

Evaluation of Operational Performance of Jawalakhel Roundabout at existing condition and Impact of Geometric Improvement on Its Operational Performance

Deepa Karkee ¹, Reshu Poudel ², Subash Dhungel ³

¹ Graduate Student, Nepal Engineering College

² Transport Engineer, Traffic and Transport Unlimited Solution (TATUS)

³ Chairman, Traffic and Transport Unlimited Solution (TATUS)

Abstract

The study provides an overview of the existing operational performance of Jawalakhel Roundabout with and without cycle lanes in terms of current and future traffic. Jawalakhel is located in the central business district of Lalitpur and connects busy approaches. This connects Pulchowk in the North, Lagankhel in the East, Ekantakuna in the South, and Zoo in the West. It is serving to minimize the resulting conflict between the vehicles; however, due to increasing vehicular movements it is facing challenges like delay, poor level of service and traffic congestion. Video graphic survey method was applied for the collection of traffic volume data and pedestrian volume data during peak hours. The environment and traffic flow parameters are modeled in software 'SIDRA Intersection 8.0'. The calibration and validation of the roundabout model in the software are performed using field data. The performance of the roundabout is assessed based on the LOS, Average Delay, Queue length and is followed by the implementation of the performance enhancement strategies. After analysis, delay; degree of saturation; level of service & 95% of queue vehicles was calculated for existing condition and performance after five years were also analyzed. As a result, the existing performance of the Jawalakhel roundabout was not found to be satisfactory. The result was observed after changing the geometric design of Jawalakhel roundabout.

Keywords: Level of Service (LOS), Average Delay, Degree of Saturation (DOS), Queue Length

1 INTRODUCTION

Transportation has been an all-important contributing factor in the development of all the nations and that too at every stage of civilization in this world. The transportation facilities have also been a prominent factor in the development of political, social, economic and cultural fields of a country. For providing a safe, effective and efficient transportation system, traffic management is essential as traffic is a complex phenomenon of random and dynamic nature. The traffic system incorporates intersections as vital components, defining the points where two or more roads intersect, converge, diverge, or cross at the same grade, giving rise to potential vehicle conflicts. In urban road networks, intersections play a pivotal role in shaping the overall capacity. The operational effectiveness of intersections hinges on factors such as geometric design, traffic attributes, volume, and the implementation of traffic calming measures. Previous studies have proved that roundabout improves efficiency and safety performance compared to other types of intersections by reducing conflict points and accident severity (Park, Lee, & Park, 2018).

Roundabouts, also known as traffic circles or rotaries, are circular intersections designed to improve traffic flow and safety. They offer several advantages over conventional intersections controlled by traffic signals or stop signs, but by far the most important one is safety. Usage of the roundabout has been increasingly popular across the world. France has 967 roundabouts per 1 million inhabitants (Buchholz, 2020). An efficient roundabout is essential in the distribution of traffic to various routes of a traffic network for smooth flow at its optimum services. A study by Insurance Institute for Highway Safety (IIHS) found that the injury crashes were reduced by 75% at the intersection previously controlled by stop signs and traffic signals (Washington State Department of Transportation).

Jawalakhel Roundabout serves as a pivotal traffic intersection within the urban fabric, connecting various routes and facilitating the movement of vehicles and pedestrians. Over time, increased traffic volume and changing urban dynamics have raised concerns about the operational efficiency of the roundabout. This research seeks to evaluate the current operational performance and explore the effects of geometric improvements on traffic flow.

2 OBJECTIVE

The main objective of this study is to assess the existing operational performances and the impact of improvement on geometry of Jawalakhel roundabout's operational performance in terms of current and future traffic using SIDRA Intersection.

3 STUDY AREA

The roundabout at Jawalakhel had been selected for this study. The roundabout at this location is essential in Kathmandu valley and is often busy in the morning and evening as the location consists of major institutions, markets, places, and hospitals. This is an un-signalized roundabout with four approaches namely Pulchowk, Lagankhel, Ekantakuna and Zoo.



Figure 1 Study area (aerial view of Jawalakhel Roundabout with its cycle lane)

4 LITERATURE REVIEW

(Shyaula, 2016) conducted study on operational analysis of roundabout under mixed traffic flow. The study includes finding out the critical and follow-up headways using Ning Wu & Raff methods and entry capacity and degree of saturation using (HCM, 2010). The study shows that entry lane which approaches Jawalakhel roundabout from Jawalakhel, Lagankhel and Pulchowk is Critical while the circulating lane approaches from Jawalakhel and Zoo is at critical state so the existing traffic flow at Jawalakhel Roundabout is Critical.

(Pandey, 2020) performed a study of performance evaluation and improvement of traffic operation at Itahari intersection in Sunsari district using Sidra intersection. To improve the performance of Itahari roundabout, he suggested three alternatives for the period of 5 years using SIDRA intersections 8.0. The three alternatives used were:

1. Geometric change of the intersection

2. Roundabout metering at the south and west approaches
3. Roundabout metering at the east and north approaches

Among them he concluded that the performance of first alternative (Geometric change of the intersection involves reduction in the diameter of central island shows the best result in terms of minimum delay and high LOS.

(Suwal, 2017) performed analysis of delay and alternatives of improvement of Prithvi Chowk, Pokhara, Nepal. It was found that the average delay was 98.86 sec/veh and LOS F. Based on the results of delay analysis, following conclusions were drawn:

- Four alternatives were given for the improvement of Prithvi chowk. First: Reducing the diameter of central island; Second: Restriction to go straight and right turn in roundabout; Third: Four phase signalized intersection without roundabout and Fourth: Indirect right turn from northbound.
- The average delay of the first alternative with reduction of radius of the central island was 77.92 sec, which is 19.56% lower with respect to the existing delay. Whereas in second alternative, the average delay was 41.3 sec i.e. 57.37% lower than the existing scenario. Similarly, in third alternative, average delay was found 105.95 sec, which is 9.38% higher than the existing delay and the fourth alternative, increase the delay to 108.90 sec, which is 12.43% higher with respect to existing scenario.
- The study recommended that reduction of the diameter of the central island and restricting through and right turn from the southbound, is the better options for reducing average delay.

(Rashid and Gupta, 2017) performed Study on Capacity and Performance Analysis on road roundabout with traffic signals in urban area of India. The purpose of this study is to analyze the capacity and performance of signalized roundabout to find out possible effective and cheaper way. This was done by determining the capacity, Level of Service (LOS), queue length and delay of a multilane roundabout with the application of SIDRA Intersection 8.0. A peak-hour traffic capacity and performances of the roundabout and traffic control system at the site was analyzed during this study. Out of the total volume of traffic, about 85% of the volume of traffic shall be accommodated by increasing the weaving section with decreasing the length of splitters. On further performance analysis of the roundabout, the remaining 15% of the traffic can be accommodated with decreasing the width of splitters so that the capacity of roundabout increases up to 100%.

5 METHODOLOGY

The study employs the Sidra Intersection 8.0 software, a widely recognized tool for traffic engineering and analysis. The methodology involves collecting real-time traffic data, inputting it into the Sidra software, and conducting simulations to model the existing conditions and proposed geometric improvements.

Initially, the problem and objectives were viewed, and the research was planned accordingly. Then, the literature review was conducted to study the existing paper in the required area, and data from primary and secondary sources were collected for this study. Then the simulation was conducted in software taking appropriate geometric and traffic characteristics consideration for computation and comparison of average delay, degree of saturation and level of services. Then after significant improvement techniques were implemented for the roundabout.

There were basically two types of data in this study: one is primary, and the other is secondary data:

Primary data serves as the main source for this study. Video graphic surveying and field measurements were carried out for this study. Classified Traffic volume data were collected for 3 days during time period 9:00 AM to 11:00 AM in the morning time and 4:00 PM to 6:00 PM in the evening time, when people usually commute more. And, as a secondary data source, many literatures, journals, articles and various manuals were reviewed and taken for references.

6 TRAFFIC VOLUME COMPOSITION OF JAWALAKHEL ROUNDABOUT

From all the approach legs, Traffic volume was recorded in CCTV footage and along with the classified turning movements at 15- minute interval time were extracted from the CCTV footage and digitized in the standard format of DOR later. ADT were calculated from these data. Refer table below for ADT volume of all approach legs.

Table 1: Total Average Daily Traffic (ADT) calculation for each leg

Vehicle Type	Ekantakuna	Zoo	Pulchowk	Lagankhel
Multi axle Truck	0	0	0	0
Heavy Truck	2	0	8	1
Light Truck	9	4	13	11
Big Bus	47	14	42	56
Mini Bus	79	17	109	84
Micro Bus	44	11	253	219
Car	1480	385	2531	1497
Motorcycles	5998	2086	8224	8675
Utility Vehicles	44	23	69	141
4-wheeled Drive	123	110	552	347
Rickshaw	2	8	6	0
3- wheeler	1	2	264	192
Power Triller	0	1	0	0
Bicycle	104	85	159	4
Total	7931	2744	12228	11226

It was found that total ADT in Pulchowk leg (12228 veh/day) was the highest followed by Lagankhel leg (11226 veh/day), while lowest was that of leg Zoo around 2744 veh/day. Among all the categories of vehicles that was taken for the traffic analysis, ADT of motorcycles were found in highest number of Jawalakhel roundabout and also, for the same case leg Lagankhel had highest number of Motorcycles of ADT 8675 veh/day.

7 EXISTING OPERATIONAL PERFORMANCE EVALUATION

For the performance evaluation of Jawalakhel Roundabout, four parameters: Degree of Saturation, Control Delay, Level of Service and 95% Queue Length were taken for the analysis.

7.1 Degree of Saturation

Table below shows the degree of saturation in all the approach of the Jawalakhel Roundabout existing configuration for both morning time and evening time, under the existing traffic (year 2022). Refer below table 2.

Table 2 Degree of Saturation (DOS) at the Jawalakhel Roundabout

S.N.	Approach Name	Total Traffic Demand (Veh/hr)	Total traffic capacity (Veh/hr)	Degree of saturation (V/C) for morning peak hour	Degree of saturation (V/C) for evening peak hour
1	Ekantakuna	2311	1280	1.805	1.278
2	Lagankhel	3656	1239	4.478	1.966

3	Pulchowk	2980	1474	2.202	2.352
4	Zoo	732	392	1.865	1.543

7.2 Delay

Table 3 below shows the existing (year 2022) average delay in seconds per vehicle in all the approaches of the Jawalakhel Roundabout for both morning time and evening time.

Table 3 Average delay (in seconds) under existing traffic for the year 2022

S.N.	Approach Name	Average delay in Sec for morning peak hour	Average delay in Sec for evening peak hour
1	Ekantakuna	385.10	134.40
2	Lagankhel	1261.50	349.70
3	Pulchowk	486.70	613.30
4	Zoo	422.20	253.30

7.3 Level of Service

Table 4 below shows the existing (year 2022) Level of Service (LOS) in all the approaches of the Jawalakhel Roundabout for both morning time and evening time.

Table 4 LOS of Jawalakhel Roundabout under existing configuration

S.N.	Approach Name	Level of Service (LOS) for morning peak hour time	Level of Service (LOS) for evening peak hour time
1	Ekantakuna	F	F
2	Lagankhel	F	F
3	Pulchowk	F	F
4	Zoo	F	F

7.4 Queue Length

Table 5 below shows the existing (year 2022) Queue Length in all the approaches of the Jawalakhel Roundabout for both morning time and evening time.

Table 5 Queue Length of Jawalakhel Roundabout under existing configuration

S. N	Approach Name	95% of back of queue (Veh) for morning peak hour time	95% of back of queue (Veh) for evening peak hour time
1	Ekantakuna	182.30	91.4
2	Lagankhel	714.40	267.50
3	Pulchowk	305	410.40
4	Zoo	116.50	103.90

8 GEOMETRIC DESIGN IMPROVEMENT OF JAWALAKHEL ROUNDABOUT AT EXISTING CONDITION

After the simulation of this base year 2022 data in SIDRA 8.0, Roundabout was found to be currently operating with LOS F in all directions. So, we had concluded that the Jawalakhel Roundabout has a very weak performance and geometric design change of this roundabout is necessary for its operational performance improvement.

For this, the central island of the roundabout was reduced from 34m to 29m, in order to increase the number of circulating lanes and circulating width. This was done to accommodate more vehicles inside the roundabout's circular path. It was not possible to increase the lanes in North (Pulchowk) and East (Lagankhel) approaches, as no possibility of extension here, thus, one lane had been added in both the South (Ekantakuna) and West (Zoo) approaches, although these legs have quite less volume compared to other legs, to reduce the delay and to achieve smooth movement of vehicles. And the result of SIDRA 8.0 can be referred from figure 2 and table 6 below.

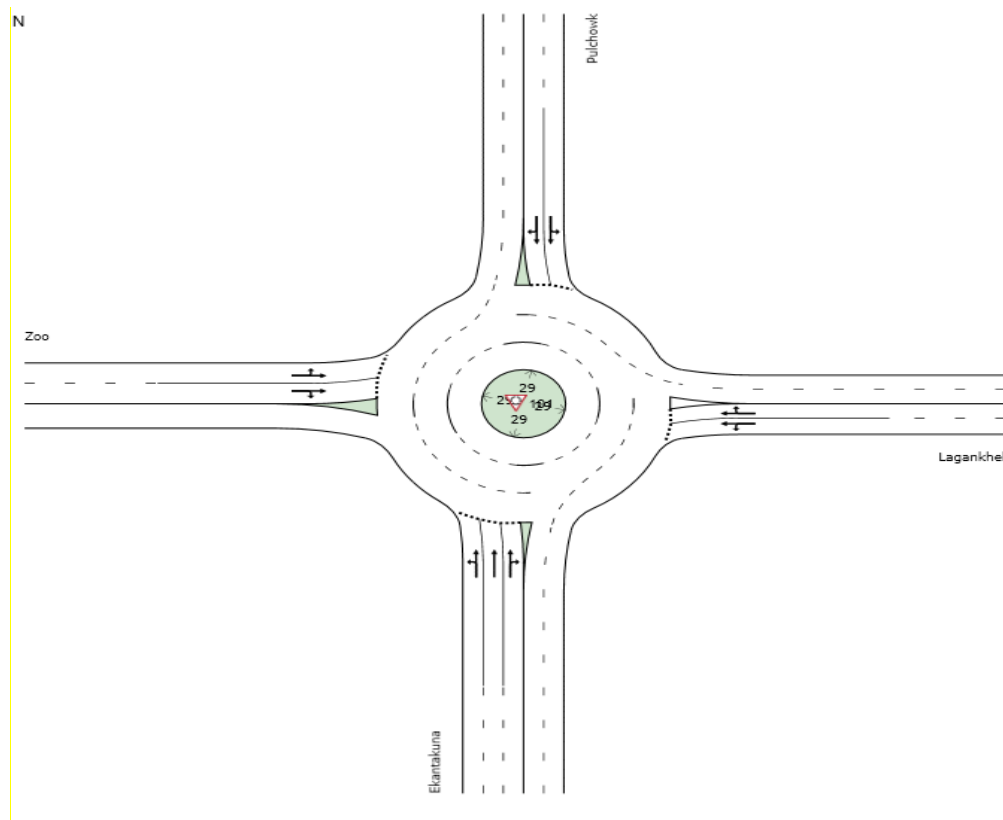


Figure 2 Layout of the geometry design change of Jawalakhel Roundabout

Table 6 Lane summary output after changing geometric design of Roundabout

S. N	Approach Name	Deg. of Saturation (V/C)	Average Delay (Sec)	Level of Service (LOS)	95% of back of queue (Veh)
1	Ekantakuna	1.068	40.8	D	38.0
2	Lagankhel	2.105	395.5	F	279.7
3	Pulchowk	2.544	661.4	F	424.0
4	Zoo	2.544	21.2	C	9.0
	Intersection	2.544	398.1	F	424.0

9 FUTURE (YEAR 2027) ROUNDABOUT PERFORMANCE AFTER CHANGING GEOMETRIC DESIGNS

From our base year (2022) data analysis, using SIDRA 8.0 software, we found the performance of Jawalakhel Roundabout in very weak condition with LOS F, average delay of 750.30 sec. So, to improve its performance, a growth rate of 1.55 % was taken in consideration for the projection of 5-year future data (year 2027).

Similar to the base year data 2022 case, this improvement technique was done for future year 2027 data and the result from SIDRA in terms of DOS, LOS, Average Delay and Queue Lengths were obtained for future year 2027 and respective result of SIDRA 8.0 on this design option is illustrated. Refer table 7 below:

Table 7 Future Traffic (year 2027) Roundabout Performance after changing geometric design

S.N.	Turning Movement	Demand Veh/hr.	Degree of saturation	Average delay	LOS	Back of queue
East Approach: Lagankhel						
1	Left Turn	966	2.480	498.7	F	345.7
2	Through	544				
3	Right Turn	1218				
South Approach: Ekantakuna						
4	Left Turn	49	1.432	181.8	F	107.4
5	Through	1441				
6	Right Turn	723				
West Approach: Zoo						
7	Left Turn	231	1.064	54.4	E	18.1
8	Through	508				
9	Right Turn	193				
North Approach: Pulchowk						
10	Left Turn	2373	3.687	1134.2	F	560.2
11	Through	1369				
12	Right Turn	692				

10 CONCLUSION

The operational performance of Jawalakhel roundabout was performed considering the four parameters (Average delay, Degree of saturation, LOS and, 95% of back of queue) under existing and future 5 years traffic condition using a simulation software SIDRA Intersection 8.0. Change in geometric design of this roundabout is also done. This research work observes the influence of altering the roundabout's geometry on its operational performance. In 2022, Ekantakuna, Lagankhel, Pulchowk, and Zoo legs of the Jawalakhel roundabout all had Level of Service (LOS) F. After modifying the roundabout's geometric design, Ekantakuna improved to LOS D, but Lagankhel, Pulchowk, and Zoo remained at LOS F. Looking ahead to 2027, despite some geometric changes, Ekantakuna stays at LOS F, Lagankhel and Pulchowk at LOS F, and Zoo at LOS E. While in compare to average delay, Lagankhel leg had the delay around 1200 seconds earlier, but it was seen drastically changed after the improvement to 395 second delay. Similarly, average delay in other legs was also seen decreased that earlier.

11 ACKNOWLEDGEMENT

The authors like to extend the sincere gratitude to Er. Hemant Tiwari for providing continuous support, guidance, and an invaluable resource in the successful completion of this research paper. We would also like to express our appreciation to Traffic and Transport Unlimited Solutions (TATUS) and organization Safe and Sustainable Travel Nepal (SSTN) for their cooperation and assistance throughout the research process.

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