing plans by modelling the existing traffic volumes and signal phasing which is applied to Mangalgadhi chowk intersection. SIDRA software is able to estimate delays and back of queue positions which has made SIDRA suitable for evaluation of different signal timing strategies under real traffic conditions.

2. RESEARCH OBJECTIVE AND SCOPE

The objective of this study is to evaluate the current traffic situation at Mangalgadhi chowk, which is one of the busiest intersections in Surkhet. As urbanization has grown, traffic congestion, delays and safety issues has become more concerning [5]. So, this study proposes optimized signal timing strategies using SIDRA intersection 8.0 and improve the overall Level of service (LOS) by enhancing traffic flow and safety at the most critical intersection of Surkhet.

3. STUDY AREA

Mangalgadhi chowk is a prominent four-legged intersection located in the center of Birendranager, Surkhet which is the capital of Karnali province. As Surkhet is experiencing rapid urbanization, Mangalgadhi intersection is facing sharp rise in traffic volumes which comprises the mix of private vehicles, public transport and pedestrians. This intersection connects several key city routes and is close to government offices, schools and commercial areas which causes movement of more than thousand people through the intersection every day. Currently, the intersection is facing issues of frequent congestion, long vehicle queues and unmanaged turning movements specially during peak hours. Due to its importance and growing traffic demands, Mangalgadhi chowk was selected for this study to evaluate its current performance and explore solutions through signal timing optimization using SIDRA Intersection 8.0.

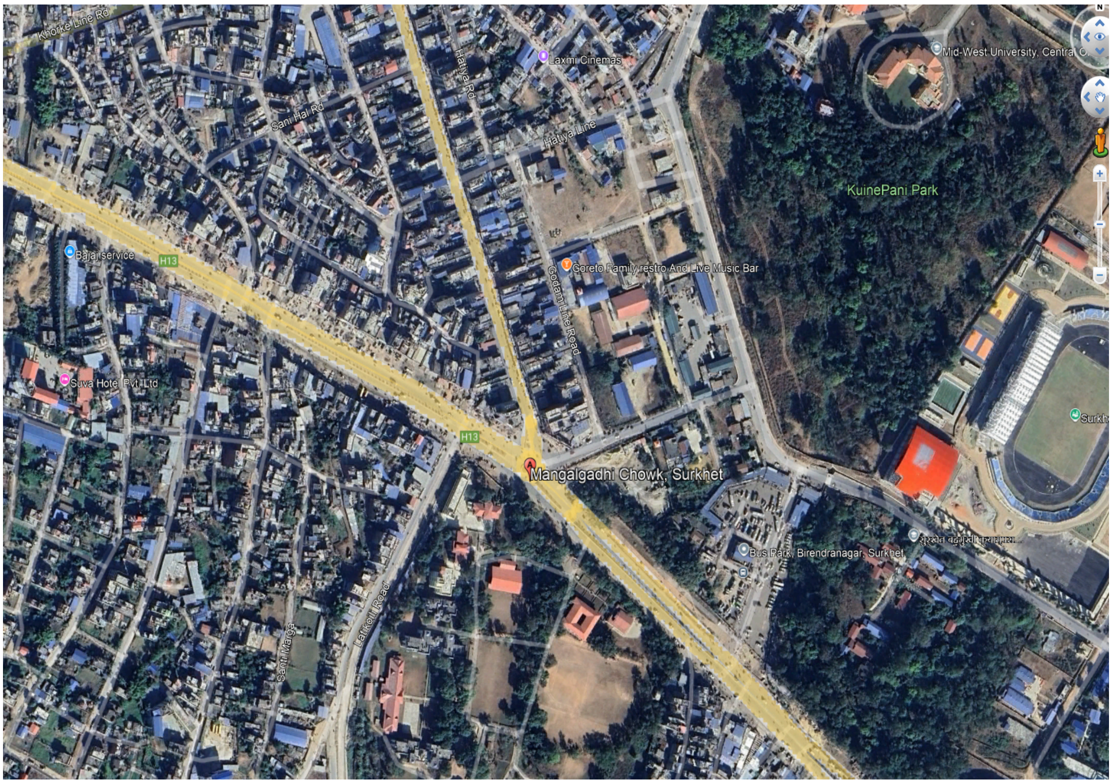

Figure 1: Study Area

4. LITERATURE REVIEW

Intersections of cities serve as critical nodes in the road network. Their operation efficiency plays important role in the overall performance of the transportation network. Increase in vehicle ownership in developing cities has caused traffic congestion, delays and safety issues. Researches in traffic engineering shows that by the use of SIDRA intersection software intersection can be evaluated whole over the world [6, 7, 8] and in Nepal as well [9, 10] .

A study conducted in Bahir Dar City, Ethiopia used SIDRA intersection software to analyze and evaluate the signalized intersection. They were evaluated on queue length, average delay and signal phasing was observed as a major factor. The existing intersection was seen in better performance by replacing it with roundabouts. Phase time adjustments along with intersection replacement with roundabouts were analyzed with significant enhancements in average delay, queue length, and overall Level of service [8]. The study on the Gaa-Akanbi intersection in Ilorin, Nigeria, highlighted increasing necessity for traffic control in growing urban areas. Based on detailed traffic volume counts and geometric surveys, the researchers studied the intersection performance and proposed a three phase signal operation of 150 second cycle. In the optimization of signal timing in the reduction of delays and flows, through SIDRA. These recommendations, if adopted by the respective local traffic agencies, would go a long way in improving safety and efficiency at unsignalized intersections in the territory [6].

In Nepal as well the use of SIDRA intersection 8.0 is very popular. Traffic modeling in Nepal has challenges peculiar to its heterogeneous types of traffic and non-standardized driving behaviors. A study found that a highway capacity would be overestimated using the default VISSIM parameters-that had to be calibrated for local conditions [5]. Similarly using SIDRA as well, calibration of the observed data is necessary. The signalized junction at Jay Nepal Hall in Kathmandu's central business district was studied to analyze its traffic performance through SIDRA Intersection 8.0. The model was calibrated and validated from the field and key performance indicators were measured for evaluation at the intersection level such as average delay, queue length and LOS. Two optimization alternatives were tested, adjustment of cycle lengths (Alternative I) and control of continuous left-turn movements under signal timing (Alternative II). It was found via results that Alternative II was able to significantly reduce delays and improve both LOS and queue lengths thus, emphasizing the effectiveness of signal timing optimization through SIDRA [11]. For severe congestion in the Kathmandu Valley, an evaluation was made at two busy intersections, i.e Kanti Children's Hospital and Shital Niwas, using the SIDRA software for intersections. Traffic volumes and geometric data were collected through field surveys during peak periods which were used for developing and validating the signalized intersection model. Several improvement alternatives, including signal coordination, were checked. The findings delineated a drop in average delay and maximum queue length. At Shital Nivas, the average delay was reduced from 106 to 26.5 seconds with a reduction in queue length from 744.7 to 122 meters, respectively, whereas, at Kanti Children's Hospital, delay reduced from 43.1 to 21.7 seconds and queue length reduced from 456.2 to 147.7 meters demonstrating the efficacy of signal coordination through SIDRA modeling [12]. A study analyzed the Satdobato intersection of Lalitpur using SIDRA intersection 8.0. The study emphasized on the impact of optimized signal cycle length and left turn control on performance indicators like LOS, average delay and queue length. The proposed improvements could reduce congestion and improve LOS from F to C during peak hours [9]. In Surkhet very limited studies related to traffic has been conducted. The speed survey study conducted on Karnali Highway (NH58) in Surkhet district analyzed speed characteristic across different vehicle types with the help of manual data collection during off-peak hours. The research revealed that despite posted speed limits ranging between 20 to 40 km/h, vehicle speed especially for two-wheelers, cars and utility vehicles averaged between 30 to 40 km/h [13].

To sum up, existing literature shows that tools like SIDRA Intersection 8.0 can improve the efficiency of the congested junctions. These findings provide a strong foundation for using similar approaches at Mangalgadhi chowk in Surkhet, where effective traffic management has become crucial due to rapid urbanization as a provincial capital.

5. METHODOLOGY

The methodological steps followed for the study is presented in the Figure 2 below.

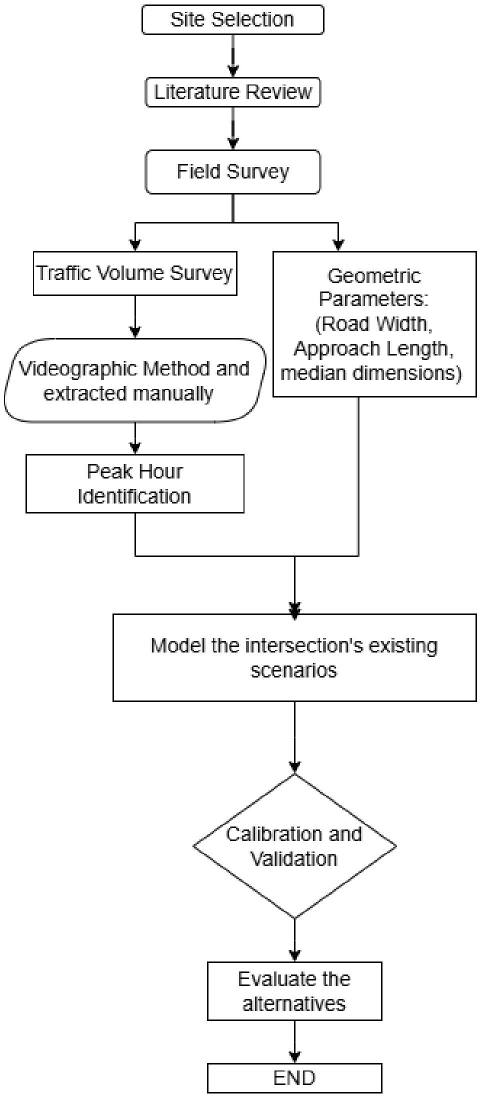

Figure 2: Methodological Flowchart

Various literatures were reviewed and site was selected for the analysis. For the analysis traffic volume survey is one of the crucial factors that impact the study. Hence, traffic volume survey was conducted for three days. It was done using a videographic camera for recording the traffic volume and was extracted manually by the experienced personnel. The traffic volume survey was conducted for three consecutive working days. The vehicles were categorized as per the vehicle type provided by Department of Roads (DOR) in Nepal. The data extracted was used to identify the peak hour for morning, evening, afternoon and night and the volumes was used for the analysis of each. Similar, geometric parameters such as road width, approach length, queue length and other parameters required by the SIDRA intersection 8 software was noted from the field.

Sidra Intersection 8 software was then used to analyses the best operation model for the Mangalgadhi Intersection. The intersection was modelled using the parameters obtained from the field and traffic volume. The model was calibrated using saturated flow values and validated using the 98th percentile BOQ obtained from field and model. After this, various scenarios were evaluated for best model in the intersection.

6. ANALYSIS

6.1 Existing Scenarios:

It is a four-legged intersection with Bazar on North, Campus Road on East, Ari Chowk on South West and Buspark on North East. The Bazar and Campus Road has two lanes of 4.5m width each while, Arichowk and Buspark has four lanes in total with two lanes on each direction of 4m lane width each and a central island of 2m The layout of the intersection is shown in Figure 3.

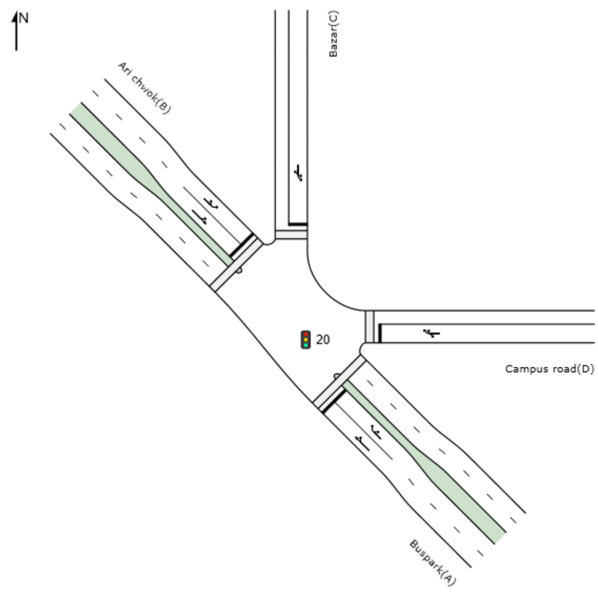

Figure 3: Intersection Layout

6.2 Traffic Flow Analysis:

For the traffic flow analysis, Vehicles were categorized as per DOR and was taken for 15 min interval as recommended by HCM 2010 [14]. The data was taken for 72 hours for the analysis and the volumes were converted into Passenger Car Units (PCU). Then, the peak hour was identified for four times of the day; morning, afternoon, evening and night. The 24 hours were divided such that for morning 8AM-12PM, afternoon 12PM-4PM, evening 4PM-8PM and night 8PM-8AM was considered for the study. It was found that night peak hours were 7:00 AM -8:00 AM, morning peak was from 8:30AM-9:30PM, afternoon peak was 15:00-16:00and evening peak hour was 16:00-17:00. The composition of motorcycles was dominant in the volume

6.3 Existing Performance:

The intersection was analyzed for different peak hour periods utilizing SIDRA Intersection 8.0 software. From the table 1, the total demand flow ranged from 2,501 veh/h to 3,497 veh/h. The highest degree of saturation was seen between 15:00 and 16:00 (0.887) which really implied capacity conditions. The average delay per vehicle ranged between 26.9 and 41.3 seconds wherein the highest delay was noted during the afternoon peak 15:00-16:00).

The LOS in the intersection was mostly LOS D which stood for stable and almost unstable flow, with the exception of 16:00-17:00 where a comparatively better LOS C was manifested. The longest queue of the 95th percentile occurred in the morning peak (8:30-9:30) and reached 494.4 meters as shown in *Figure 4*.

Table 1: Existing performance of the intersection

Time	Demand Flow (veh/h)	Degree of Saturation (v/c)	Avg Delay (sec)	LOS
7:00–8:00	2,501	0.879	36	D
8:30–9:30	3,497	0.732	36.1	D
15:00–16:00	3,002	0.887	41.3	D
16:00–17:00	3,389	0.858	26.9	C

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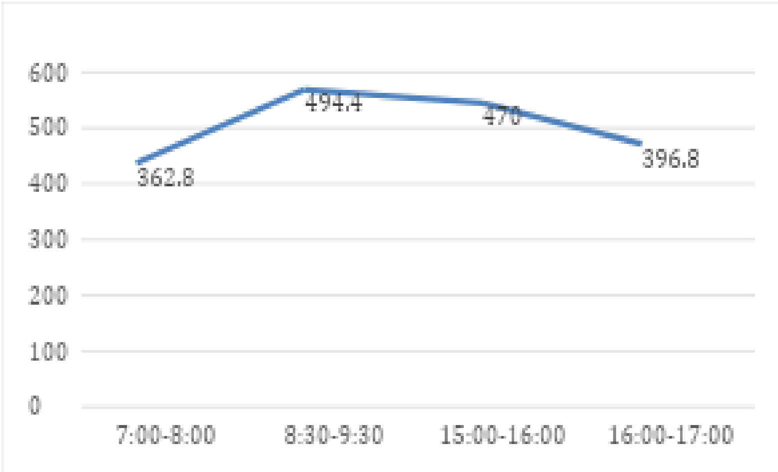

Figure 4: Peak Hours BOQ

6.4 Calibration and Validation of SIDRA model:

The model was calibrated using the saturated flow observed on the field as shown in table 2. The observed data and the obtained data from the software was compared and adjusted accordingly. However, no significant differences were found.

Table 2: Calibration of Model

Parameters	Value	Remarks
Base Saturation Flow	2350	Field measurement by videographic method
Lane Utilization Ratio	Program	Program Calculated
Saturation Speed		Program Calculated
Capacity Adjustment	0%	No Capacity Adjustments
Signals		
Buses Stopping	0veh/hr	No bus bays within 75m
Parking Manoeuvres	0veh/hr	No Parking Lane

6.5 Validation of Model:

It can be observed that the difference between the modeled and the observed BOQ from then field was between the 20% for all the peak hours [15]. Which validated the usability of the software. Details are present in table 3.

Table 3: Validation of model from BOQ

Approach	Time	Modelled BOQ (m)	Observed BOQ(m) from Field	Difference (%)
SouthEast: Buspark(A)	7:00–8:00	216.3	200.3	7.40
	8:30–9:30	346.1	282	18.52
	15:00–16:00	330.1	279	15.48
	16:00–17:00	219.1	198.5	9.40
East: Campus road(D)	7:00–8:00	179	164	8.38
	8:30–9:30	282	254.5	9.75
	15:00–16:00	253.2	241.4	4.66
	16:00–17:00	190.8	156.4	18.03
North: Bazar(C)	7:00–8:00	362.8	345.6	4.74
	8:30–9:30	494.4	412	16.67
	15:00–16:00	470	453.4	3.53
	16:00–17:00	396.8	389	1.97
NorthWest: Ari chwok(B)	7:00–8:00	241.1	232.3	3.65
	8:30–9:30	455.8	450.3	1.21
	15:00–16:00	394.6	315.7	19.99
	16:00–17:00	331.2	325.6	1.69

6.6 Alternatives Suggested:

A. Optimizing the cycle time:

The Mangalgadhi intersection was operated by traffic police and the cycle timing was decided by them. The manual traffic signal used by traffic police was taken as the existing cycle. The cycle time was then optimized using the SIDRA intersection. It can be seen that for all the peak hours the BOQ has decreased than the existing condition. The LOS which changed from D to C for 7:00-8:00 and 15:00-16:00 and increased form C to D on 16:00-17:00. However, the 98th Percentile BOQ has decreased from 362.8 to 304.2 in 7:00-8:00, 494.4 to 362.8 on 8:00-9:00, 470 to 337.5 on 15:00-16:00 and 396.8 to 369.8 on 16:00-17:00. There was reduction in cycle time at all the peak hours as shown in Figure 5.

Table 4: Sample of optimized cycle time result from the software for 7:00-8:00

Lane Use and Performance						
	Demand Flows	Deg.	Average	Level of	95% Back of Queue	
	Total	Satn	Delay	Service	Veh	Dist
	veh/h	v/c	sec			m
SouthEast: Buspark(A)						
Lane 1	470	0.172	0.5	LOS A	1.8	22.3
Lane 2	407	0.858	43.5	LOS D	19.8	236.4
Approach	877	0.858	20.5	LOS C	19.8	236.4
East: Campus road(D)						
Lane 1	331	0.495	37.7	LOS D	12.4	156.6
Approach	331	0.495	37.7	LOS D	12.4	156.6
North: Bazar(C)						
Lane 1	577	0.791	44.3	LOS D	24.7	304.8
Approach	577	0.791	44.3	LOS D	24.7	304.8
NorthWest: Ari chwok(B)						
Lane 1	285	0.103	36.3	LOS D	10.3	143
Lane 2	432	0.629	37.6	LOS D	17.6	212.7
Approach	717	0.629	37.1	LOS D	17.6	212.7
Intersection	2501	0.858	33	LOS C	24.7	304.8

Table 5: Results for different peak hours after optimizing the cycle time

Time	Degree of Saturation (v/c)	Avg Delay (sec)	LOS	98% Queue (m)
7:00–8:00	0.858	33	C	304.8
8:30–9:30	0.879	36	D	362.8
15:00–16:00	0.999	34.5	C	337.5
16:00–17:00	1.177	40.4	D	369.8

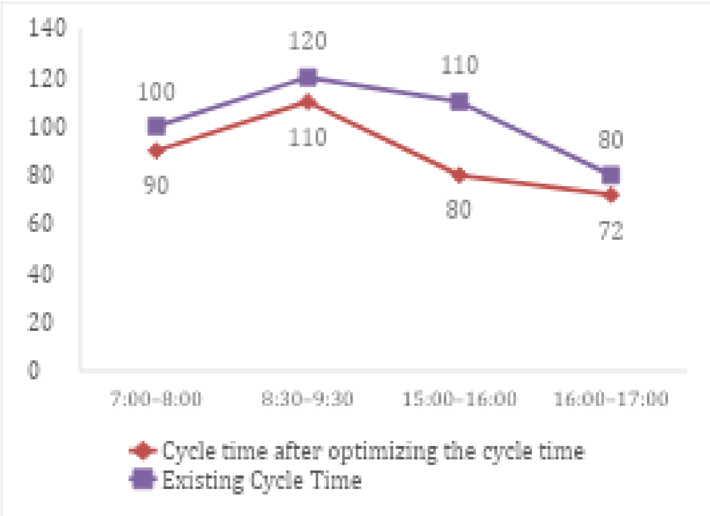

Figure 5: Cycle Time differences

B. Left Turn Controlled:

The left-turn movement is free at all the approaches at the intersection. For this approach, left turn is also obstructed and controlled for vehicle movement. The LOS of the intersection at all the peak hours was found to be 'C'. The degree of saturation (DOS) is less than 1 for all the peak hours which indicates the good performance of the intersection from this approach. The 98th Percentile BOQ has decreased from 362.8 to 228.1 in 7:00-8:00, 494.4 to 355.2 on 8:00-9:00, 470 to 288.4 on 15:00-16:00 and 396.8 to 283.2 on 16:00-17:00. The average delay per vehicle at the intersection was not greater than 35 sec for any duration. The details can be seen from Table 6.The phase diagram forms this analysis is shown in Figure 6 as a sample for morning peak hour. The overall cycle time for morning peak hour is 89 sec and all the remaining peak hour is 72 secs.

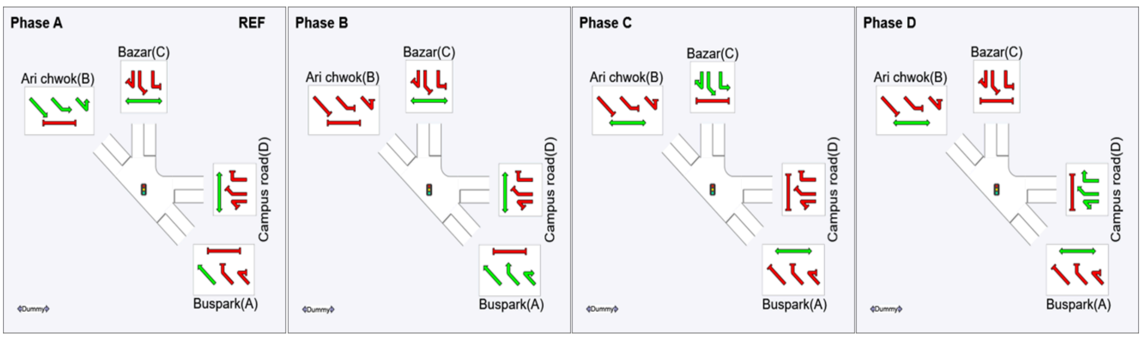

Figure 6: Phase diagram for morning peak hour

Table 6: Results for different peak hours after left turn control

Time	Degree of Saturation (v/c)	Avg Delay (sec)	LOS	98% Queue (m)
7:00–8:00	0.637	27.8	C	228.1
8:30–9:30	0.826	32.3	C	355.2
15:00–16:00	0.71	28.1	C	288.4
16:00–17:00	0.78	25	C	283.2

7. RESULTS:

7.1 Queue Length:

Among the two alternatives, it was found that while both of them reduced the overall BOQ on the intersection, controlling the left turn movement at all the intersection reduces the BOQ most. There was 37%, 28%, 39%, 29% reduction in BOQ while controlling the left turning movement, at 7:00-8:00, 8:00-9:00, 15:00-16:00 and 16:00-17:00 respectively as compared to the existing condition. The reduction in the BOQ can also be seen if compared the BOQ in Optimum cycle time (Alternative I) and Left turn controlled (Alternative II). 25%, 2%, 15% and 23% reduction can be seen for the respective time period from Left turn control alternative. It can be seen from the Figure 7 below:

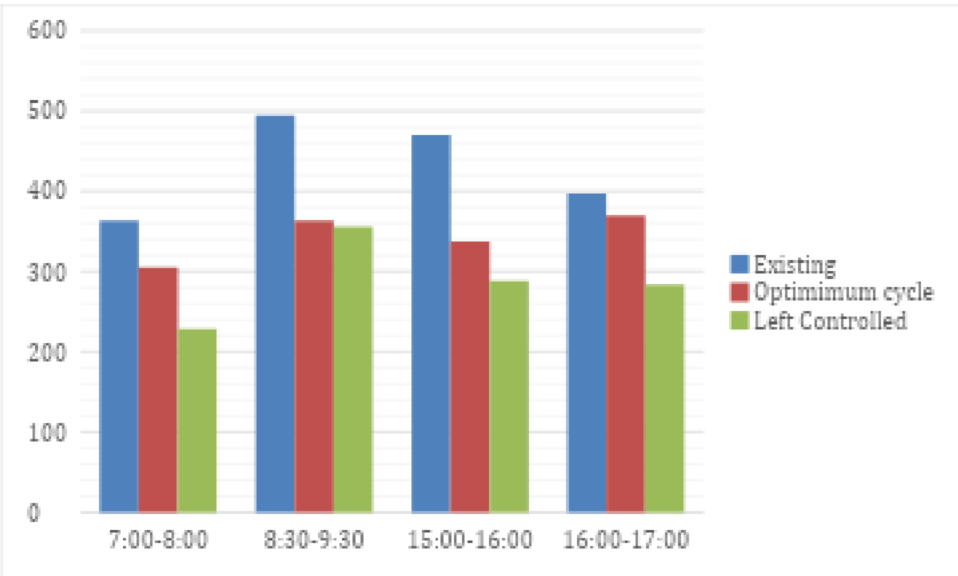

Figure 7: Comparison of BOQ (m)

7.2 Average Delay:

The study on average vehicular delay observed at various times of the day under the three signal control scenarios brings in some critical viewpoints concerning the operation of the intersections. From 7:00 to 8:00, average delays have slightly dropped from 36 seconds under existing conditions to 33 seconds under optimized cycle time settings and if a left-turn controlled signal had been considered, the average delay would have been further reduced to 27.8 seconds, indicating greater operational efficiency due to lesser conflicts. During the morning peak, optimized cycle timings show little improvement in delay (from 36.1 to 36 seconds) compared to 32.3 seconds for the left-turn control. This further implies that during periods of high saturation, cycle-length optimization may not necessarily be sufficient and might have to be supplemented by other control measures. In the afternoon (15:00–16:00), perhaps with the highest delay of 41.3 s, the optimized cycle managed to bring the delay down to 34.5 and the left-turn control further shrunk it to 28.1 seconds as a true face of congestion management. During this time interval (16:00–17:00), the optimized cycle surprisingly increased the average delay from 26.9 seconds to 40.4 seconds, which was most likely due to the improper phase allocation or that demand was less than the preset cycle time. Meanwhile, the left-turn controlled signal held the lowest delay of 25.0 seconds. The left-turn controlled in general gave the best results for all periods under study. It can be seen on the Figure 8 below:

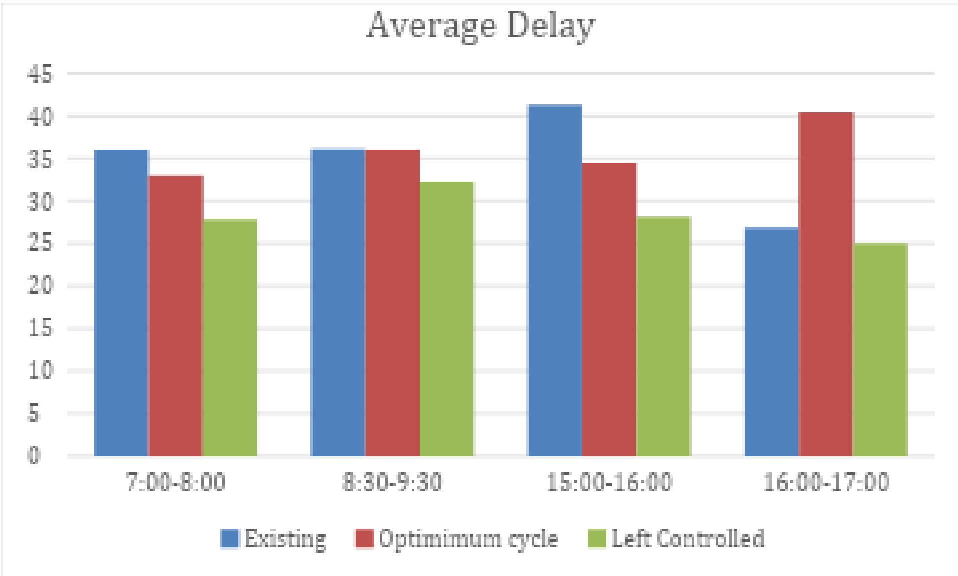

Figure 8 Delay Comparison

7.3 Level of service:

Level of Service (LOS) is another important parameter used to estimate the performance of the intersection. While comparing the LOS with different signal control options, current conditions, optimal cycle length (Alternative I), and left-turn controlled signals (Alternative II). The LOS rating from A (free flow) to F (oversaturated) provides a good quantitative indication intersection efficiency. In the existing conditions, LOS was at D under all the peak hours except for afternoon (16:00-17:00) which indicated a moderate degree of delay and congestion. LOS was

C for the 16:00–17:00 which indicated in a relatively improved traffic condition. With the implementation of best cycle timing, LOS was improved in some cases, most notably at 7:00–8:00 and 15:00–16:00 where LOS was converted from D to C. However, between 8:30–9:30 and 16:00–17:00, LOS was the same at D or even worsened from existing conditions, showing that changes in cycle times alone might not always result in better performance, especially under mixed traffic conditions. In contrast, the left-turn control strategy always upgraded LOS to C during any time period which demonstrated the effectiveness of movement-specific signal control to reduce turning conflicts and maximize flow of vehicles. In summary, the results suggest that control of left turns not only reduces delays and queuing but also tends to make traffic operation more efficient. Heatmap representing the LOS can be seen below Figure 9.

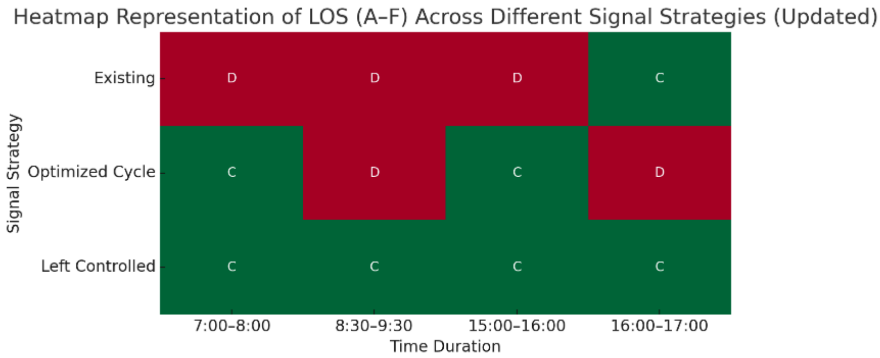

Figure 9: Heatmap for LOS

8. CONCLUSION:

This study compared the performance of Mangalgadhi Chowk, located in Surkhet, Nepal using the tool called SIDRA Intersection 8.0. The study was to compare existing conditions and evaluate two strategies to enhance the intersection: optimized signal cycle timing and left-turn controlled movements. For this, traffic volume survey was conducted on three working days and information on road geometry, lane width, and observed saturation flow was documented for calibration of the SIDRA model. Model validation was done by comparing the field measured 98th percentile BOQ lengths, with variation still within acceptable ranges (mainly less than 20%).

Under existing conditions, the intersection has significant delays (up to 41.3 seconds) and extensive queues (up to 494.4 meters) and overall Level of Service (LOS) at D except for one period at C. This indicates unstable traffic flow in most time intervals. With optimizing signal cycle times, there were modest improvements. BOQ and delays decreased in the majority of time periods and LOS even improved from D to C for a few cases (7:00–8:00 and 15:00–16:00). However, in 16:00–17:00, delay surprisingly increased which shows that cycle time adjustments alone may not always guarantee balanced improvements. On the other hand, the left-turn controlled signal plan worked better consistently than existing and optimized cycles. BOQ was reduced significantly by up to 39%, delays were less than 30 seconds in all time intervals and LOS was upgraded to C consistently across the board.

Overall, the study concludes that while optimizing cycle lengths may help in some instances, controlling left-turn movements on all approaches produces the most equitable and overall best traffic performance improvement at Mangalgadhi Chowk. The conclusion justifies the use of movement-specific controls during signal design to mitigate congestion and delay issues in rapidly growing cities.

ACKNOWLEDGMENTS

The authors would like to acknowledge Traffic and Transport Unlimited Solutions for their help in data collection and Hemant Tiwari for the guidance to complete the work.

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