

# PERFORMANCE EVALUATION AND OPTIMIZATION OF TWO CLOSELY SPACED INTERSECTIONS: A CASE STUDY OF EKANTAKUNA AND NAKKHU DOBATO INTERSECTIONS IN LALITPUR

Sujan Thapa<sup>1\*</sup>, Pradeep Kumar Shrestha<sup>2</sup>

<sup>1\*</sup>Graduate Research Student, Department of Civil Engineering, Pulchowk Campus, Institute of Engineering

<sup>2</sup>Assistant Professor, Department of Civil Engineering, Pulchowk Campus, Institute of Engineering

\*Correspondence to: [sujanthapa32@gmail.com](mailto:sujanthapa32@gmail.com) (S. Thapa)

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## ABSTRACT

Most of the intersections in Kathmandu Valley suffer from long queues and delays, especially during peak hour times of the day. Such long queues and delays are more pronounced in those intersections which are situated near to one another because of lack of coordination among the flow between the two intersections and also due to queue spillback from one intersection to the another. One such place is situated at Ekantakuna Lalitpur where two intersections viz. Ekantakuna Intersection and Nakkhu Dobato intersections are situated close to one another (~300m). Currently operating under manual traffic police control, these intersections face significant congestion due to high traffic volumes and terminal queuing interference. Using SIDRA INTERSECTION software, the existing traffic condition of the intersections were modelled to determine the existing Level of Service (LOS), Degree of Saturation (DOS) and Average delay at each of the intersections. It was found that Nakkhu Dobato intersection exhibited a global DOS of 2.33 (LOS F) while Ekantakuna reached a DOS of 1.63 (LOS E) during the peak hours. Then the software was used to optimize the intersections, individually with traffic signals and with coordinated traffic signal system to determine the improvement of the traffic flow through the intersections. The results showed that while isolated optimization provides marginal improvement, coordinated signal control yields the most significant improvements for the corridor. Under coordination, the global DOS at Ekantakuna improved to 0.98 (LOS D) and even though the Nakkhu Dobato intersection exhibited DOS of 1.7 (LOS D), it was far better than the original DOS at the intersection. These findings suggest that implementing coordinated signal systems is essential for managing the closely spaced intersections in oversaturated urban environments like the Kathmandu Valley.

**Keywords:** Closely spaced intersections, SIDRA INTERSECTION, Signalization, coordinated signal control, Level of Service (LOS)

## 1. Introduction

The total vehicle registration has increased from around 10% in the Kathmandu Valley from the

fiscal year 2018/19 to 2019/20 (Thapa & Adhikari, 2021). However, the traffic infrastructure has not been developed as rapidly as number of vehicles. This imbalance has created a severe rise in congestion and delay in routes of the valley. Congestion is generally seen at the intersections, where it is more pronounced in areas where two or more intersections are close to one another. Traffic intersections being close to one another have been the main reason for traffic congestion and delay, where traffic from one intersection can spill back to the other intersection, the phenomenon known as terminal queuing. One such location is at Lalitpur where Ekantakuna and Nakkhu Dobato intersections are situated relatively close to one another causing severe congestion and delay at the location especially during the peak hour periods.

Currently, these intersections are manually controlled by traffic police. While traffic police can make adjustment to the traffic flow visually, it lacks the precision of actual traffic signals and also the coordination among the intersections is not possible. That is why systematic signal timing plan is necessary to make precise traffic flow control to minimize the delay and high degree of saturation in these intersections (Akcelik, 1981; IHCM, 1993). In traffic engineering, one of the popular concepts is signal coordination. It generally refers to the timing of the signals so that a platoon of cars traveling on a street arrives at a succession of green lights and proceeds through multiple intersections without stopping (Bhattarai & Marsani, 2017). Improvement of traffic signal timing and using traffic signal coordination are two of the most important strategies for reducing delay, travel time and queue length in urban area (Nesheli et al., 2009).

The Ekantakuna-Nakkhu corridor serves as a vital link for commuters moving through the ring road and towards southern Lalitpur. Previous observations have indicated that during peak hours, the traffic demand in this corridor is higher than the capacity of the road, resulting in Level of Service (LOS) of F at Nakkhu Dobato and LOS E/F at Ekantakuna. Specifically, the heavy right turning movement and the high volume of straight through traffic on the ring road creates the bottlenecks which manual traffic control struggles to mitigate.

## 1.2 Problem Statement and Objectives

The rapid growth of vehicles in Kathmandu valley has outpaced the development of traffic infrastructures and the implementation of modern traffic management systems (Luitel, et al., 2025). Ekantakuna and Nakkhu Dobato intersections is one of those examples where traffic demand is more than the capacity of the intersection during peak hour periods and the performance of the corridor is dependent on efficiency of one another.

The core challenges for the corridor can be summarized as follows:

- **Inefficiency of Manual Control:** Manual traffic control system lacks precision to synchronize the timing between adjacent intersections to allow for smooth break free movement through the intersections.
- **Intersection Oversaturation:** Preliminary observations indicate that both the intersections are operating beyond their practical capacities.
- **The Spillback Effect:** Due to short distance between the intersections, queues from downstream intersections expand into the upstream crossing blocks (IHCM, 1993; Roess, et al., 2010).
- **High Control Delays:** Absence of automated control system have resulted in excessive control delays and commuter time losses (Akcelik, 1981).

The general objective of this study is to assess the operational performance of the Ekantakuna and Nakkhu Dobato intersections and to develop strategies for improving traffic efficiency. The Specific objectives are:

- To evaluate the current operational performance using key parameters such as delay, DOS and LOS through SIDRA INTERSECTION Software.
- To develop optimization alternatives, including network offset coordination and signal adjustments.
- Comparing the structural performance shifts between alternative scenarios.

## 2. Literature Review

Intersections determine the actual operational efficiency of urban road networks (Roess, et al., 2010). In Kathmandu valley, congestion generally occur at the intersections especially in those that are situated close to one another. At these locations spillback or terminal queuing occurs where the queues from a downstream intersection obstruct the upstream node. This results in excessive delays and reduced travel efficiency. Previous studies by the Asian Development Bank (ADB, 2020) and JICA (JICA, 2016) emphasize that inadequate public transport and reliance on private vehicles further strain these unmanaged junctions.

One of the standard measures of efficiency of intersection is vehicle delay where the vehicle spends additional time while traversing a junction compared to an uninterrupted flow (Roess, et al., 2010). To provide a qualitative assessment, the Level of Service (LOS) is utilized to categorize performance from A to F based on the Indonesian Highway Capacity Manual (IHCM, 1993). Under this framework, LOS A represents free-flow conditions with minimal delay, while LOS F signifies oversaturated, forced-flow conditions where demand exceeds capacity and delays are extreme.

Traffic signal coordination is essential for managing closely spaced intersections (IHCM, 1993). The primary goal is to facilitate a “green wave”, where traffic from one intersection flows uninterrupted through the other intersection. This is achieved by calculating optimal “offsets” - the time relationship between green phases at adjacent nodes. Research by the FHWA (Federal Highway Administration (FHWA), 2008) and recent studies in Nepal (Tiwari et al., 2023) indicate that coordinated systems significantly reduce fuel consumption, emissions, and stop-and-go cycles compared to isolated or manual control.

Traffic performance of any intersection can be analyzed through microsimulation or micro-analytical modeling. SIDRA INTERSECTION is a prominent micro-analytical tool that uses lane-by-lane analysis to estimate capacity, delay and queue lengths (Akcelik, 1981). Unlike aggregate models, SIDRA accounts for specific lane configurations and geometric constraints, making it highly effective for modeling complex urban intersections (Akçelik, 1990; Akcelik, 1981).

There are many studies conducted in Nepal as well as other countries having similar traffic conditions as in Nepal. A study conducted in Pakistan used SIDRA INTERSECTION to model and improve the traffic condition at the Muslim Town intersection. It was successful in improving the existing performance of the intersection from Level of Service (LOS) F to D (Khalid & Jameel, 2024).

There are many studies conducted in Nepal as well where SIDRA was used to simulate the traffic scenario and test various alternatives to minimize delay (Pokhrel, et al., 2023; Budhathoki & Shrestha, 2024; Adhikari, et al., 2025). For instance, a performance evaluation of the Ekantakuna intersection

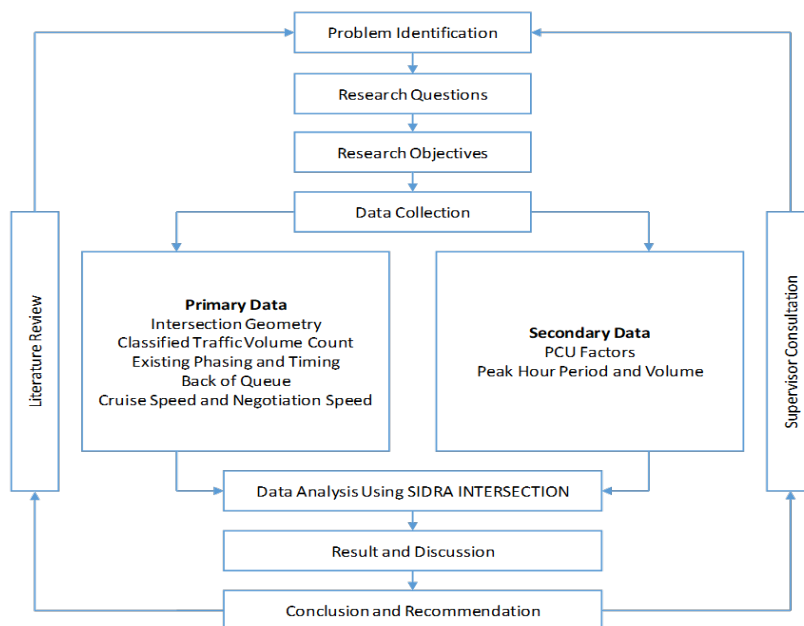
using SIDRA 8.0 showed that the base scenario operated at a poor LOS E with an average delay of 72.7 seconds; however, the model demonstrated that signal optimization could drop delays to 53.6 seconds, while grade separation would reduce delays down to 40.1 seconds (Hollander & Liu, 2008). Similarly, a study at the heavily congested Satdobato intersection utilized SIDRA 9.0 to evaluate signalization strategies, determining that optimizing individual signal phasing and cycle timings could significantly drop baseline vehicle delays (Marler, 1993). Another micro-analytical assessment at Satdobato using SIDRA 8.0 found that while optimal signal timing could improve the intersection, introducing a structural flyover alternative yielded the highest performance enhancement, upgrading the intersection from LOS F to LOS C.

Studies have shown that while SIDRA may provide slightly higher delay estimates than some simulation tools, its results for capacity and signal timing optimization are highly reliable when calibrated with local field data (Roess et al., 2010).

### 3. Methodology

#### 3.1 Research Design and Approach

This study adopts a quantitative approach to evaluate the operational performance of two closely spaced intersections; Ekantakuna and Nakkhu Dobato Intersection situated approximately 300 meters apart on the Ring Road corridor in Lalitpur, Nepal. The research framework consists of field data collection, geometric modeling and traffic simulation using SIDRA INTERSECTION software (Akcelik, 1981). The methodology follows a structured sequence; site characterization, primary and secondary data collection, model calibration/validation and scenario-based performance evaluation. The overall methodological sequence adopted in this study is illustrated in Figure 1.



*Figure 1. Flowchart of Research Methodology*

Primary traffic data were collected via CCTV footage over three consecutive weekdays (March 3-5, 2025). Morning and evening peak hours were then established for both the intersections. Heterogeneous traffic was standardized using Passenger Car Units (PCU) to ensure comparable analysis. PCU factors were adopted from the Department of Roads (DoR) Highway Management Information System guidelines (Bhattarai & Marsani , 2017).

**Table 1. Key Local PCU Factors**

| Vehicle Type   | PCU Factor |
|----------------|------------|
| Heavy Truck    | 3.0        |
| Bus / Mini-Bus | 2.5        |
| Car / Utility  | 1.0        |
| Motorcycle     | 0.5        |
| Bicycle        | 0.25       |

### 3.2 Study Area

Ekantakuna and Nakkhu Dobato Intersections are two major intersections on Ring Road which are located around 300 meters apart. The Ekantakuna intersection functions as a key junction connecting the Ring Road with the Jawalakhel-Satdobato corridor, while the Nakkhu Dobato intersection serves traffic movements from the Nakkhu and Lagankhel directions. Each intersection has four legs and their proximity results in strong interaction between traffic streams. Currently, traffic operations at both locations are manually controlled by traffic police rather than signalized systems.



**Figure 2 .Ekantakuna and Nakkhu Dobato Intersection**

### 3.3 Desk and Field Study

Extensive literature reviews of previously done research were done. Datasheet for volume count and other measurements were prepared.

Using videographic survey, traffic volume data of both intersections were determined. Data was collected manually where probable errors in counting and efficiency were kept in mind. Data was

collected for three consecutive weekdays from 3 to 5 March 2025 in a 15-minute time interval. Measurements of geometrical properties of intersections were also measured.

### 3.4 Modeling, validation and calibration

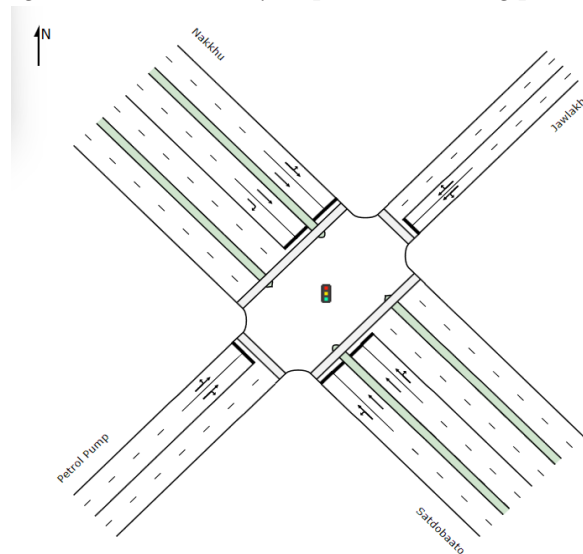
From the analysis of traffic volume data, two peak periods, a morning peak and an evening peak were found. Necessary data for SIDRA Intersection software was then input and model was constructed. The data obtained from the field was then checked for validation and necessary calibration was done to achieve the most accurate replication of local traffic conditions as measured in the field by the model. The SIDRA model was calibrated using data from the first two study days, focusing on localized gap-acceptance and discharge rates. The calibration and validation of the model were analyzed based on queue data and the queue length as calculated from the field and model was compared such that error would be within 20% margin.

## 4. Data Analysis & Results

After creating the model in SIDRA INTERSECTION software, individual existing performance of both intersections were determined through simulation analysis. Then, at first both intersections were optimized through the software one at a time and performance analysis of the intersection was determined and it was compared with the existing performance of the intersection. After that, network of intersections was created in the software and again performance evaluation was done through coordinated signalized control system. Finally, the results were compared to determine the best alternative for the corridor to minimize the congestion and delay.

Firstly, Ekantakuna Intersection was analyzed for its existing performance. It is a four-legged cross junction located on the ring road of Kathmandu valley which connects four approach roads, Nakkhu, Jawalakhel, Satdobato and Petrol Pump.

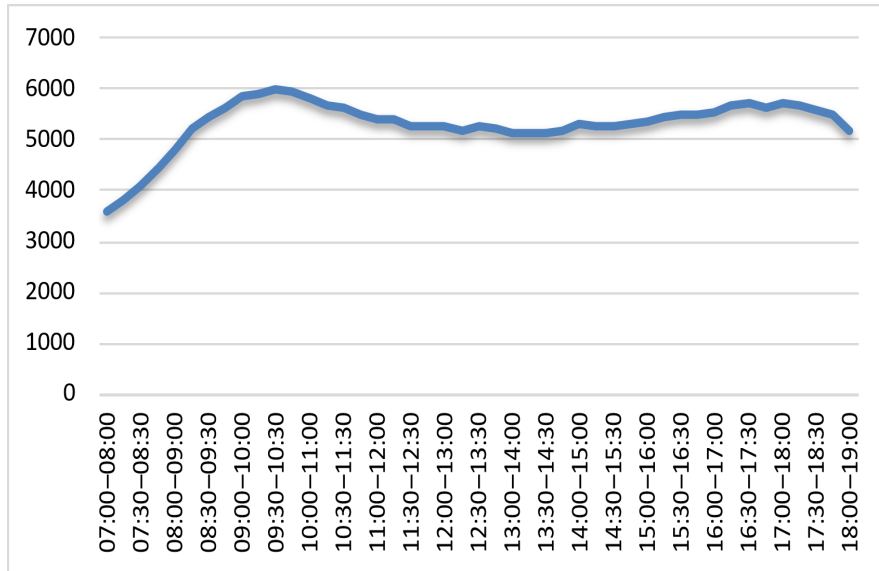
Traffic is managed through manual control by Nepal Police during peak hours.



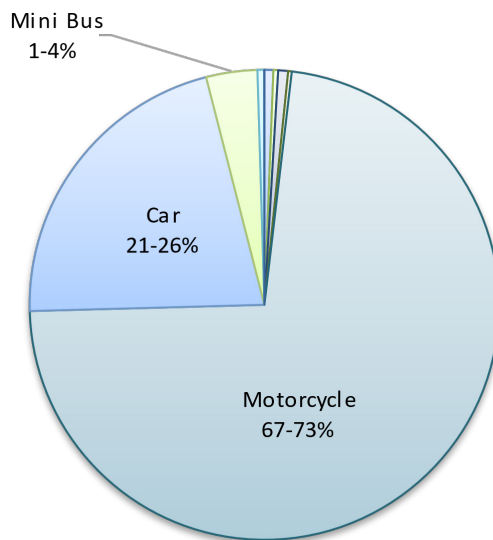
**Figure 3 .Ekantakuna Intersection**

When traffic counting was completed and analyzed, the peak hour was found to be 9:30-10:30 in

the morning with peak traffic volume of 5988.5 PCU/h and 16:30-17:30 in the evening with peak traffic volume of 5727 PCU/h.



**Figure 4 .Traffic Volume Distribution**



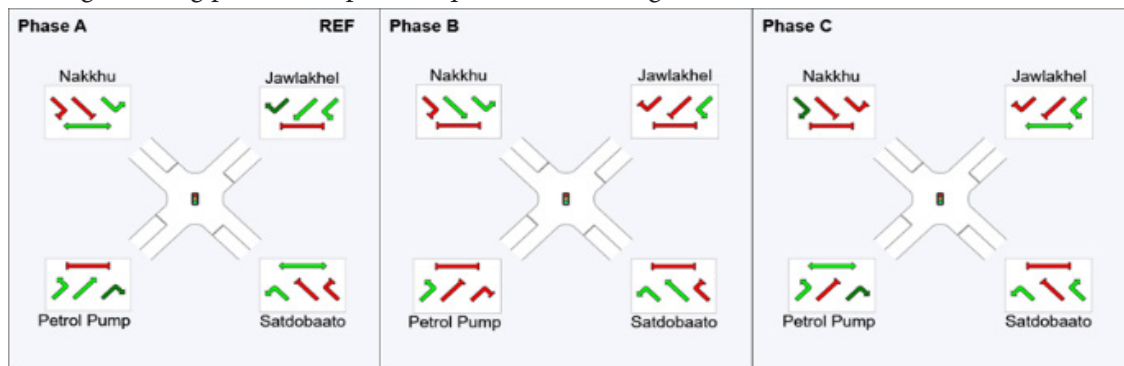
**Figure 5. Vehicle Proportion in Ekantakuna**

The vehicle composition of Ekantakuna Intersection shows that during both the peak hours; the proportion is significantly dominant by Motorcycles (>50%) followed by the car.

After analyzing the videographic data, it was found that the intersection operates with a three-phase system during morning period and a four-phase system during the evening period. To analyze the operational timing under manual control, the duration of each cycle was recorded continuously

over a one-hour period. The collected data was then averaged to determine the typical cycle length and the average duration of each phase within the cycle.

During morning period, the phase sequence and timing were found as below:



*Figure 6. Phase sequence of Ekantakuna during morning*

*Table 2. Phase Timing of Ekantakuna during Morning*

| Phase                   | A   | B   | C   |
|-------------------------|-----|-----|-----|
| Phase Change Time (sec) | 0   | 39  | 76  |
| Green Time (sec)        | 34  | 32  | 12  |
| Phase Time (sec)        | 39  | 37  | 17  |
| Phase Split             | 42% | 40% | 18% |

Under Existing condition, the operational performance of Ekantakuna Intersection was analyzed in SIDRA INTERSECTION. It was found as follows:

*Table 3. Existing Performance of Ekantakuna Intersection during Morning*

| Existing Condition (cycle time: 93 sec) |              |                    |                     |              |
|-----------------------------------------|--------------|--------------------|---------------------|--------------|
| Approaches                              | Existing DOS | Existing BOQ (Veh) | Existing BOQ (DIST) | Existing LOS |
| Satdobato                               | 0.81         | 21.4               | 93                  | C            |
| Jawalakhel                              | 1.11         | 48.4               | 211                 | D            |
| Nakkhu                                  | 0.6          | 14.8               | 64                  | C            |
| Petrol Pump                             | 0.94         | 28.1               | 122                 | D            |
| Intersection                            | 1.11         | 48.4               | 211                 | C            |

Under the existing signal timings with a 93-second cycle, the Ekantakuna intersection exhibits

mixed operational performance across its approaches. The Satdobato and Nakkhu approaches operate at moderate saturation while Jawalakhel and Petrol pump approaches operate at higher saturation. Overall, the intersection has Degree of Saturation of 1.11 and Back of Queue distance of 211m.

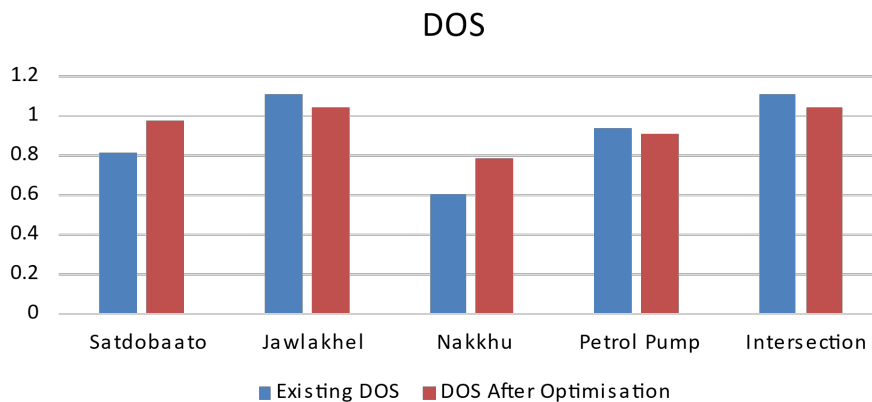
After optimizing the intersection in SIDRA Intersection, phase time values were changed with overall cycle time of 90 seconds, which resulted in performance as shown below:

**Table 4. Phase Timing at Ekantakuna Intersection during morning after Optimization**

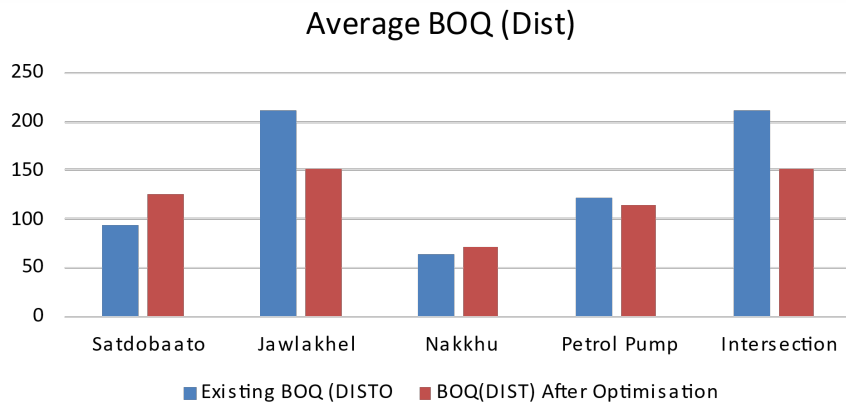
| Phase                   | A   | B   | C   |
|-------------------------|-----|-----|-----|
| Phase Change Time (sec) | 0   | 45  | 74  |
| Green Time (sec)        | 40  | 24  | 11  |
| Phase Time (sec)        | 45  | 29  | 16  |
| Phase Split             | 50% | 32% | 18% |

**Table 5. Performance at Ekantakuna Intersection during morning after optimization**

| Signal Optimization (Cycle time 90 sec) |      |         |         |     |
|-----------------------------------------|------|---------|---------|-----|
| Approaches                              | DOS  | BOQ (V) | BOQ (D) | LOS |
| Satdobato                               | 0.98 | 28.6    | 126     | D   |
| Jawalakhel                              | 1.04 | 34.9    | 152     | C   |
| Nakkhu                                  | 0.78 | 16.5    | 72      | C   |
| Petrol Pump                             | 0.91 | 26.7    | 115     | C   |
| Intersection                            | 1.04 | 34.9    | 152     | D   |



**Figure 7. DOS comparison before and after optimization at Ekantakuna Intersection during morning period**



**Figure 8. Average BOQ Distance comparison between before and after optimization at Ekantakuna Intersection during Morning Period**



**Figure 9. Phase Sequence of Ekantakuna Intersection during evening period**

A comparison of existing and optimized signal timings at the Ekantakuna intersection shows notable improvements in traffic operations. Since it is not possible to increase the dimensions of the lanes, optimization basically mitigated severe localized congestion by equitably redistributing capacity across the corridor. Under existing condition, there was a critical bottleneck at the Jawalakhel approach, which operated at a failing DOS of 1.11 and generated a severe BOQ of 211 meters. After optimization DOS was brought down to 1.04 and queue length was shortened by 28 % i.e. 152 meters and successfully upgrading its individual level of Service (LOS) from D to C. Interestingly, it can be observed that although optimization helped mitigate issues in approaches of the intersection but overall, LOS of the intersection changed from C to D. It happened due to an increase in average weighted delay on the major approaches after the optimization.

During the evening peak, the Ekantakuna intersection operates under a four-phase control system within a total cycle length of 93 seconds. Phase sequence and timing are as follows:

**Table 6. Phase Timing of Ekantakuna during Evening Peak**

| Phase                   | A   | B   | C   | D  |
|-------------------------|-----|-----|-----|----|
| Phase Change Time (sec) | 0   | 28  | 59  | 85 |
| Green Time (sec)        | 23  | 26  | 21  | 3  |
| Phase Time (sec)        | 28  | 31  | 26  | 8  |
| Phase Split             | 30% | 33% | 28% | 9% |

And the operational performance of the intersection during peak evening period was obtained as follows:

**Table 7. Performance of Ekantakuna during Evening Peak**

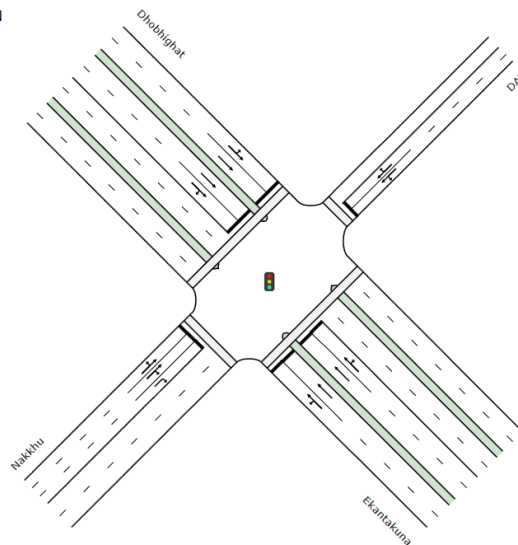
| Existing Condition (cycle time: 93 sec) |              |                    |                     |              |
|-----------------------------------------|--------------|--------------------|---------------------|--------------|
| Approaches                              | Existing DOS | Existing BOQ (Veh) | Existing BOQ (DIST) | Existing LOS |
| Satdobato                               | 1.63         | 47.4               | 201                 | F            |
| Jawalakhel                              | 0.54         | 14.7               | 64                  | C            |
| Nakkhu                                  | 0.64         | 15.3               | 68                  | C            |
| Petrol Pump                             | 0.92         | 34.5               | 151                 | D            |
| Intersection                            | 1.63         | 47.4               | 201                 | E            |

The overall LOS of the Ekantakuna intersection during evening peak was found to be E with DOS of 1.63.

The existing practical cycle time of 93s was then re-optimized using SIDRA INTERSECTION; however, the model retained the same cycle length. The optimized results showed no change in the degree of saturation, queue length or level of service across all approaches. This indicated that the current cycle time was already near-optimal for the prevailing traffic demand and that further improvements could not be made through cycle length adjustment alone under existing traffic

conditions.

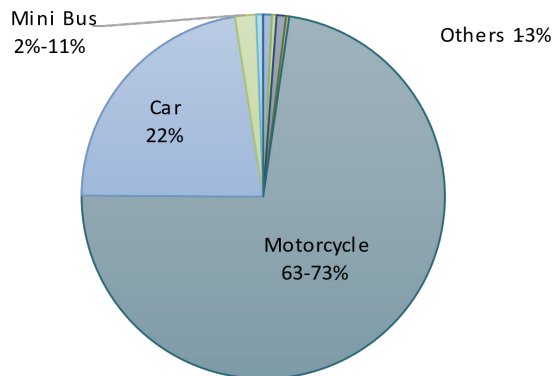
After Ekantakuna Intersection, Nakkhu Dobato Intersection was analyzed for its morning and evening peak hour period.



**Figure 10. Nakkhu Dobato Intersection**

This intersection has four approaches viz. Dhobighat, Nakkhu area, Ekantakuna and DAV School area. After analyzing the videographic data, it was found that the morning peak was 5720 PCU/h at 09:00-10:00 and evening peak was 5628 PCU/h at 16:45-17:45.

Like Ekantakuna Intersection, Major vehicle class through Nakkhu Dobato Intersection was also found to be motorcycles as shown in Figure below:

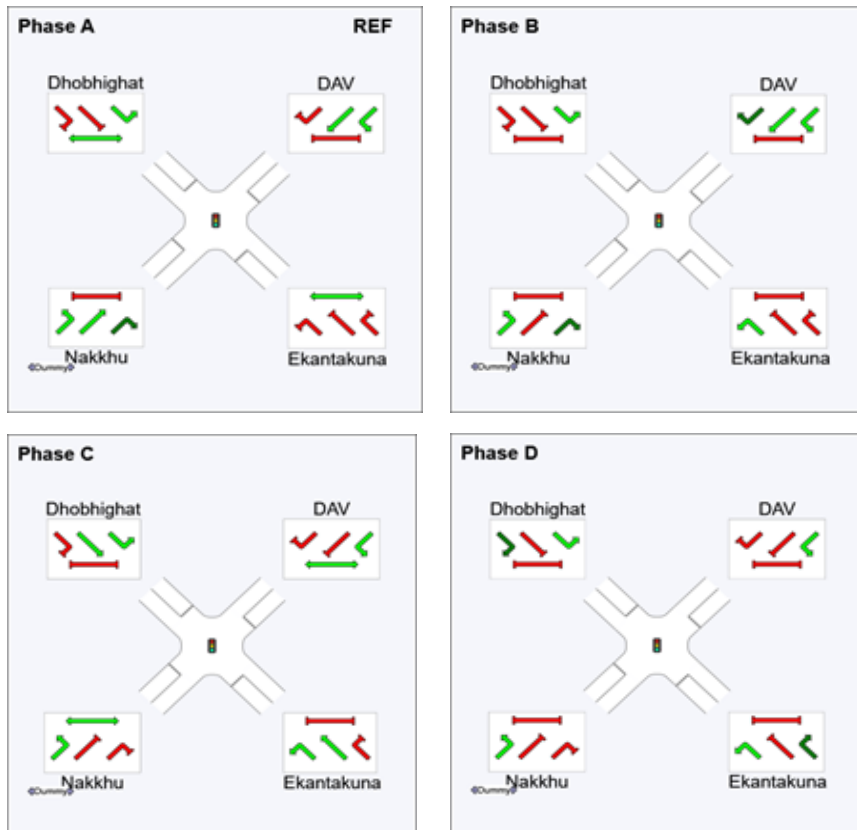


**Figure 11. Proportional Vehicle in Nakkhu Dobato**

Like Ekantakuna Intersection, this intersection is also managed manually by traffic police during

peak hour periods. The intersection operated with a four-phase system, where each phase corresponds to the movement of vehicles from specific approach legs or movement types.

During morning peak period, the phase sequence and timing of Nakkhu Dobato intersection was found to be as follows:



**Figure 12. Phase Sequence of Nakkhu Dobato Intersection during Morning Peak**

**Table 8. Phase time summary of Nakkhu Dobato Intersection during Morning Peak**

| Phase                   | A   | B   | C   | D   |
|-------------------------|-----|-----|-----|-----|
| Phase Change Time (sec) | 0   | 27  | 38  | 61  |
| Green Time (sec)        | 24  | 8   | 20  | 36  |
| Phase Time (sec)        | 27  | 11  | 23  | 39  |
| Phase Split             | 27% | 11% | 23% | 39% |

After analyzing the intersection in SIDRA INTERSECTION, the existing performance of the intersection was found to be as follows:

**Table 9. Existing traffic performance of Nakkhu Intersection during morning peak**

| Existing Condition (cycle time: 100 sec) |              |                    |                     |              |
|------------------------------------------|--------------|--------------------|---------------------|--------------|
| Approaches                               | Existing DOS | Existing BOQ (Veh) | Existing BOQ (DIST) | Existing LOS |
| Ekantakuna                               | 1.04         | 36.6               | 161                 | E            |
| DAV                                      | 1.98         | 32.4               | 140                 | F            |
| Dhobighat                                | 2.33         | 65.9               | 286                 | F            |
| Nakkhu                                   | 0.97         | 36.7               | 159                 | D            |
| Intersection                             | 2.33         | 65.9               | 286                 | F            |

Here we can see the existing operational performance of Nakkhu Dobato Intersection during morning peak is characterized by extreme oversaturation and operation failure with global level of service of F. Analysis indicated intersection has a critical Degree of Saturation of 2.33 which is significantly higher than practical limit of 1.0. leading to maximum BOQ of 286 meters.

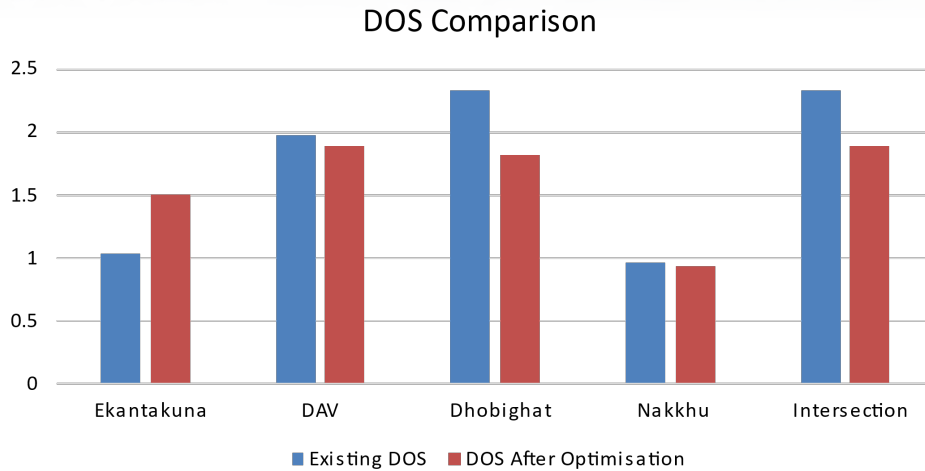
After optimizing the intersection in SIDRA INTERSECTION, the signal timings were optimized, reducing the total cycle length from the existing 100 seconds to a more efficient 89 seconds. Phase timing and the performance of the intersection after optimization were as follows:

**Table 10. Optimized Phase Timing of Nakkhu Dobato Intersection during Morning Peak**

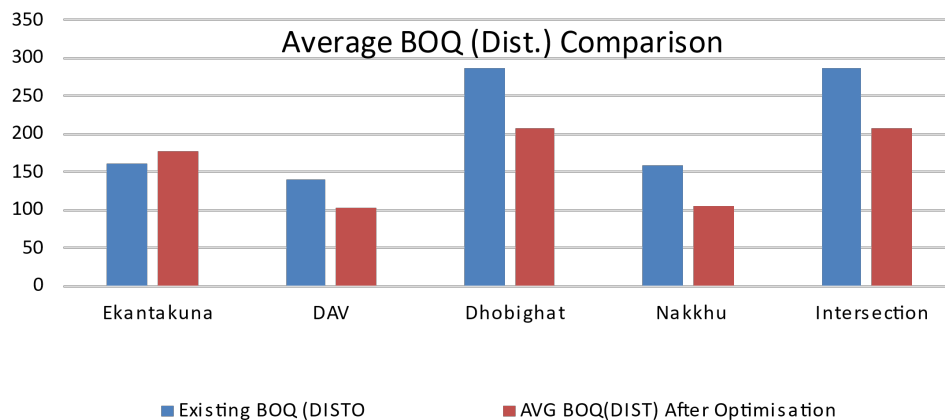
| Phase                   | A   | B   | C   | D   |
|-------------------------|-----|-----|-----|-----|
| Phase Change Time (sec) | 0   | 25  | 35  | 53  |
| Green Time (sec)        | 22  | 7   | 15  | 33  |
| Phase Time (sec)        | 25  | 10  | 18  | 36  |
| Phase Split             | 28% | 11% | 20% | 40% |

**Table 11. Optimized performance of Nakkhu Dobato Intersection during Morning Peak**

| Signal Optimization (Cycle time 89 sec) |      |           |            |     |
|-----------------------------------------|------|-----------|------------|-----|
| Approaches                              | DOS  | BOQ (VEH) | BOQ (DIST) | LOS |
| Ekantakuna                              | 1.5  | 51.4      | 178        | F   |
| DAV                                     | 1.89 | 30.3      | 102        | F   |
| Dhobighat                               | 1.82 | 60.6      | 208        | F   |
| Nakkhu                                  | 0.94 | 31.6      | 105        | D   |
| Intersection                            | 1.89 | 60.6      | 208        | F   |



**Figure 13. DOS comparison before and after optimization at Nakkhu Dobato Intersection during Morning Peak**



**Figure 14. Average BOQ Comparison**

After the optimization of the intersection for morning peak, existing 100-second cycle was optimized to 89-second timing. In its existing state, the intersection operated under severe congestion at a global level of service (LOS) F, with degree of saturation (DOS) of 2.33 and average BOQ of 286 meters. Although, even after the optimization the LOS remained at F, SIDRA INTERSECTION optimized the intersection in such a way that the global DOS reduced to 1.89 and BOQ of 208 meters. Consequently, while the intersection remains saturated, the optimization provides a measurable 18.9% improvement in capacity utilization and a 78-meter reduction in maximum queue lengths.

During the evening peak hour, the intersection operates under the same four-phase signal system with a 100-second cycle length as in the morning peak hour. The phase sequence is same as in the morning period with signal timing as follows:

**Table 12. Signal Timing of Nakkhu Dobato Intersection during Evening Peak**

| Phase                   | A   | B   | C   | D   |
|-------------------------|-----|-----|-----|-----|
| Phase Change Time (sec) | 0   | 27  | 46  | 76  |
| Green Time (sec)        | 24  | 16  | 27  | 21  |
| Phase Time (sec)        | 27  | 19  | 30  | 24  |
| Phase Split             | 27% | 19% | 30% | 24% |

The existing traffic performance of the intersection during evening peak was found to be as follows:

**Table 13. Performance of Nakkhu Dobato Intersection During Evening Peak**

| Existing Condition (Cycle Time: 100) |              |                    |                      |              |
|--------------------------------------|--------------|--------------------|----------------------|--------------|
| Approaches                           | Existing DOS | Existing BOQ (Veh) | Existing BOQ (DISTO) | Existing LOS |
| Ekantakuna                           | 0.93         | 23                 | 115                  | D            |
| DAV                                  | 1.54         | 34.2               | 167                  | F            |
| Dhobighat                            | 1.5          | 46.4               | 226                  | F            |
| Nakkhu                               | 0.73         | 19.3               | 94                   | C            |
| Intersection                         | 1.54         | 46.4               | 226                  | E            |

The existing signal cycle timing was 100-seconds with Back of queue length of 226 meters, global DOS of 1.54 and LOS E. The intersection is oversaturated beyond the functional capacity of the intersection. Approaches DAV and Dhobighat were above the capacity of 1.0 and LOS F.

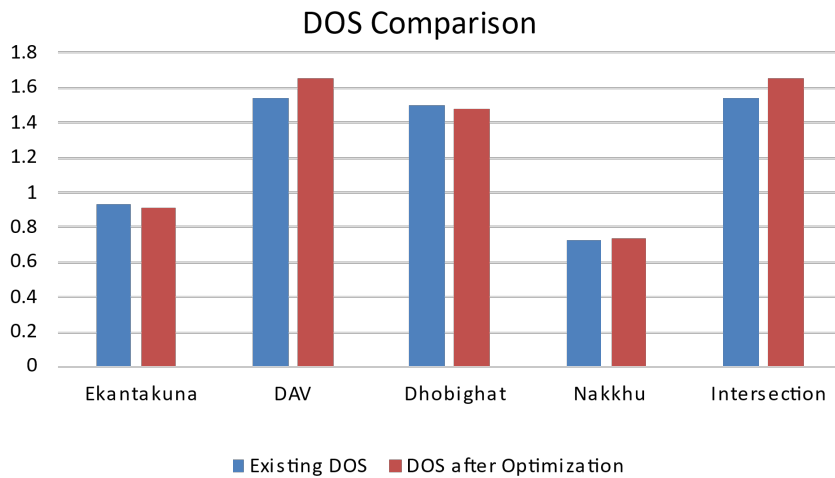
And after the optimization in SIDRA INTERSECTION, the resulting cycle timing and performance of the intersection were seen as follows:

**Table 14. Optimized Phase Timing of Nakkhu Dobato Intersection during Evening Peak**

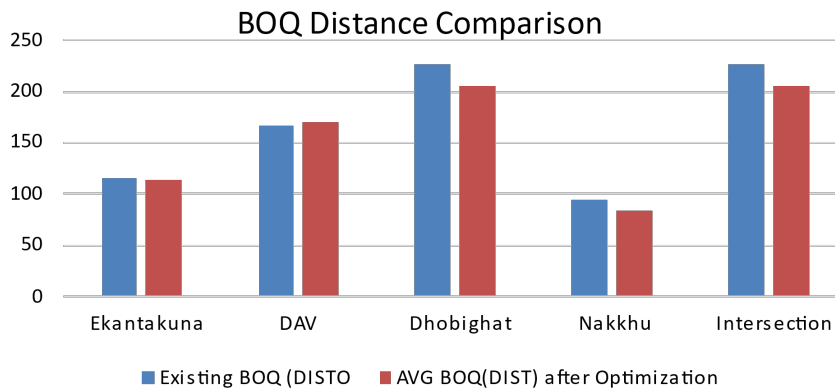
| Phase                   | A   | B   | C   | D   |
|-------------------------|-----|-----|-----|-----|
| Phase Change Time (sec) | 0   | 24  | 39  | 64  |
| Green Time (sec)        | 21  | 12  | 22  | 22  |
| Phase Time (sec)        | 24  | 15  | 25  | 25  |
| Phase Split             | 27% | 17% | 28% | 28% |

**Table 15. Optimized Performance of Nakkhu Dobato Intersection during Evening Peak**

| Optimization: Cycle time = 89 sec |      |               |               |     |
|-----------------------------------|------|---------------|---------------|-----|
| Approaches                        | DOS  | AVG BOQ (VEH) | AVG BOQ(DIST) | LOS |
| Ekantakuna                        | 0.91 | 22.7          | 113           | D   |
| DAV                               | 1.66 | 34.9          | 170           | F   |
| Dhobighat                         | 1.48 | 42            | 205           | F   |
| Nakkhu                            | 0.74 | 17.2          | 84            | C   |
| Intersection                      | 1.66 | 42            | 205           | E   |



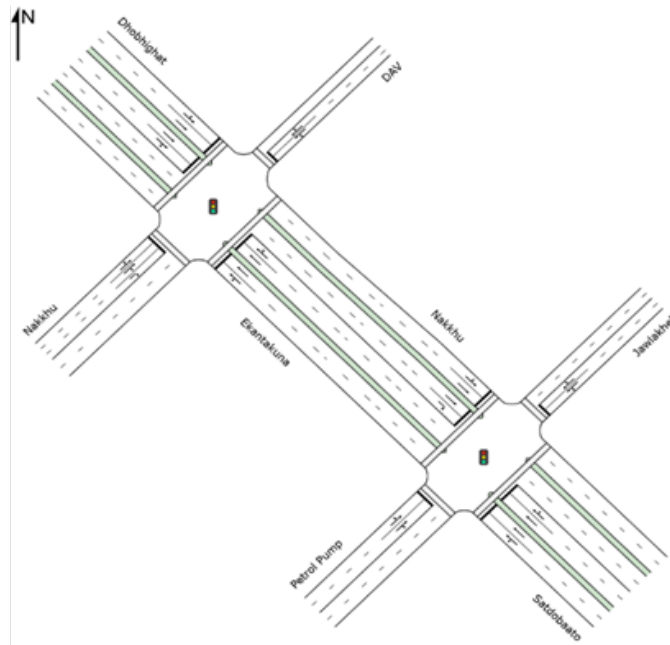
**Figure 15. DOS comparison before and after optimization in Nakkhu Dobato Intersection during Evening Peak**



**Figure 16. Average BOQ Distance comparison before and after optimization in Nakkhu Dobato Intersection during Evening Peak**

After optimization in SIDRA INTERSECTION, the total signal cycle time was reduced to 89 seconds, which reduced the average Back of Queue (BOQ) distance from 226 meters to 205 meters. However, it made the approach DAV worse from the original state in expense of improvement of other approaches. The global LOS of the intersection is still at E which means further enhancement of the performance of the intersection at the current peak hour flow is not possible only through signal timing optimization.

After evaluating the two intersections individually and optimizing their performance under isolated signal control, the intersections were subsequently modeled as a network in SIDRA INTERSECTION. The combined network was then analyzed and optimized using a coordinated signal control system to assess its operational performance under the coordinated conditions.

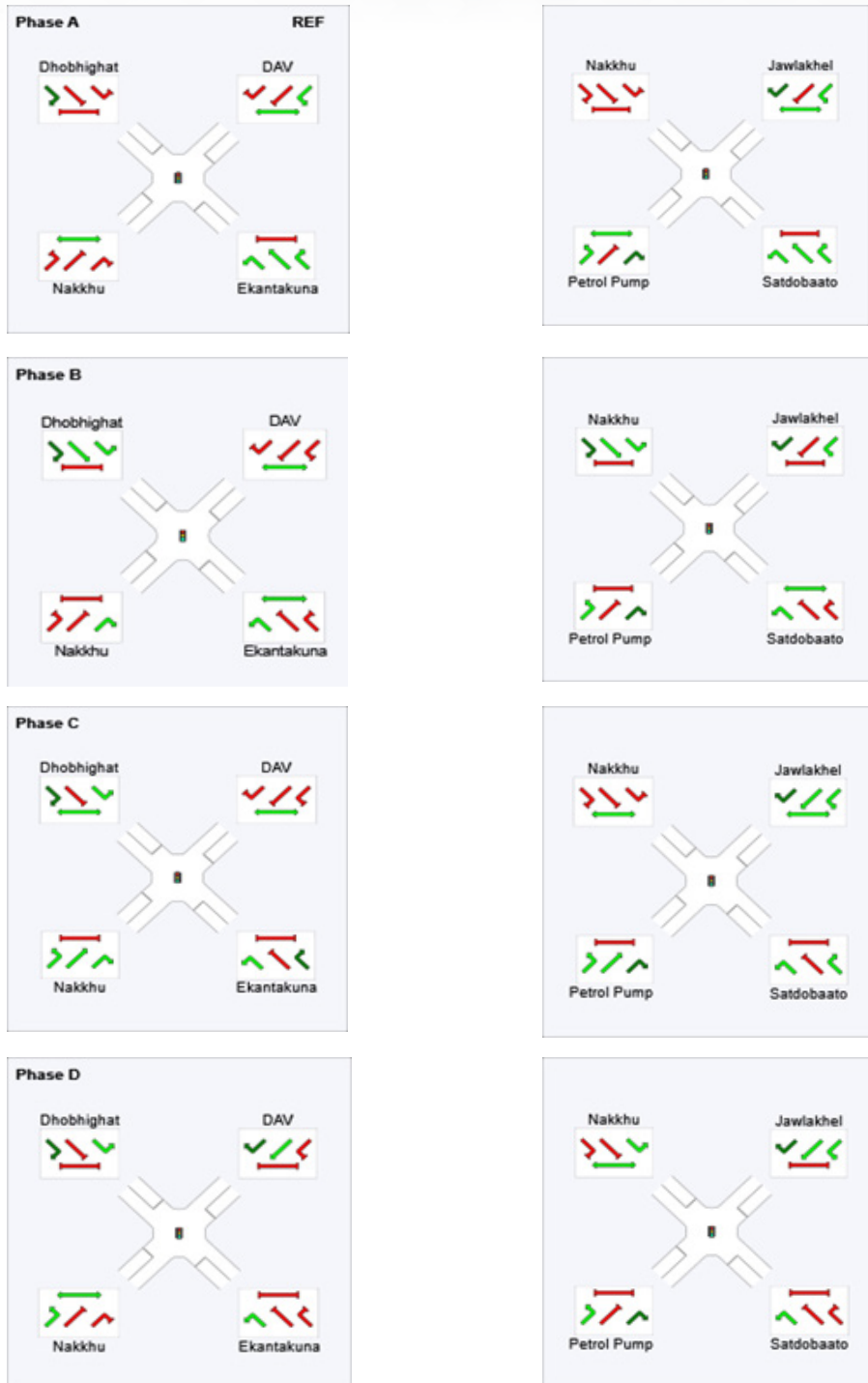


The two intersections were modeled as a coordinated network operating under a common four-phase signal system, with phase sequencing and timing maintained to ensure effective coordination between the intersections.

And the phase timing summary of the intersections in coordinated system are as follows:

**Table 16 Phase signal timing of coordinated system**

| Phase                   | A   | B   | C   | D   |
|-------------------------|-----|-----|-----|-----|
| Phase Change Time (sec) | 0   | 24  | 53  | 82  |
| Green Time (sec)        | 18  | 23  | 23  | 10  |
| Phase Time (sec)        | 24  | 29  | 29  | 16  |
| Phase Split             | 24% | 30% | 30% | 16% |



**Figure 18. Phase sequence of coordinated system**

With these phase sequences and timings, SIDRA INTERSECTION analyzed the performance of the

intersections and found it to be as follows:

**Table 17. Traffic performance of Ekantakuna Intersection in coordinated signal control**

| Approaches   | DOS  | BOQ (VEH) | BOQ(DIST) | LOS |
|--------------|------|-----------|-----------|-----|
| Satdobato    | 0.98 | 29.9      | 162       | E   |
| Jawalakhel   | 0.58 | 26.9      | 146       | C   |
| Nakkhu       | 0.73 | 18.7      | 102       | D   |
| Petrol Pump  | 0.87 | 32        | 175       | C   |
| Intersection | 0.98 | 32        | 175       | D   |

**Table 18. Traffic performance of Nakkhu Dobato Intersection in coordinated signal control**

| Approaches   | DOS  | BOQ (VEH) | BOQ(DIST) | LOS |
|--------------|------|-----------|-----------|-----|
| Ekantakuna   | 0.77 | 20.8      | 90        | D   |
| DAV          | 1.7  | 94.3      | 398       | F   |
| Dhobighat    | 1.11 | 56.7      | 243       | F   |
| Nakkhu       | 0.83 | 31.5      | 130       | D   |
| Intersection | 1.7  | 94.3      | 398       | F   |

The implementation of a coordinated signal control system for the Ekantakuna and Nakkhu Dobato intersections yields significant operational benefits compared to isolated optimizations, as shown in the performance evaluation results. Operating under a standardized 98-second coordinated cycle, the system synchronizes traffic pulses between the two nodes to improve the overall flow along the Ring Road corridor (Hollander & Liu, 2008).

The Ekantakuna intersection demonstrates a highly efficient operational state under the coordinated system, achieving a global Level of Service (LOS) D. The global Degree of saturation for this junction is reduced to 0.98, indicating that the intersection is successfully operating within its design capacity (Marler, 1993; Roess, et al., 2010).

While the high traffic volumes at the Nakkhu Dobato intersection maintain its global Level of Service (LOS) at F, the coordinated strategy successfully reduces the intersection's global Degree of Saturation (DOS) to 1.7, down from the isolated optimized value of 1.9.

Collectively, these results demonstrate that signal coordination is a superior strategy for managing regional traffic demand, effectively reducing the global Degree of Saturation at both nodes and facilitating a more stable, synchronized flow across the network.

#### 4. Conclusion and Recommendation

The baseline evaluations confirmed that the current manual traffic control system is insufficient for

properly handling modern urban volumes, yielding systemic operational failure (LOS F). While isolated timing updates maximize localized approach turnover, corridor-wide coordination built upon synchronized cycle networks delivers a critical buffer. It prevents terminal spillbacks and achieves stable traffic progression along high-saturation arterial links.

It is highly recommended that operational management transition to a coordinated automated signal layout running optimized Time-of-Day timing splits (Nesheli, et al., 2009). Concurrently, the Department of Roads should execute long-term geometric modifications- specifically adding dedicated left-turn slip lanes and intersection approach widening-alongside robust mass public transport investments to sustainably reshape demand patterns.

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