Journal of Engineering Issues and Solutions

Assessment of Traffic Operational Performance: A Case Study of Maharajgunj Intersection of Kathmandu Valley

Shesh Raj Kafle[1*], Arbin Amgain[2], Aarju Kalathoki[3], Dhiraj Bohara[4]

[1,2,3,4] *Department of Civil Engineering, Lalitpur Engineering College,*
Institute o Engineering, Tribhuvan University, Nepal
**Corresponding email: sheshrajkafle@lec.edu.np*
Received: May 5, 2025; Revised: July 5, 2025; Accepted: July 12, 2025

https://doi.org/10.3126/joeis.v4i1.81589

Abstract

Urban intersections are important for controlling traffic and ensuring effective mobility, especially in cities that are growing speedily. Intersections are one of the major reasons of congestion in the Kathmandu valley and congestion is proving itself as the chronic disease for the road transportation. This study evaluates the operational performance of the Maharajgunj intersection which is one of the major and busy intersection at Kathmandu Valley. Using a mix of field data and numerical simulation tools, the study examines several performance parameters such as Level of Service (LoS), queue length and degree of saturation. Comprehensive data including volume count, cruise speed, back of queue (BOQ) and intersection geometry data are obtained, and incorporated into SIDRA INTERSECTION 8.0 for calibration, validation and scenario analysis. Various alternatives were explored and evaluated to improve the operational performance of the intersection.

For Maharajgunj intersection,two alternatives were proposed:(1) Constructing a flyover between Basundhara and Chabahil approaches and (2) Restriction of right turn in minor approaches. In the existing condition, the intersection was performing at Level of Services (LoS) F, also average vehicles delay at 216 sec and average back of queue (BoQ) with 385.3 m. After implementing flyover, the performance improved to LoS C with a delay of 22.6 seconds and a average back of queue 121.9m , and the restriction of right turn in minor approaches yielded LoS F with a average control delay 105.6 seconds and average back of queue 333.9m. Based on comparison of performance indicators alternatives 1 shows the best results for the improvement of this intersection. It is recommended to constructed flyover on the major approaches for efficient flow of vehicles in that intersection.

Keywords: *Intersection, Peak hour volume, Back of Queue (BoQ), Delay, Level of Service(LoS)*

1. Introduction

Road intersection is a location where multiple roads meet and hence vehicles need to cross each other at the same time in order to get from one point of intersection to another. This creates vehicle conflict. Vehicle conflict is situation where the paths of vehicles intersect which creates the risk of collision. In order to reduce the risk of collision, vehicles need to either slow down or wait in turns to cross the intersection. Vehicles' flow being interrupted at intersections due to common crossing point at common point of time increases delay time. The difference in travel times with and without traffic obstructions is known as delay time, and it has a direct impact on queue length (Brilon, 2008).

Long delays will lead to congestion. Intersection congestion has been one of the most severe problems in urban traffic where traffic is excessive and road space inadequate congestion follows. Traffic jam is a common view in the cities, especially at the crossings, as the urbanization has spread its wings rapidly. Falcocchio and Levinson suggest that, traffic congestion, in addition to contributing to mental stress and interfering with people's daily routines also leads to other problems such as negative mood state, raised blood pressure, and frustration etc. (Falcocchio & Levinson, 2015).

Kathmandu Valley is facing similar problem in many intersections. People commuting daily must leave their home early just to reach their destination on time (Shrestha & Bajracharya,2020) . Among these, the Maharajgunj intersection lies at the very heart of the valley and the importance of this intersection can also be justified by the presence of hospitals, educational institutions, administrative offices, and businesses in and around this area. (Road, 2022)

2. Problem Statement and the objective of the Study

2.1 Problem Statement

Kathmandu valley is the national capital of administration, industrial, commercial, social and economic activities. It is the most densely populated region in Nepal and its population has been increasing rapidly during the past two decades. The rapid unplanned urbanization of the Kathmandu valley caused by the informal process of settlement development in the past has brought several physical, social, and environmental problems in the Kathmandu valley. Due to this rapid and unplanned urbanization traffic flows in the riad network in Kathmandu valley are facing unacceptable congestion and delay mainly during the peak hours. As an initiative to improve the traffic condition in Kathmandu valley, national authorities such as the Ministry of Physical Infrastructure and Transport (MoPIT), Department of Roads (DoR) jointly with international organizations such as Asian Development Bank (ADB) and Japan International Cooperation Agency (JICA) have been conducting several intersection improvement and signalization related projects. As a result, over the past few years, many intersections in the valley have been signalized.

Maharajgunj Intersection in Kathmandu, a crucial junction near prominent institutions like Tribhuvan University Teaching Hospital and the U.S. Embassy is facing severe traffic congestion. This issue arises from narrow roadways, heavy vehicle volumes and outdated infrastructure. The situation worsens due to road narrowing, disorganized traffic flow, absence of pedestrian crossings and encroachment by street vendors, all contributing to traffic bottlenecks.

2.2 Objectives

1. To assess performance of the intersections in existing condition.
2. To propose an alternatives scenario to improve traffic conditions at the intersections.

3. Literature Review

3.1 Sidra Intersection

SIDRA Intersection is a strong micro-analytical tool applied by transportation professionals all over the world that offers advanced lane-based models for analyzing of intersection types, i.e., signals, roundabouts, sign control, and pedestrian crossings within a single network (Overview : Sidra Solutions, 2024).

In Lane-group based model analysis, multiple lanes are aggregated in the single lane group where there is a shared lane in an approach i.e., all the lanes have the same movement groups. In it, if the lane group accommodates two light vehicles (PCU=1) with queue space of 4.2m, it is halved representing two lanes, likewise, if the lane group accommodates 1 light vehicle and a motorcycle (PCU=0.25), the equivalent queue space is 4.2/ (1+0.25) = 3.36m (Akcelik, 2016)

The environment and traffic flow parameters are modeled in SIDRA Intersection, calibration and validation of the intersection model in the software are performed using field data. As per as (Kiran Dhakal, 2023) performance of intersection is evaluated using parameters like Level of Service (LOS), delays, and Back of Queue. The SIDRA Model supports various intersections types, including signal-controlled, roundabouts, sign-controlled, and pedestrian crossings, all within one integrated network.

SIDRA Intersection software complements the Highway Capacity Manual (HCM) as an advanced intersection and network analysis tool. This software is compatible with the Highway Capacity Manual. According to (Overview : Sidra Solutions, 2024) unlike other software, the SIDRA HCM Setup doesn't just duplicate Highway Capacity Manual (HCM) processes; it extends and enhances the capabilities offered by the HCM.

Tianzi et al. used SIDRA and VISSIM on signalized intersection and concluded that the use of SIDRA is preferred for simpler operation and easier network construction. The study however also suggested that both software can be used for evaluation of impacts of traffic control methods and to make data-backed informed decisions for improvement of urban traffic congestion ((Chen Tianzi, 2013).

3.2 Others

For the analysis, evaluation and improvement of the intersection many researchers have conducted studies on the intersection. To see how efficiently an intersection is operating, they usually look at three main things: how much traffic the intersection can handle (capacity), how long vehicles are typically delayed (average delay), and the total amount of emissions produced (pollution). (Prakash Ranjitkar*, 2014). HCM defines an analytical model as "A model that relates system components using theoretical considerations that are tempered, validated and calibrated by the field data. The service quality of an intersection can be improved through signal optimization which results in controlled air pollution and fuel consumption can be reduced. (Challa Prathyusha, 2020) described on peak hours, there is a requirement of change in effective green time of an intersection for major approaches. Using SIDRA Software, in Nicosia, Cyprus, (Shaban Ismael albrka Ali, 2018) analyzed the performance of signalized intersection and roundabouts and also comparison of flow parameters during morning and evening was done. Also in Nepal it has been seen widely utilization of traffic analytical tools including SIDRA for the improvement of traffic conditions and reduction of congestion on the intersections. Based on (Ashok Dhakal, 2023) for evaluation and performance assessment of Gandak intersection, Birgunj SIDRA intersection software had been used. The authors proposed an optimal signal timing generated by the software to improve Level of Services (LoS) from E to D along with a 42% decrease in average delay. Using SIDRA Intersection (Hemant Tiwari, 2023) analysis performance at signalized intersection through signal coordination in two intersection i.e Shital Nivas and Kanti Children's

Hospital. The study showed that by coordinating the signal systems of two intersections the average delay and maximum queue length were significantly reduced at both intersections. (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. (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.

4. Methodology

4.1 Study Area

Maharajgunj intersection is selected for this research study which is at the position of 27°44'24.32" N latitude and 85°20'13.66" E longitude. The main approaches of this intersection is Basundhara and Chabahil and minor approaches is Maharajgunj and Bansbari. Bansbari road has the minimum road width among all due to which clearance between two vehicles in different lanes is minimum. Major approaches have 6 lanes having 3 approach lanes and 3 exist lane with each lane width is 3.75m where the minor approaches have 4 lanes having 2 approach lane and 2 exist lane with each lane's width is 3.5m. It's approach legs include Bansbari leg about 900 m towards the north, Maharajgunj leg about 300 m towards south, Basundhara leg 700 m towards the west as shown below and Chabahil leg 2700 m towards east.

Figure 1: Site Location

4.2 Data Collection

For the intersection analysis, it is important to collect data related to geometric features, traffic flow volume and signal and phase timing. Mostly these data is collected from the primary sources including viedographic surveys and on-site field observations. The Viedographic Survey was carried out on July 23rd,22ndand 23rd of 2024. In order to determine the peak hours and the corresponding volumes, the traffic volume data was taken from the viedo recordings at 15-minutes interval during the morning peak hours(9:00-11:00) on these days. The following data were collected:

1. Geometry of intersection and approach
2. Vehicle counts
3. Phase signal timing
4. Back of queue
5. Cruise Speed

Other data required like PCUs, Basic saturation flow, approach leg distance, vehicle dimensions, queue space were obtained from secondary data.

4.3 Traffic Volume

Viedographic Survey was carried out on July 23rd,22ndand 23rd of 2024. In order to determine the peak hours and the corresponding volumes, the traffic volume data was taken from the viedo recordings at 15-minutes interval during the morning peak hours(9:00-11:00) on these days. PCU factors were applied to the vehicles types, with the values of Nepal Road Standard (NRS).

Legs	Chabahil			Bansbari			Maharajgung			Basundhara		
ID	L_2	T_1	R_2	L_2	T_1	R_2	L_2	T_1	R_2	L_2	T_1	R_2
Moring Peak												
Time	9:00 - 10:00	9:30 - 10:30	9:45 - 10:45	9:00 - 10:00	9:00 - 10:00	9:30 - 10:30	9:45 - 10:45	10:00 - 11:00	10:00 - 11:00	9:15 - 10:15	9:30 - 10:30	9:15 - 10:15
LV	556	1077	197.25	589	1011	328	317	413	178	491	1016	190
HV	19	103	6.5	12	18	27	23	16	16	21	128	19
TV	576	1180	203.75	601	1029	355	340	429	194	512	1144	209
PHF	0.946	0.984	0.887	0.946	0.878	0.814	0.973	0.893	0.879	0.985	0.887	0.803

4.4 Back of Queue

A total of 50 observations were made for the measurement of the BOQ at all four approaches in the Maharajgunj Intersection 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)

4.5 Cruise Speed

For the measurement of cruise speed at the approaches of the Maharajgunj intersection, a total of 268 uninterrupted speed observations (67 at Mahalaxmisthan leg, 68 at Hattiban leg, 65 at Gwarko leg and 68 at Lagankhel leg) were made at 7:00AM to 9:00AM. As mentioned in TRB (1993), the 85th percentile speed provides a good estimate of top speed limit that the majority of drivers consider. Therefore, the cruise speed for the SIDRA model was used as the obtained 85th percentile speeds. Similar to that in Shrestha (2018) and Bajracharya (2022), it was assumed that the exit cruise speed in each leg was equal to the approach cruise speed.

4.4 Intersection Modelling

SIDRA intersection, a computer-based micro-analytical program, was used to analyze the acquired data. Using the provided data, a SIDRA model of the intersection of Maharajgunj was built, and this model was subsequently utilized for determining the existing performance and proposed alternatives to improve traffic flow at that intersection.

4.5 Calibration and Validation of Model

4.5.1 Calibration of Model

The intention of calibration in term of queue length within the traffic simulation model is to make the difference between the observed and the simulated queue lengths remains within a 20% differences. (Florida Department of Transportation, 2021). So, calibration was done for adjusting the model parameters with the field- measured traffic conditions.

4.5.2 Validation of Model

Validation provides an independent check of replication of the field into the model. For validation of the calibration model, the model was tested for traffic data of Day 3. The model output BoQ and actual field BoQ was compared and checked if the difference is within 20% of the actual field data. (Florida Department of Transportation, 2021)

5. Results and Discussion

5.1 SIDRA Base Models

Using SIDRA Intersection Version 8.0 Maharajgunj intersection base model was creted as shown in figure 2.

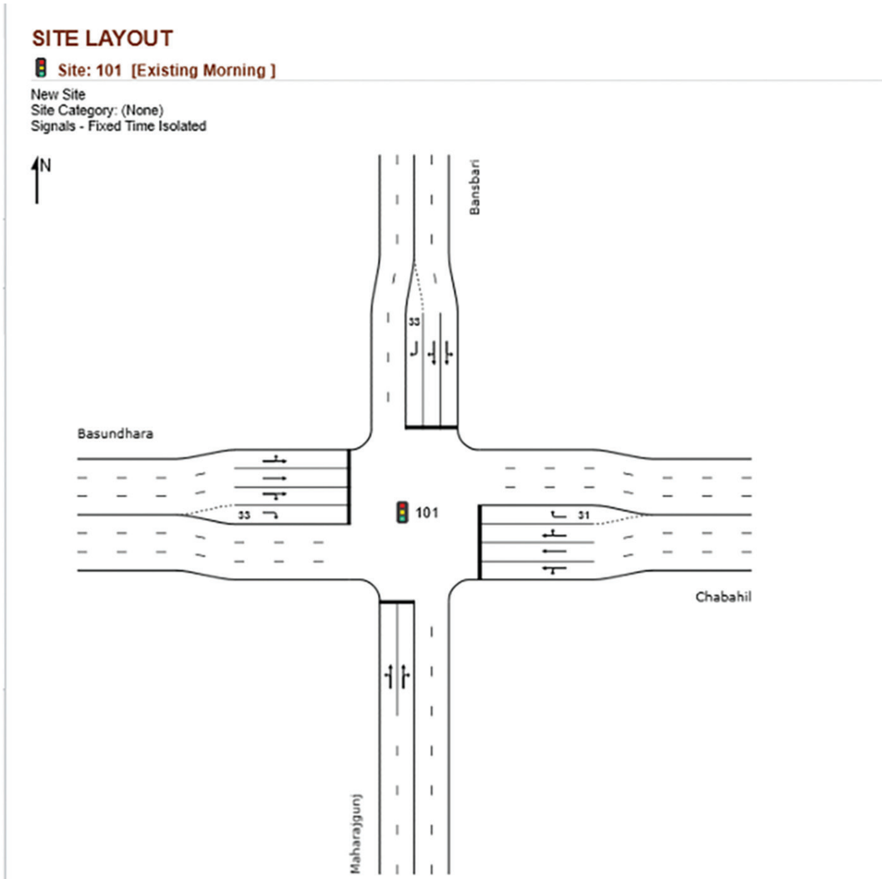

Figure 2: SIDRA Base Model for Maharajgunj Intersection

During peak hours in the major approches the right-turing vehicles are stored at the exist lanes and then cleared out. After clearence, that lane is used as exist lanes for through vehicles. Hence to show this effect in developed model,right-turning lanes were added to both of the approches.

5.2 Calibration and Validation

5.1.1 Calibration for Back of Queue

The difference percantages of observed queue length for day 1 and day 2 and queue length output from the model is shown in the table 1.

Table 1: Calibration of Back of queue

Approach	Average BOQ (m)		
	Model Estimated	Field Estimated	Difference %
Chabahil Approach	270.5	252.22	6.75
Basundhara Approach	261.7	222.52	14.97
Bansbari Approach	403.8	339.72	15.86
Maharajgunj Approach	208.9	246.33	17.91

5.1.2 Validation for Back of Queue

The difference percantages of observed queue length for day 3 and queue length output from the model is shown in the table 2.

Table 2: Validation of Back of queue

Approach	Average BOQ (m) Model Estimated	Field Estimated	Difference %
Chabahil Approach	271.7	231.5	14.79
Basundhara Approach	264.5	215	18.71
Bansbari Approach	397.1	330.82	16.69
Maharajgunj Approach	207.8	242.52	16.70

5.2 Performance Analysis Under Existing Conditions

Base model was developed for the morning peak hour after collecting a data from primary and secondary parmaters then model was calibrated and validated respectively for adjusting the model parameters with the field- measured traffic conditions. Table 3 shows the operational performance of existing condition. Here L2 represent Left turn, T1 represent Though turn and R2 represent Right turn.

Table 3: Operational Performance of Existing Condition

Movement ID	Turn	Demand flows Total veh	HV%	DOS	Average Delay	LOS	Average BoQ Vehicle	Distance	Average speed (kmph)
South: Maharajgunj									
1	L2	350	2.6	1.350	219.8	LOS F	45.4	195.4	5.3
2	T1	479	2.7	1.350	221.5	LOS F	45.4	195.4	4.0
3	R2	221	9.2	1.350	226.6	LOS F	40.3	178.3	10.8
Approach		1049	4.1	1.350	222.0	LOS F	45.4	195.4	6.2
East:Chabahil									
7	L2	607	3.3	1.346	214.1	LOS F	60.3	254.4	12.5
8	T1	1258	4.7	1.346	203.3	LOS F	60.3	254.4	12.4
9	R2	244	3.2	1.346	226.2	LOS F	39.8	191.0	11.4
Approach		2109	4.1	1.346	209.1	LOS F	60.3	254.4	12.3
North:Bansbari									
4	L2	635	1.9	1.394	235.1	LOS F	91.9	385.3	9.6
5	T1	1172	1.7	1.394	238.1	LOS F	91.9	385.3	3.9
6	R2	417	5.8	1.136	142.3	LOS F	30.4	130.7	6.5
Approach		2224	2.5	1.394	219.4	LOS F	91.9	385.3	6.3
West: Basundhara									
10	L2	520	4.2	1.361	221.7	LOS F	58.0	242.9	4.6
11	T1	1290	4.2	1.361	210.8	LOS F	58.0	242.9	11.3
12	R2	262	3.3	1.361	230.9	LOS F	38.4	187.5	5.5
Approach		2071	4.1	1.361	216.0	LOS F	58.0	242.9	9.3
All Vehicles		7453	3.6	1.394	216	LOS F	91.9	385.3	8.9

After analyzed it was found that intersection is performaing at Level of Services(LoS) F and Degree of Saturation greater than 1. A critical issue was identified regarding the queue length for left-turning vehicles at multiple approaches. Specifically, the absence of a dedicated left-turn lane has led to operational inefficiencies. Vehicles intending to turn left are forced to queue within the through lane, causing significant blockage and extending the overall queue length for through-moving vehicles. This merging of turning and through traffic not only disrupts flow but also increases delay and contributes to traffic spillback, especially during peak hours. Such geometric and operational limitations are indicative of poor lane channelization, which significantly undermines intersection performance (Aryal et al., 2021; Sharma & Adhikari, 2020).The average delay on the intersection was 216 seconds which indicated the poor traffic condition and high possibilty of congestion in intersection. Due to insufficient green signal duration ,the average back of queue is high in that intersection which is 385.3m.

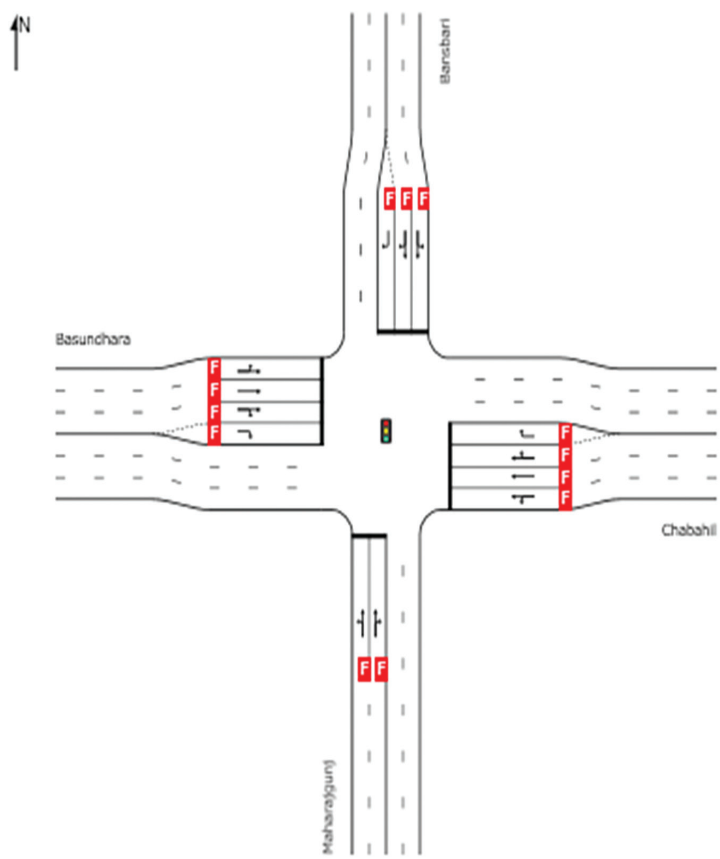

Figure 3: LOS of different approaches in existing condition

5.3 Improvement to the system and analysis of outcomes

A. Construction of Flyover in Major Approches (Alternative 1)

After construction of the flyover it is expected to improve the overall performance of intersection.The construction of flyover was proposed which will have 2 approches lanes and 2 exist lanes each width 3m. The width of the puropsed flyover is 12m and two exist lanes, each with a width of 2.625m have been proposed for the both the basundhara and Chabahil. The scenario in SIDRA Model was as shown in figure 4.

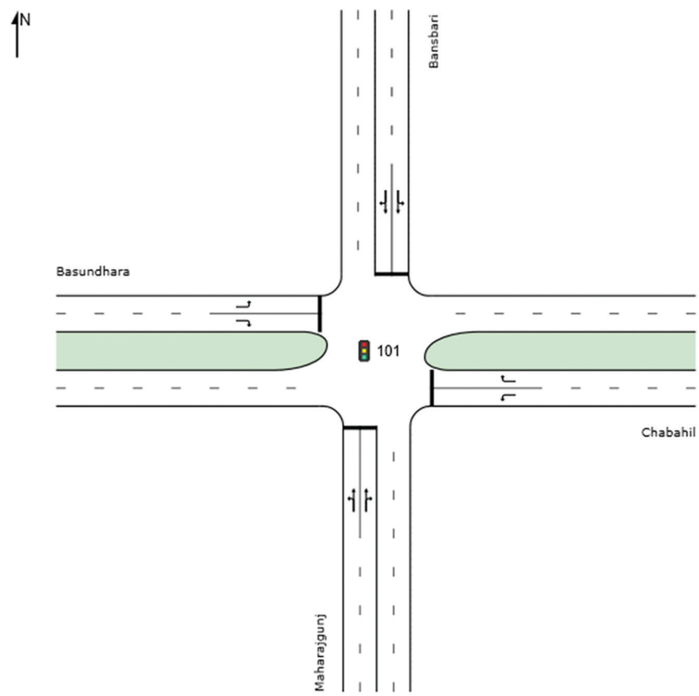

Figure 4: Geometric layout with Flyover option

Table 4:Operational Performance of Alternatives 1

Movement ID	Turn	Demand Flows Total veh/h	HV %	Deg. Of Sat	Average Delay Sec	LOS	Average Back Of Queue Vehicles veh	Distance m	Average speed km/hr
West:Basundhara									
10	L2	520	4.2	0.290	3.1	LOS A	1.3	5.5	31.7
12	R2	262	3.3	0.215	12	LOS B	3.3	14.5	27.8
Approach		781	3.9	0.290	6.1	LOS A	3.3	14.5	30.0
South: Maharajgunj									
1	L2	350	2.6	0.870	36.1	LOS D	15.2	65.3	19.5
2	T1	479	2.7	0.870	38.0	LOS D	15.2	65.3	15.6
3	R2	221	9.2	0.870	43.8	LOS D	14.4	63.6	24.6
Approach		1049	4.1	0.870	38.6	LOS D	15.2	65.3	20.0
East: Chabahil									
4	L2	607	3.3	0.333	4.4	LOS A	1.6	6.7	40.7
6	R2	244	3.2	0.4	31.5	LOS C	5.3	23.0	31.8
Approach		851	3.3	0.4	12.1	LOS B	5.3	23.0	37.9
North:Bansbari									
7	L2	635	1.9	0.887	24.2	LOS C	28	119.8	24
8	T1	1172	1.7	0.887	24.6	LOS C	28.1	121.9	17.3
9	R2	417	5.8	0.887	27.4	LOS C	28.1	121.9	18.2
Approach		2224	2.5	0.887	25.0	LOS C	28.1	121.9	20.7
All Vehicles		4905	3.2	0.887	22.6	LOS C	28.1	121.9	24.9

The overall LoS of the intersection decreased from F to C, average delays decreased up to 89.53% and that of back of queue decreased up to 68.36%.

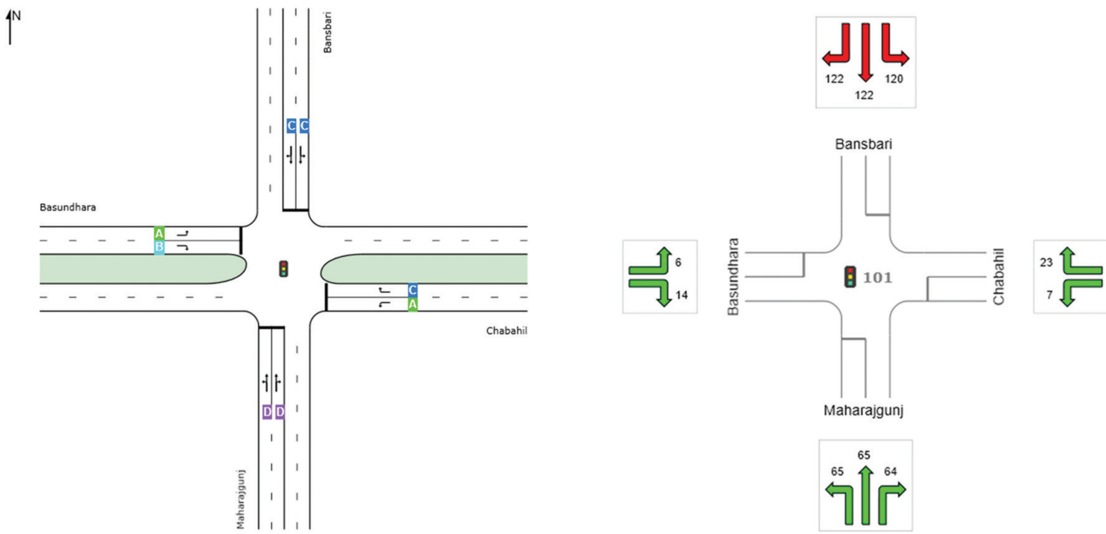

Figure 5: Performance Statistics after proposing flyover.

B. Restriction of Right-turn movement in Major Approches (Alternative 2)

Restriction of right-turn movements at intersection is a widely used traffic engineering idea with an intention to improved operational efficiency and safety. After implementing this alternative, it eliminates conflicts points and reduces vehicle delay due to which during peak hours it minimize the congestion and makes a smooth flow of traffic at the intersection.

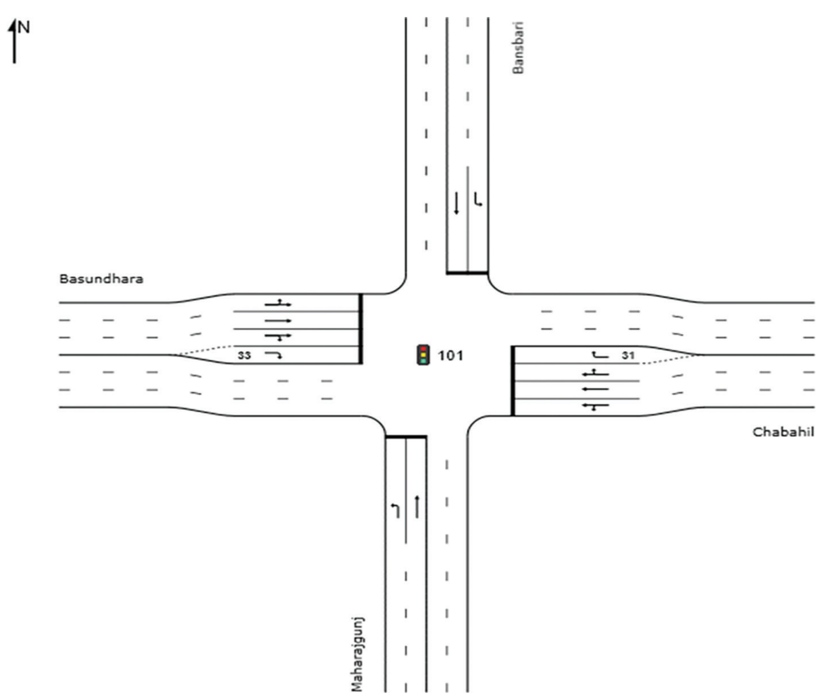

Figure 6: Geometric layout with Flyover option

Table 5:Operational Performance of Alternative 2

Movement ID	Turn	Demand Flows Total veh/h	HV %	Deg. Of Sat	Average Delay Sec	LOS	Average Back Of Queue Vehicles veh	Distance m	Average speed km/hr
East:Chabahil									
4	L2	307	1.9	1.182	138.0	LOS F	50.8	218.9	17.0
5	T1	1636	4.5	1.182	141.0	LOS F	50.8	218.9	17.3
6	R2	244	3.3	1.116	125.8	LOS F	13.5	58.5	17.4
Approach		2487	3.2	1.182	138.8	LOS F	50.8	218.9	17.2
North:Bansbari									
7	L2	1010	4.4	0.576	2.2	LOS A	3.7	16.4	27.4
8	T1	1172	1.7	1.228	155.0	LoS F	78.2	333.9	5.9
Approach		2182	2.9	1.228	84.2	LOS F	78.2	333.9	13.9
West:Basundhara									
4	L2	520	4.2	1.156	127.4	LOS F	45.8	200.1	7.4
5	T1	1508	4.0	1.156	128.8	LOS F	45.8	200.1	16.2
6	R2	262	6.1	1.156	138.7	LOS F	27.1	118.2	8.6
Approach		2290	4.9	1.156	129.6	LOS F	45.8	200.1	14.0
South:Maharajgunj									
1	L2	549	4.7	0.315	2.80	LOS A	1.4	6	31.2
2	T1	479	2.7	0.512	25.7	LoS C	12.2	52.7	19.3
Approach		990	13.7	0.345	3.0	LOS B	1.4	52.7	25.2
All Vehicles		7987	3.7	1.228	105.1	LOS F	78.2	333.9	15.6

The overall intersection LoS remain same as that of existing but the average delay decreased into 105.1 seconds and average back of queue slightly decreased into 333.9m. And show that only Maharajgunj approaches is performing good.

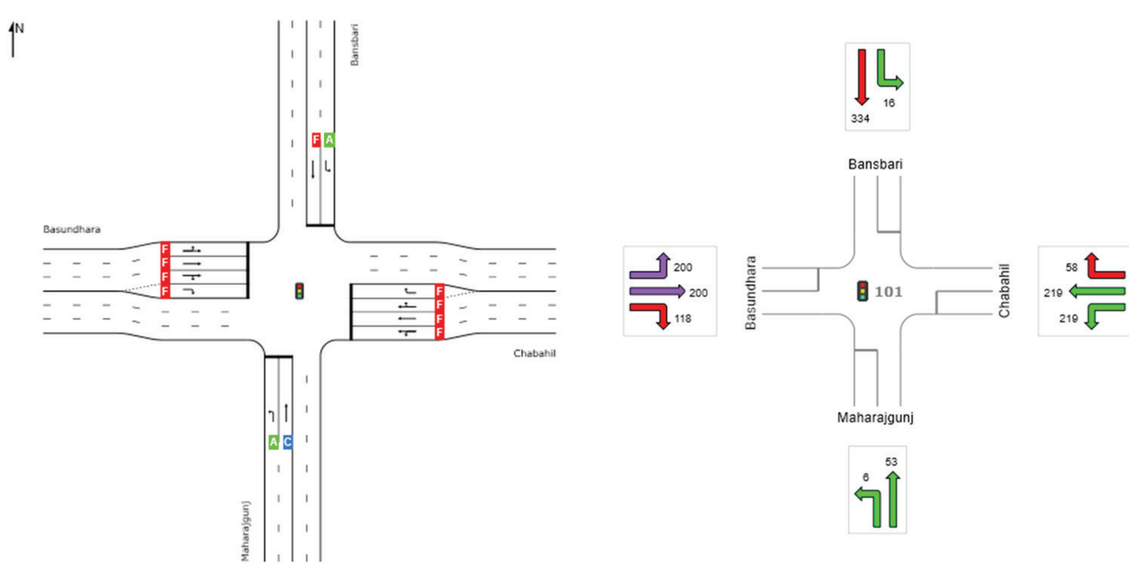

Figure 6: Performance Statistics after proposing alternatives 2

6. Conclusion

This research aims on determining the performance of a heavily congested four-legged intersection namely Maharajgunj Intersection that lies in the Kathmandu Valley, with the help of SIDRA Intersections 8 software. The following are the key findings:

- The initial performance evaluation of the intersection verified that the intersection was operating at LOS F with degree of saturation 1.337and average delay of 216sec
- Out of 2 alternatives proposed alternatives 1(Construction of Flyover in major approaches i.e Basundhara to Chabahil) showed the best result at the intersection with a performance index of LoS C, 22.6 seconds and Back of queue is 121.9m. Here, by 89.5% and 68.36% the average delay and back of queue decreased than existing case respectively. However, alternative 2 doesnot shows the realistic Hence it is recommended to constructed flyover in major approaches.

Acknowledgements

The authors express their sincerely thankfully to the Department of Civil Engineering, Lalitpur Engineering College for providing the fund and essential resources and extend their appreciation to everyone who supported directly or indirectly for the completion of this researches.

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