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**Research Article**

# Performance Assessment of a Signalized Intersection: A Case Study of Gandak Intersection of Birgunj, Nepal

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## I N F O

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## A B S T R A C T

Tribhuvan Highway and Birgunj Bypass Road converge to form the Gandak intersection which is situated at Birgunj Metropolitan City, Nepal. The study aims to provide an overview of the existing scenario for the Gandak intersection along with the measures to enhance the performance of the intersection. With the help of the data collected, the current condition of the Gandak intersection is known. Further, SIDRA Intersection 8.0, a traffic analysis tool, is utilized to model the environment and traffic flow parameters for the calibration and validation of the intersection. The performance assessment for the field data as well as the program-generated data is carried out keeping the level of service, average delay, and queue length under consideration. To enhance the performance of the intersection, the practical signal timing was replaced with that of the software-generated timing that increased the LOS of the intersection from E to D along with a 42% decrease in average delay and a 20% decrease in the back of queue.

**Keywords:** calibration, validation, level of service, average delay, queue length, capacity.



## Introduction

An intersection is a point where two or more roads meet or cross each other forming a complex network. The traffic from various directions converges at the intersection hence there is a higher chance of congestion at the intersection. Traffic congestion, which is a result of rapid urbanization, has been a major issue in the developed cities. Traffic congestion has been creating a major inconvenience to the residents as they have to deal with it regularly. The increase in the traffic volume has an inverse impact on travel time. Likewise, the quality of life of an individual is also impacted leading to increased mental stress, alteration in the daily schedule, increased travel costs, and so on. The traffic management system, poor road infrastructure, and massive population density are the main contributors to the traffic delays.

For urban areas, the management of traffic congestion can be done in multiple ways. Enhancement in signal timing can contribute to an increment in the traffic capacity of the intersection which can be achieved by optimization of the green light duration for various phases resulting in a decrease in travel time and queue length.[1] Likewise, the allocation of dedicated turning lanes also helped for reducing the delays. Further, another important measure for creating a smooth traffic flow is coordinating the traffic signals at different intersections which significantly improves the delay and queue length at intersections.[2] With the improvement in the signal timing, the flow of the vehicle at the entry and exit of the main road is smooth with minimal interruptions. The primary step for this process is figuring out the capacity of the intersection which is computed by obtaining the maximum number of vehicle that enters a particular intersection for a given period under prevalent road, traffic, and environmental circumstances. The maximum number of vehicles was figured out using the PCU value for various vehicular categories in regard to non-lane heterogeneous conditions of traffic.[3] Moreover, microscopic traffic simulation, with the use of tools like VISSIM, can give a different dimension to traffic analysis as individual vehicular behavior is taken into consideration during this analysis.[4]

Birgunj Metropolitan City, one of the important commercial as well as industrial cities of Nepal, has a major transit route for trade with India that is likely to increase the traffic volume. There is a great chance for traffic congestion at the major intersections of the city. The LOS of the Buspark intersection at Birgunj Metropolitan City was found to be E with an average delay time of 66.4 sec.[5] Pedestrians at intersections in Birgunj often attempted to avoid the traffic rules creating a larger challenge for the management of traffic.[6] Likewise, the evaluation of the traffic flow in Birgunj is a tough task given that the traffic composition is mixed and the absence of lane discipline. The primary objective of the study is to evaluate the performance of the Gandak intersection and carry out a comparative analysis of the exiting signal timing with the results obtained from the simulation.

## Study Area

Gandak intersection is one of the busiest intersections in Birgunj Metropolitan City, Madhesh Province, Nepal. It is a three-legged intersection surrounded by Simara in the North, Power House in the South, and Pratima Chowk in the South East. The lane width of this intersection is measured as 3.0 m in the North and South-East directions, while 2.6 m in the South direction. The pictorial representation of the intersection is presented below in Figure 1.

The Google map image of the intersection is presented in Figure 2 below.

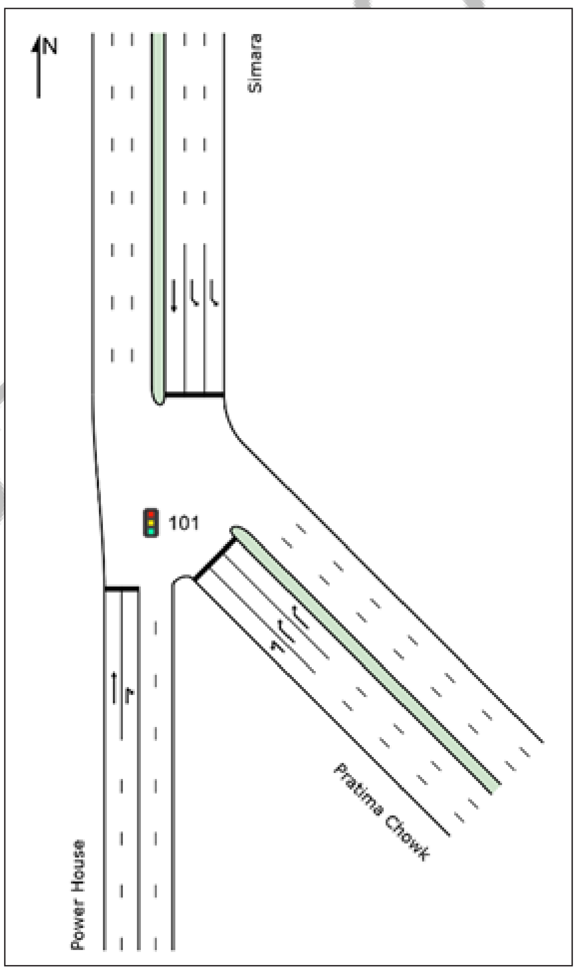


**Figure1.Gandak Intersection**

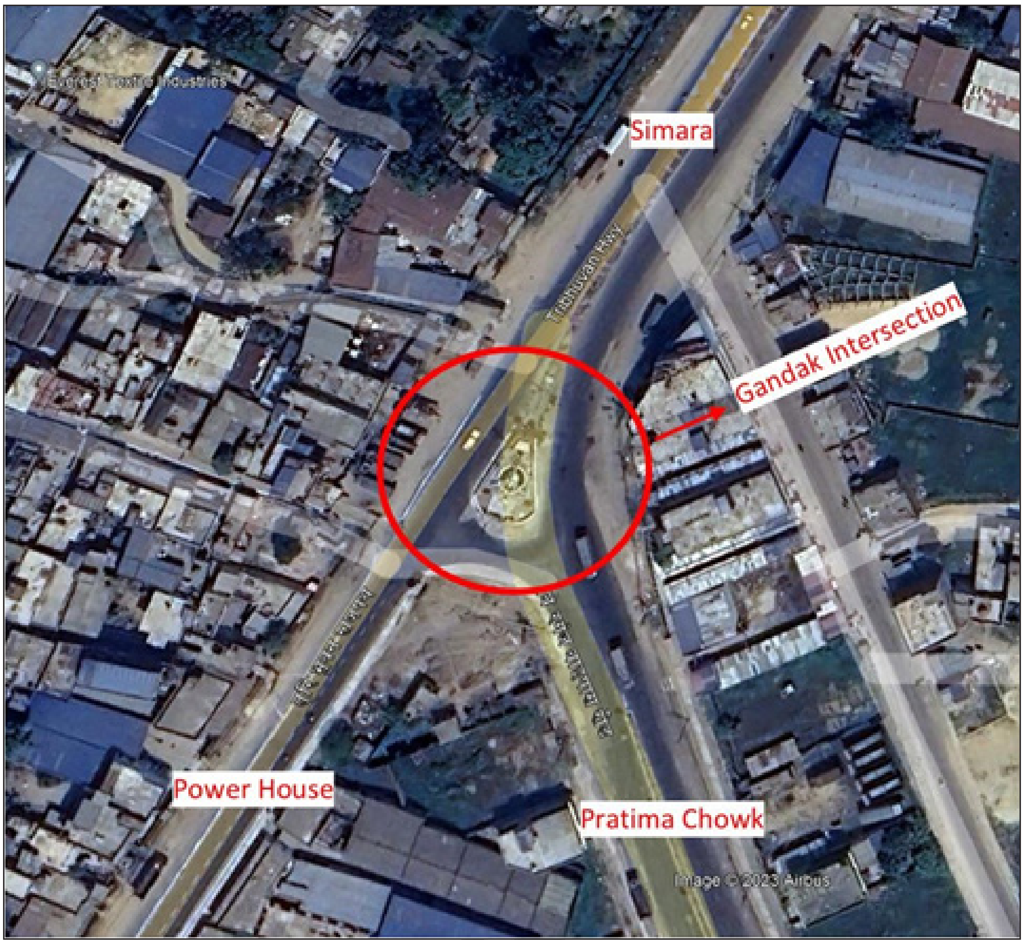


**Figure 2.Google map image of Gandak Intersection**



## Methodology

Before the start of the study, numerous research article was studied and the location for the study was selected. Traffic volume count, being a significant parameter for intersection performance evaluation, was carried out by manual counting on normal working days. During the process of collection of traffic data, the vehicles were categorized into different types. Distances were approximately measured from Google Maps. Likewise, phase data and turning movement were also observed manually. Data were collected for the peak hours in the morning and evening for three days during May 2023.

The data obtained from the field was utilized for modeling the existing scenario on SIDRA Intersection 8.0 which keeps parameters such as traffic flow, geometry of intersection, and signal timing under consideration. After that, the model was calibrated using the saturation flow values. The data that was recorded in the field was then compared with the one generated in the software. Then, the 95$^{th}$ percentile Back of the Queue was taken to validate the model. Finally, the intersection was evaluated in SIDRA by considering different scenarios. The flowchart representing the sequence of activities is illustrated in Figure 3.

## Literature Review

Different studies have been reviewed for the evaluation of the performance of the signalized intersection.

Kiran Dhakal[7] conducted a study on the existing situation of signalized intersections in Satdobato. The intersection's calibration and validation were done with the use of data collected in the field. For the optimization of the signal timing cycle length was changed and the left-turning movement was also controlled.

Deepa Karkee[8] carried out a video graphic survey for the classification of traffic volume, and subsequently, the data was converted into passenger car units during the peak periods of morning and evening. The analysis as well as simulation for the performance of the intersection was carried out by utilization of SIDRA 8.0 software. The performance of the intersection has been assessed with parameters such as degrees of saturation, LOS, and 95% degree of saturation.

Ranjitkar et al;[9] performed an analysis of the operational efficiency of the different intersections for a varied traffic volume with the use of SIDRA software. The intersection's capacity, overall emission, and average delay were

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the factors taken into consideration for the analysis. The analysis showed the strengths as well as weaknesses of the intersections for varied demand and traffic conditions.

Sisiopiku[10] studied the behavior of pedestrians at various urban crosswalks to figure out the perception of the pedestrians towards various roadside facilities. The facilities that were taken into consideration included signalized and un-signalized crosswalks, physical barriers, and warning signs. Pedestrian behavior was observed through video recording while the user survey helped in obtaining the perception of the pedestrian.

Fichera[11] compared the use of VISSIM and SIDRA for traffic analysis over intersections. Based on the comparison, SIDRA showed a higher average delay than VISSIM for the intersections with low traffic demand. Likewise, the research showed SIDRA was a better alternative given that the study is being carried out in a limited timeframe and smaller budget.

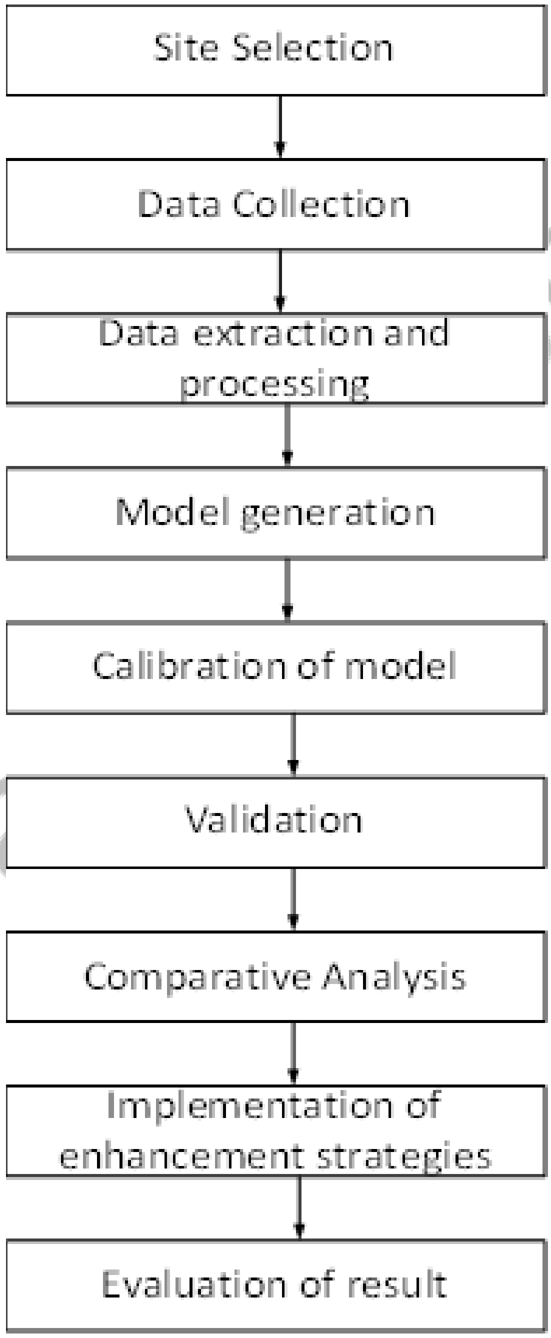


**Figure 3.Flowchart for evaluation of performance of the signalized intersection**

## Assessment of the current scenario

### Traffic Flow Analysis

Classified vehicle counts along a total of 6 directions were taken in the intersection. For analysis, the traffic volume was converted to passenger car equivalent (PCU). As recommended by HCM guidelines, the count was taken in 15-minute intervals. The traffic volume data was collected for a whole 24 hours on three weekdays. The number of motorcycles was significantly higher in comparison to other categories of the vehicle.

### Phase and Sequence Data

The intersection is isolated and already has a particular phase, operating in a three-phase cycle that takes 150 seconds to complete. The signal timing for the intersection had a pre-determined pattern and was maneuvered during higher traffic conditions. The existing phase and signal timing are presented in Table 1.

### Performance Analysis

In the three-legged intersection, Gandak Intersection, it was observed that the degree of saturation (DOS) was nearly one or higher on all approaches. Both the average delay, 67.6 sec, and LOS (E) of the intersection indicated the poor traffic conditions and the greater potential for congestion. Lane 1 is designated for left turns, Lane 2 is for straight movement and Lane 3 is for the straight as well as right turn direction of vehicles. The approach is the combination of lane 1, lane 2 and lane 3.

The average distance of the queue at the back of the intersection is 517.2, which implies that the green signal duration is insufficient to clear the queue at the approach. The summary for the performance measures in peak hour is presented in Table 2 below.

### Level of Service

The LOS of the intersection during peak hours is outlined in

**Table 1.Existing Phase and Signal Timing For Peak Hour Timing**

| Phase | A | B | C |
|---|---|---|---|
| Phase Change Time (sec) | 0 | 55 | 105 |
| Green Time (sec) | 47 | 42 | 37 |
| Phase Time (sec) | 55 | 50 | 45 |
| Phase Split | 37% | 33% | 30% |

**Table 2.Performance Measures in Peak Hour of The Intersection**

| | Performance Measures | | | | |
|---|---|---|---|---|---|
| | Demand Flows | Average | Level of | 95% Back of Queue | |
| | Total | Delay | Service | Veh | Dist. |
| | veh/h | sec | | | m |
| **South: Power House** | | | | | |
| **Lane 1** | 605 | 23.6 | LOS C | 26.6 | 215.5 |
| **Lane 2** | 193 | 244.7 | LOS F | 29.8 | 244.3 |
| **Approach** | 798 | 77 | LOS E | 29.8 | 244.3 |
| **South East: Pratima Chowk** | | | | | |
| **Lane 1** | 400 | 163.3 | LOS F | 48.6 | 517.2 |
| **Lane 2** | 494 | 57.8 | LOS E | 32.1 | 239.7 |
| **Lane 3** | 494 | 57.8 | LOS E | 32.1 | 239.7 |
| **Approach** | 1388 | 88.2 | LOS F | 48.6 | 517.2 |
| **North: Simara** | | | | | |
| **Lane 1** | 336 | 16.2 | LOS B | 10.2 | 102.4 |
| **Lane 2** | 336 | 16.2 | LOS B | 10.2 | 102.4 |
| **Lane 3** | 768 | 65.6 | LOS E | 60.4 | 341.1 |
| **Approach** | 1441 | 42.6 | LOS D | 60.4 | 341.1 |
| **Intersection** | 3627 | 67.6 | LOS E | 60.4 | 517.2 |



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Table 3 below. The LOS on the intersection was observed to be E. The level of service for the intersection is represented in Figure 4.

## Sidra Model Calibration and Validation

### Calibration

The field saturation flow data is compared to the software-generated data for saturation flow. Since there was no significant difference between the two, the computation was carried out using the input parameters listed in Table 4.

### Validation

The parameter for the validation is the 95th percentile of the queue at the back. The difference in the value of the observed queue at the back and the model-generated value is within a range of 20% which is presented in Table 5 below.

## Modifications After Performance In Optimum Cycle Length

To minimize the delay, the program-generated optimum signal time was adopted, replacing the current practical signal time by optimizing the phase split and cycle time, while keeping all other operating conditions constant. The optimum cycle time results are shown in Figure 5 and optimized phase timing is presented in Table 6 below. The process led to a decrease in average delay from 67 secs to 39 secs and an improvement of LOS to D. The LOS after using optimum phase timing is shown in Table 7.

**Table 3.Level of Service in the Intersection**

| | Approaches | | | Intersection |
|---|---|---|---|---|
| | South | Southeast | North | |
| LOS | E | F | D | E |

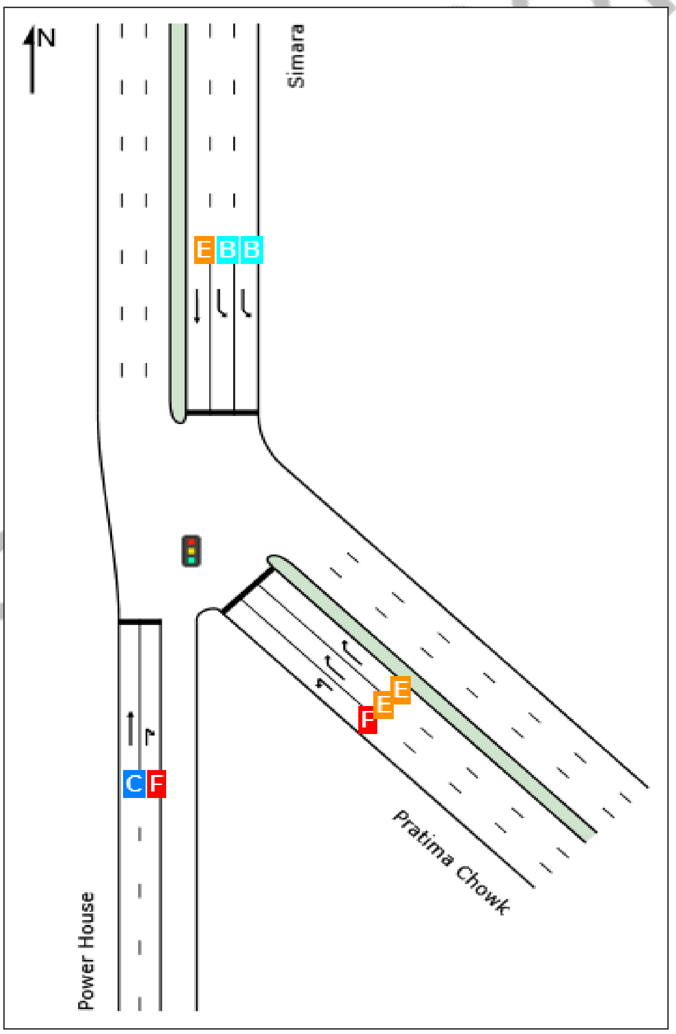


**Figure 4.LOS of Intersection**

**Table 4.Sidra Calibration Input**

| Parameters | Value | Remarks |
|---|---|---|
| Base Saturation Flow | 1900 | Program Recommended |
| Lane Utilization Ratio | Program | Program Calculated |
| Saturation Speed | Program | |
| Capacity Adjustment | 0% | No Capacity Adjustments |
| Buses Stopping | 0 veh/hr | No bus bays within 75m |
| Parking Maneuvers | 0 veh/hr | No Parking Lane |

**Table 5.Observed vs Model-Generated Back of Queue**

| Approach | Mode | Observed | Difference (%) |
|---|---|---|---|
| South: Power House | 602 | 490 | 18.6 |
| North: Simara | 1210 | 978 | 19.2 |
| South East: Pratima Chowk | 785 | 638 | 18.7 |

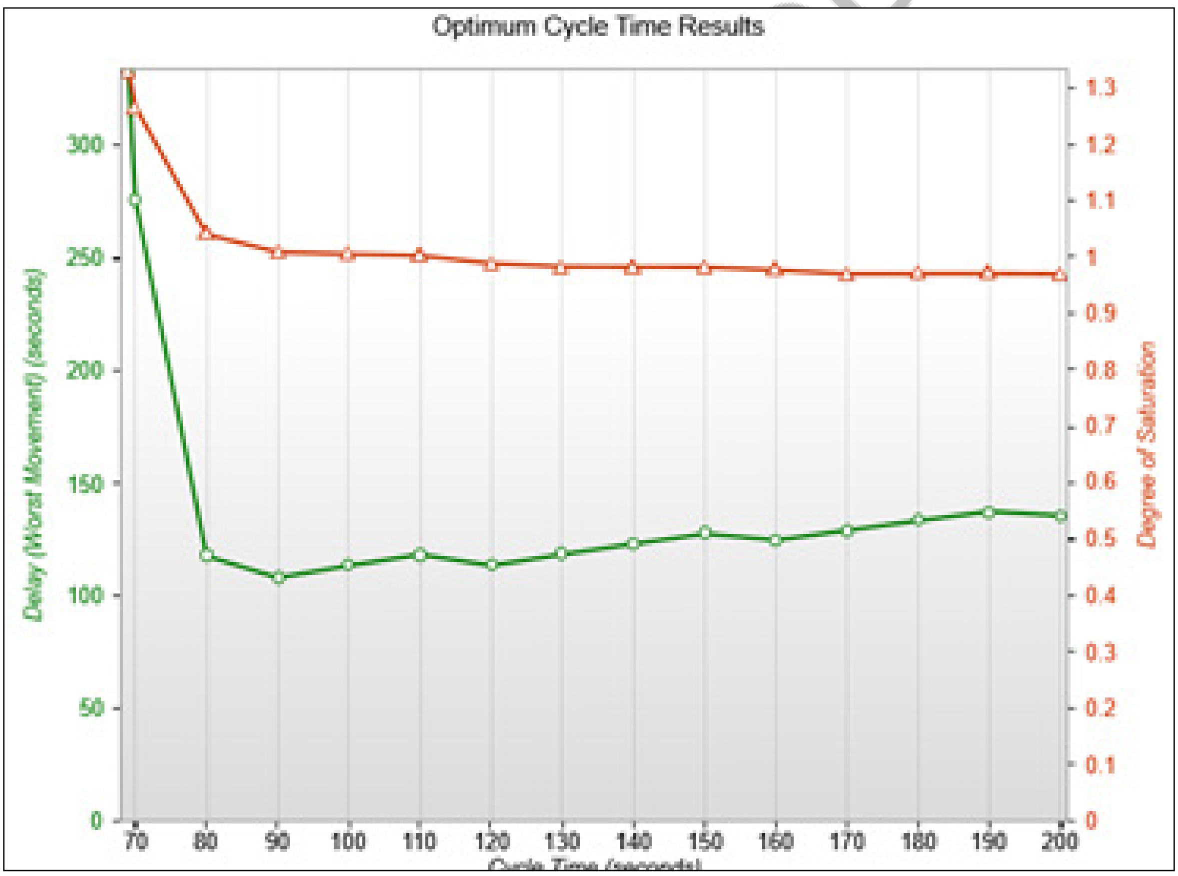


**Figure 5.Optimum Cycle Time Results**

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**Table 6.Optimized Phase Timing**

| Performance | | | | | |
|---|---|---|---|---|---|
| | Demand Flows | Average | Level of | 95% Back of Queue | |
| | Total | Delay | Service | Veh | Dist |
| | veh/h | sec | | | m |
| **South: Power House** | | | | | |
| **Lane 1** | 605 | 18.2 | LOS B | 16.9 | 136.4 |
| **Lane 2** | 193 | 117.1 | LOS F | 15 | 123.4 |
| **Approach** | 798 | 42.1 | LOS D | 16.9 | 136.4 |
| **South East: Pratima Chowk** | | | | | |
| **Lane 1** | 400 | 7.5 | LOS A | 2.2 | 23.9 |
| **Lane 2** | 494 | 44.7 | LOS D | 21.4 | 159.7 |
| **Lane 3** | 494 | 44.7 | LOS D | 21.4 | 159.7 |
| **Approach** | 1388 | 34 | LOS C | 21.4 | 159.7 |
| **North: Simara** | | | | | |
| **Lane 1** | 336 | 5.4 | LOS A | 1.6 | 16.2 |
| **Lane 2** | 336 | 5.4 | LOS A | 1.6 | 16.2 |
| **Lane 3** | 768 | 75.3 | LOS E | 48.6 | 274.4 |
| **Approach** | 1441 | 42.7 | LOS D | 48.6 | 274.4 |
| **Intersection** | 3627 | 39.2 | LOS D | 48.6 | 274.4 |

**Table 7.Los of the Intersection After Optimum Phase Timing**

| | **Approaches** | | | **Intersection** |
|---|---|---|---|---|
| | South | Southeast | North | |
| LOS | D | C | D | D |

## Comparison of the Results

Keeping the criteria such as Average Delay, LOS, and Back of Queue, under consideration, the performance variances are figured out. The saturation in one lane affects the adjacent lane due to a lack of lane discipline. Thus, the shift in the level of saturation in individual lanes is not considered for the evaluation of the performance of the system after modifications. Instead of using the program-determined approach Back of Queue, a comparison is made using the average back of queue in lanes of an approach measured in distance. This is done while taking into account how neighboring lane queues are adjusted during rush hour by road users.

For the existing condition, the level of service was E. After the analysis of the possible scenario, the level of service was improved to D after the optimization of signal time. The average delay was decreased by 42% while adopting the changes. Likewise, the average Back of Queue also had a decrement of 20% after incorporating the changes. The graphical comparison for the average delay and queue length is presented in Figure 6 and Figure 7 respectively.

## Conclusion

The study focused on the evaluation of the performance of the Gandak intersection, which is a very busy intersection. The degree of saturation was equal to one and the level of service was poor i.e., E. The average delay time was also quite high causing a higher queue length. The existing condition of the intersection can be concluded as severe as the delay time as well as queue length is high for both morning and evening. To address the issue, optimization for the phase split and cycle time was done for the current operational condition. Upon making the change the average delay time was reduced significantly and the level of service was also improved to D.

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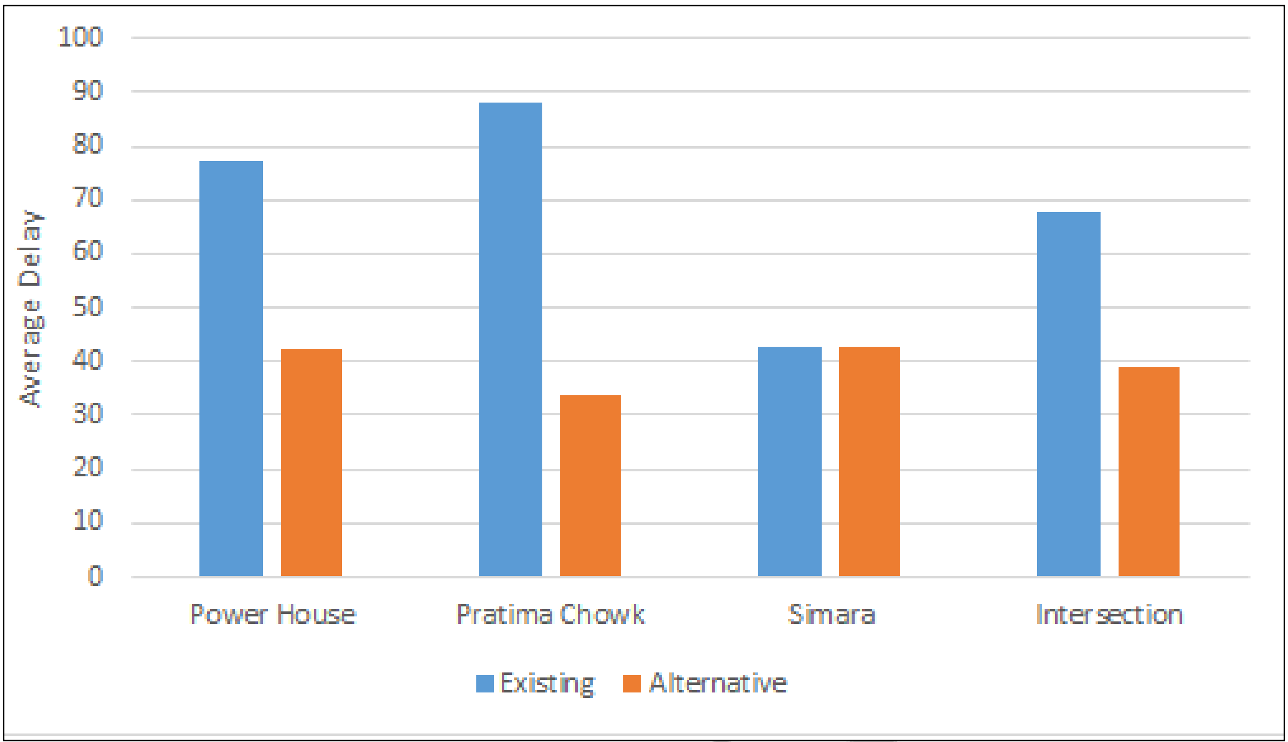


**Figure 6.Average Delay Comparison Chart**

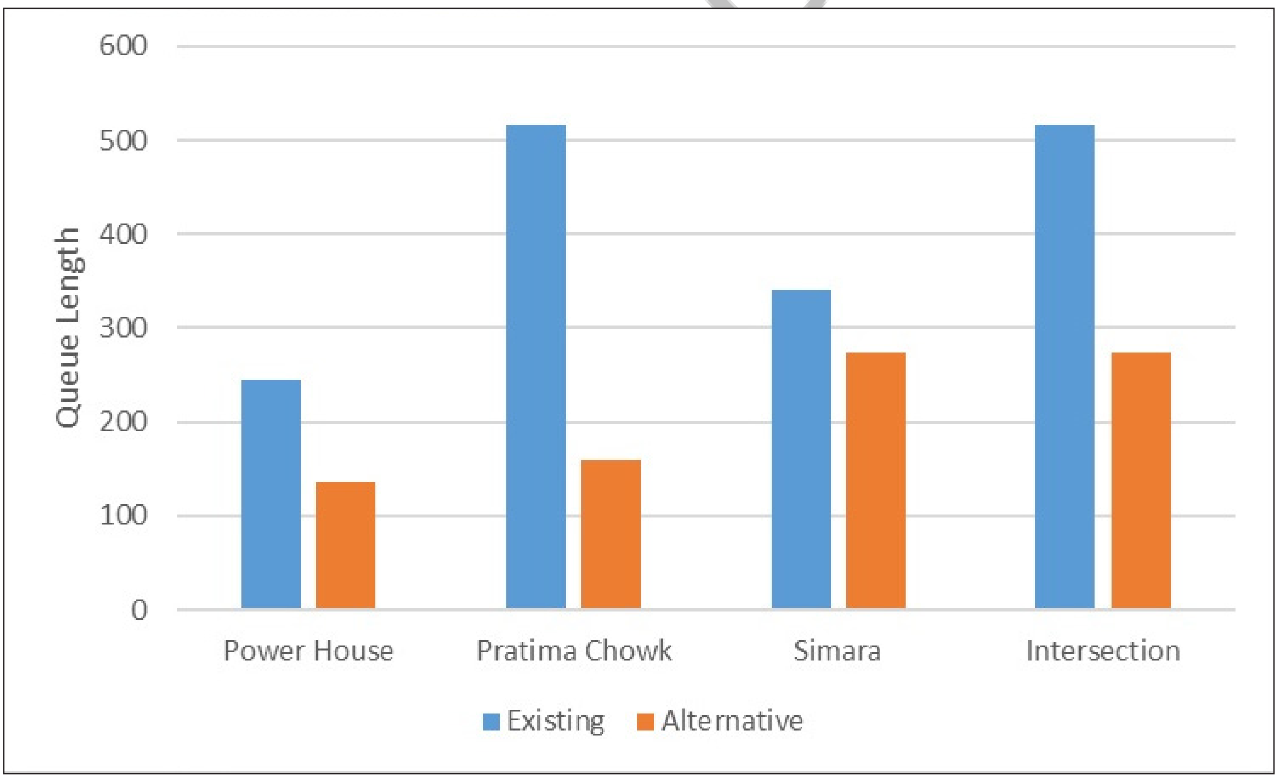


**Figure 7.Queue length comparison Chart**

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## Reference

1. A Pokhrel, D S Basnyat, S Luitel, et al. "Performance Assessment of a Signalized Intersection : A Case Study of Jay Nepal Intersection," International Conference on Engineering & Technology, KEC Conference Proceedings, 2023.
2. H Tiwari, S Luitel, A. Pokhrel, "Optimizing Performance at Signalized Intersections through Signal Coordination in Two Intersections of Nepal Optimizing Performance at Signalized Intersections through Signal Coordination in Two Intersections of Nepal," *Journal of Transportation Systems*, vol. 8, no. 1, pp. 22–32, 2023, doi: 10.46610/JoJoTS.2023.v08i01.004.
3. S. Shrestha, A. Marsini, "Development of Saturation Flow and Delay Model at Signalised Intersection of Kathmandu Data Analysis," Proceedings of IOE Graduate Conference, pp. 387–392, 2014.
4. K Prajapati and H Tiwari, "Traffic Delay Assessment And Scenario Projection Of Ekantakuna- Satdobato Section Of Kathmandu Ring Road ( NH-39 )," International Conference on Engineering & Technology, KEC Conference Proceedings, pp. 155–161, 2022.
5. S Luitel, A Pokhrel, H Tiwari. et al. "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*, vol. 10, no. 2, pp. 22–33, 2023, doi: https://doi.org/10.24321/2456.4370.202307.
6. G K Jha, A Acharya, H Tiwari, "Public Perception Study On Road Crossing Facilities And Determination Of Waiting Time," International Conference on Engineering & Technology, KEC Conference Proceedings, pp. 145–148, 2022.
7. K Dhakal, H Tiwari, S Luitel, "Evaluation and Performance Enhancement of four Legged Intersection: Satdobato, Nepal," Journal of Advanced Research in Construction and Urban Architecture, vol. 8, no. 1, pp. 23–30, 2023, doi: 10.24321/2456.9925.202303.
8. D Karkee, H Tiwari, S Dhungel, "Impact of Roundabout Metering on the Operational Performance of Impact of Roundabout Metering on the Operational Performance of Roundabout : A Case Study of Jawalakhel, Nepal," *Journal of Transportation Systems*, vol. 8, no. 2, pp. 26–33, 2023, doi: 10.46610/JoTS.2023.v08i02.004.
9. P Ranjitkar, A Shahin, F Shirwali, "Evaluating Operational Performance of Intersections Using SIDRA," *The Open Transport Journal*, vol. 8, pp. 50–61, 2014.
10. V P Sisiopiku, D Akin, "Pedestrian behaviors at and perceptions towards various pedestrian facilities : an examination based on observation and survey data," Transportation Research Part F: traffic psychology and behavior, vol. 6, no. 4, pp. 249–274, 2003, doi: 10.1016/j.trf.2003.06.001.
11. Fichera A. A practical comparison of VISSIM and SIDRA for the assessment of development impacts 2011.