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**Performance Evaluation of Ekantakuna Intersection**

**By**

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**A THESIS**

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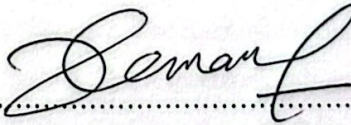
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## ABSTRACT

Majority of the intersections in Kathmandu valley are unsignalized and hence traffic management becomes one of the emerging issues for traffic police and designers. Delay estimation is crucial for determining level of service at such intersections. This study provides an overview of current traffic situation of unsignalized four-legged intersection in Ekantakuna located in ring road of Kathmandu Valley which connects busy approaches such as Satdobato, Nakkhu, Bhaisepati and Jawalakhel during morning and evening peak hours. Videographic surveying and field measurements were carried out in field. The videos were taken for morning and evening peak hours for three days (Monday, Tuesday and Wednesday) at two different times in a day – 9:00 to 11:00 AM in the morning and 4:00 to 6:00 PM in the evening. PTV VISSIM was used for the development of the model. The model was calibrated and validated for traffic volume, queue length and average speed so that the model realistically represents the real-world traffic environment. Five alternatives were analyzed to find the best solution for reducing congestion at the Ekantakuna intersection for both current and future traffic. The intersection with an LOS rating of ‘D’ and an average delay of 25.104 seconds, experienced localized improvements under restrictions on service and main lane movements (Alternatives 1, 2, and 3) though some lanes faced increased congestion. The combined scenario (Alternative 3) reduced queue length and delay by 4.948% and 4.117%, respectively, while restricting right turns with a U-turn (Alternative 4) improved corresponding values by 8.103% and 7.388% respectively. The most effective solution was converting the intersection into a grade-separated signalized intersection (Alternative 5) which introduced an underpass, improving LOS from D to B and reducing queue length and delay by 33.789% and 39.060%. For the 10-year forecasted traffic, the LOS was projected to F with a delay of 50.031 seconds. Alternative 5 remained the best solution, reducing queue length by 39.340% and delay by 42.243% improving LOS from F to D.

**Keywords:** VISSIM, Intersection, Delay, Level of Service, Queue, Model, Calibration

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## LIST OF ABBREVIATIONS

ADT	Average Daily Traffic
FDOT	Florida Department of Transportation
GEH	Geoffrey E.Havers
JICA	Japan International Cooperation Agency
LOS	Level of Service
NRS	Nepal Road Standard
ODOT	Oregon Department of Transportation
PTV	Planung Transport Verkehr
PCU	Passenger Car Unit
VISSIM	Verkehr in Station Simulation Model
WHO	World Health Organization
CBS	Central Bureau of Statistics
HCM	Highway Capacity Manual

# CHAPTER 1: INTRODUCTION

## 1.1 Background

Intersection can be defined as the area where two or more roads cross or join. They are nodes in transportation network, the point at which two or more roads meet or cross. General intersection forms include yield-controlled intersections, stop-controlled intersections, signalized intersections and modern roundabouts. Intersections can be distinguished into two types based on traffic control measures: Unsignalized intersection and Signalized intersection. Unsignalized intersections are controlled by either yield or stop signs and often represent relatively low-volume junctions. Signalized intersections are controlled by traffic signals and is alternating red-yellow-green indication to conflicting approaches.

The Central Bureau of Statistics of Nepal predicts that the population of the Kathmandu Valley will reach four million by 2035 (CBS 2018; JICA 2017). Along with the population increase, the number of registered vehicles including motorcycles increased from 150,000 to 570,000 in the last 10 years, resulting in traffic congestion in the city. JICA report stated that although the government of Nepal is aiming to reduce traffic congestion through improvement of the road network including widening of the Ring Road, the traffic infrastructure is still inadequate to deal with the steadily growing traffic volume.

Majority of the intersections in Kathmandu valley are unsignalized and hence traffic management becomes one of the emerging issues for traffic police and designers. The number of vehicles in Kathmandu Valley is increasing at the rate of 12% annually (Department of Transport Management, 2018). Increase in traffic volume will result in congestion at intersections. Traffic congestion is characterized by slower speeds, longer travel times and a rise in vehicular queuing (FHA, 2007). Delay estimation is crucial for determining LOS at such intersections. The degree of service that a roadway facility is offering to its users is referred to

as the level of service (LOS) of a road. Determining LOS is essential to evaluate the performance of the road at the moment and if necessary make improvements. LOS is defined as “a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience”.

This study provides an overview of current traffic situation of unsignalized traffic police controlled intersection in Ekantakuna, located in ring road of Kathmandu Valley which connects busy approaches. It is a four legged unsignalized intersection controlled by traffic police. Ekantakuna intersection has been taken into consideration to determine the current performance and suggest possible enhancement measures during morning and evening peak hours of the day. Implementations of field experiments are generally prevented due to legal and financial constraints while traffic simulation is a cost effective, objective and flexible approach to analyze and evaluate transportation system Rakha. et al, (1996). In our study, PTV VISSIM has been used as micro-simulation software to simulate the flow in given different sets of conditions. The expansion of Ring Road aimed at improving traffic flow and urban connectivity failed to deliver the expected results in several ways. Despite substantial investment and years of construction, the project did not address key transportation issues effectively. One main goal of the expansion was to reduce traffic congestion but the wider roads did not significantly ease traffic congestions. The lack of proper traffic management systems, inadequate road planning and poor public transportation infrastructure continued to cause bottlenecks, especially at major intersections. A number of research works have been done in regard to the performance evaluation of intersections using PTV VISSIM in Nepal nowadays. Traffic simulation techniques, which are widely used to model and evaluate the impacts of a wide range of urban mobility interventions, offer opportunities to investigate the impacts of city logistics interventions (Hadi, 2024). The government had announced that flyovers were to be constructed at Gwarko, Satdobato and Ekantakuna in the valley. The study for constructing an underpass similar to the one in Kalanki at Satdobato and Ekantakuna had already been completed. However, apart from Gwarko, work had not begun anywhere else. The construction of the flyover at Gwarko was ongoing (Kantipur, 2080).

## 1.2 Problem Statement

Kathmandu valley constitutes of three central districts: the capital city Kathmandu, Bhaktapur in east and Lalitpur in the south, thus forming the country's most densely populated region. This high population density as well as the centralization of economic, administrative and political power in the valley has put immense traffic load on the center core region of the valley. To control this traffic flow, the ring road plays the vital role. The ring road circles the center region of the valley where the population density is the highest and is filled with work place, educational institute and administrative offices. The increasing number of vehicles in the Kathmandu valley has made the need for wider road networks with advanced traffic control systems. However, the increasing population and haphazard urban sprawl have imposed limitations on land acquisition for road widening. In Nepal, diverse vehicles share the same road space without segregation, resulting in significant urban traffic congestion. This problem is particularly severe at closely spaced intersections, intensifying congestion during peak hours. The expansion of the Ring Road, intended to enhance traffic flow and urban connectivity did not achieve the anticipated outcomes. Despite the wider roads, traffic congestion persisted as the improvements failed to alleviate congestion significantly. Issues like insufficient traffic management, poor road planning and inadequate public transport infrastructure led to continued bottlenecks, particularly at key intersections.

Located in ring road of Kathmandu Valley, Ekantakuna Intersction is one of the busiest intersections in Kathmandu. It caters the traffic from the most congested areas such as Satdobato, Nakkhu, Bhaisepati and Jawalakhel during morning and evening peak hours. Due to this, the traffic volume has increased over the years and congestion is becoming a major concern to stakeholders. The problem has been a topic of concern, but appropriate data-backed congestion alleviation strategies are lacking. Therefore, studies need to be conducted in this intersection to find alternatives in relieving the congestion without developing new infrastructure due to area limitation.

### **1.3 Objectives of study**

The main objective of the study is to evaluate the performance of the four-legged intersection of Ekantakuna and suggest strategies to enhance the performance of the intersection. The specific objectives of the studies are as follows:

- 1) To quantify the existing operational traffic performance and LOS of intersection.
- 2) To suggest possible solutions (alternatives) to improve performance of intersection by making comparative analysis among alternatives (scenarios) based on traffic performance measures (Delay, Level of Service and Queue length) for base year and forecasted year traffic conditions.

### **1.4 Scope of Study**

Urban intersections are critical hubs in city transportation networks, where various roads and transportation modes converge. Urban intersections are busiest during the peak hours of the day and congestion occurs characterized by slower speeds, longer travel times and increased vehicle queues due to a higher volume of traffic. Ekantakuna Intersection is one of such urban intersections used for our study. The study aims to depict the current operational efficiency of Ekantakuna Intersection and suggest probable alternatives to improve traffic flow in that intersection. The study uses comprehensive data on traffic volume, speed, vehicle types and intersection layout to simulate real world at Ekantakuna Intersection using PTV VISSIM as micro-simulation software. The study also highlighted the growing traffic issues in Kathmandu Valley particularly at unsignalized intersections which had become a significant concern due to the rising number of vehicles. The study emphasized the need for more efficient traffic management strategies at major intersections like Ekantakuna, which serves as a critical node connecting several congested areas. This was done using data collected with the help of video-graphic surveying and manual counting. The queue length data obtained from the field will successfully aid in the validation of the data.

## 1.5 Limitations of Study

The research has been carried out with the following limitations:

- 1) Pedestrian data were not considered and their movement was not given priority in the simulation. The focus of this study is the vehicles and the impact on congestion. Delays due to pedestrians were not considered.
- 2) Bicycles were not considered for the study since its frequency is relatively low compared to other vehicle types.
- 3) The U-turn movement of vehicles has not been considered.
- 4) The effect of weather variation was not considered.
- 5) The analysis of the intersection was conducted independently without taking into account the effects of nearby intersections.

## 1.6 Organization of Report

The report is organized in five chapters as:

**Chapter 1: INTRODUCTION** which describes shortly about performance evaluation of an intersection along with objectives, scope and limitations of study.

**Chapter 2: LITERATURE REVIEW** which discusses the available literatures related to performance evaluation and improvement.

**Chapter 3: RESEARCH METHODOLOGY** which describes each and every step from data collection to data analysis. This chapter provides a framework for proceeding ahead.

**Chapter 4: RESULTS AND DISCUSSIONS** which includes analysis of extracted data and calibration of the VISSIM model, along with the interpretation of results.

**CHAPTER 5: CONCLUSION AND RECOMMENDATION** which presents summary of the results obtained from the research works and recommends suggestions for future works.

## **CHAPTER 2: LITERATURE REVIEW**

### **2.1 Overview of Unsignalized Intersection**

An unsignalized intersection is a road junction where traffic flow is not controlled by traffic signals but instead relies on road signs, right-of-way rules and driver awareness. These intersections are common in areas with lower traffic volumes and are often regulated by stop signs, yield signs or no signs at all. Although unsignalized intersections are more cost-effective and suitable for less congested areas, they can pose higher risks of accidents due to the potential for misjudgment lack of visibility or failure to yield.

### **2.2 Delay and Intersection Level of Service**

Delay is defined as “the additional travel time experienced by a driver, passenger, or pedestrian” (HCM, 2010). The total delay experienced by a road user can be defined as the difference between the travel time actually experienced and the reference travel time that would result in the absence of traffic control, changes in speed due to geometric conditions any incidents and the interaction with any other road users. Delays are fixed and operational. Fixed delay is caused due to traffic control devices and operational delays are caused during the traffic operation.

Control delay at an unsignalized intersection refers to the additional time that vehicles experience while waiting to pass through the intersection due to the presence of conflicting traffic, pedestrians, or other conditions. This delay occurs because drivers must stop, slow down or yield to other vehicles that have the right of way, particularly on the major road. It is a principal service measure to evaluate level of service. HCM 2010 provides equations for calculating control delay. The Level of Service (LOS) of a road is a qualitative measure used to assess the operational conditions and overall performance of a roadway. The HCM defines Level of Service for unsignalized intersections in terms of control delay using delay thresholds given in Table 2.1.

Table 2. 1 LOS thresholds at unsignalized intersections

<b>LOS</b>	<b>Average total delay per vehicle (Sec)</b>
A	0-10
B	> 10-15
C	> 15-25
D	> 25-35
E	> 35-50
F	> 50

### 2.3 Calibration Parameters

There are controllable and uncontrollable input parameters and the controllable input parameters, lane change distance, waiting time before diffusion, desired speed, minimum head way distance, minimum and maximum look ahead distance can be used for the calibration of a model Schneeberger (2002). Uncontrollable input parameters are the geometrical features of the road, traffic counts and Current signal timing plans.

### 2.4 VISSIM

VISSIM is a microscopic or stochastic multi-modal traffic flow simulation software package developed by PTV Planung Transport Verkehr AG in Karlsruhe, Germany in 1992. The name VISSIM is derived from "Verkehr In Städten - SIMulationsmodell" (German for "Traffic in cities - simulation model"). VISSIM is widely used to evaluate different traffic scenarios and to identify the best scenario before implementation of traffic projects (Gao, 2013). VISSIM is also renowned for its adaptability in behavior-based microsimulation, and is also used for modeling of complex transportation projects, and alternative analysis as per Washington State Department of Transportation (WSDOT, 2021).

## 2.5 Calibration and Validation of VISSIM Model

Calibration refers to the process of adjusting model parameters to ensure that the simulation accurately reflects real-world traffic conditions. Calibration is a critical step in traffic modeling because it improves the reliability and validity of the simulation results, making them more applicable for planning and decision-making. In calibration, the parameters are adjusted so that the model outputs are similar to observed data (Hollander, 2008). The best universal measure to compare field data and simulation outputs is the GEH formula (ODOT, 2011).

For hourly flow, the GEH formula is

$$GEH = \sqrt{\frac{2(m-c)^2}{(m+c)}} \dots\dots\dots \text{Equation 2.1}$$

Where,

m = Output traffic volume from the simulation model (Vph)

c = Input traffic volume (Vph)

Table 2. 2 GEH Statistics Guidelines

<b>GEH statistics</b>	<b>Remarks</b>
GEH < 5.0	Acceptable Fit
5.0 <= GEH <= 10	Possible model error or bad data
GEH > 10	Unacceptable

(Source: ODOT (2011))

The traffic volume calibration criteria are listed in Table 2.3.

Table 2. 3 Traffic Volume Calibration Criteria

Criteria	Acceptance Target
GEH < 5.0	At least 85 % of freeway links within calibration area
GEH < 5.0	All entry and exit locations within calibration criteria
GEH < 5.0	All entry and exit ramps within calibration criteria
GEH < 5.0	All intersection turn movements greater than 100 vph
Individual flows within 400 vph flow exceeding 2,700 vph	At least 85 % of applicable main links
Sum of all links flows within calibration area	Within 5%

Source: ODOT (2011)

For calibrating of queue length and speed, Root Mean Squared Normalized Error (RMSNE) can be used, which measures the percentage deviation of the simulated data from field observed data. A RMSNE of less than 0.15 is considered acceptable for traffic model calibration (FDOT, 2014).

$$RMSNE = \sqrt{\frac{1}{N} \sum \frac{(y_{i,sim} - y_{i,obs})^2}{y_{i,obs}}} \dots\dots\dots \text{Equation 2.2}$$

Where,

N = total number of traffic measurement observations

y<sub>i,sim</sub> and y<sub>i,obs</sub> = simulated and observed data

Validation is the process of comparing simulated model with field measurement in order to determine the accuracy of the simulation model. Validation is used to check the applicability of the simulation model for real field scenario. A new data set to different traffic should be used for validation of simulation model. The thresholds given by GEH statics and RMSNE generally used for validation of calibrated model (MDOT, 2016).

The calibrated parameter value for driving behavior suggested by (S M P and Ramadurai, 2013) for Indian heterogeneous condition has been presented in the Table 2.4. Such parameter has been taken as a reference for the determination of calibrated parameter value for the preparation of the model as the driving behavior in case of India and Nepal are somehow similar.

Table 2. 4 Reference calibrated parameter value

<b>Parameter</b>	<b>Value</b>
Minimum headway (front/rear)	0.11 m
Average standstill distance	1.00 m
Additive part of safety distance	0.20
Multiplicative part of safety distance	0.78
Minimum lateral distance-bike at 0kmph	0.62 m
Look ahead distance-min	27.91 m
Look back distance-min	14.31 m

Source: S M P and Ramadurai (2013)

## **2.6 Driving Behavior Parameters**

### **2.6.1 Minimum Headway Distance**

Minimum Headway distance is the minimum distance that should be maintained between two vehicles in motion, usually measured from the front bumper of one vehicle to the front bumper of the following vehicle, to ensure safe operation and avoid collisions (AASHTO, 2018).

### **2.6.2 Look Ahead Distance/ Look Back Distance**

The look ahead distance is the distance a driver should scan ahead of their vehicle to identify potential hazards, such as other vehicles, pedestrians or obstacles, and be able to respond in a timely manner (California Driver Handbook, 2019). The look back distance is the distance a driver should maintain behind their vehicle to be aware of the presence and movements of vehicles or objects behind them (Virginia Driver's Manual, 2020).

### 2.6.3 Average Standstill Distance

Average standstill distance is the distance a vehicle travels, on average, after coming to a complete stop from a certain speed. It encompasses the distance covered during the driver's perception time, reaction time and braking time (NHTSA, 2016).

### 2.6.4 Additive Part of Safety Distance

The additive part of safety distance is the extra distance that allows for a safe margin in case of unexpected events or emergency situations on the road (RoSPA, 2018).

### 2.6.5 Multiplicative Part of Safety Distance

The multiplicative part of safety distance is a factor that is multiplied by the speed of the vehicle to calculate the total stopping distance. It is used in the calculation of safe following distances to ensure that drivers maintain an appropriate distance based on their speed (NSC, 2017).

Research works by Marsani and Acharya (2020) using VISSIM as micro-simulation software has been done in the New Baneshwor intersection in the past. The calibrated parameter value for driving behavior implemented by Marsani and Acharya(2020) in the past research has been presented in the Table 2.5.

Table 2. 5 Calibrated Driving Parameter Values

<b>Parameter</b>	<b>Value</b>
Look ahead distance-min	30.00 m
Look back distance-min	5.00 m
Average standstill distance	0.30 m
Additive part of safety distance	0.19
Multiplicative part of safety distance	0.71
Minimum headway (front/rear)	0.50 m

Source: Marsani and Acharya (2020)

## 2.7 Findings from Reviewed Pieces of Literatures

Lin and Gao (2013) developed a VISSIM model for the evaluation of road network of CBD (Central Business District) in Beijing, China for 2020. Four interval streets were taken which constitute four small intersections. The traffic demand for 2020 was forecasted based on current traffic and origin Destination (OD) matrices was figured out for traffic volume as an input and signal was set. This paper studied the operational conditions of four scenarios of Beijing CBD area in 2020 using traffic simulation software VISSIM. The paper was still a preliminary study for the simulation of CBD core area in 2013.

Baza (2021) studied on performance evaluation of selected intersection in Jimma city. The performance of roadway intersection in Jimma city which located around Merkato was observed and special effect of pedestrians, and other motorized vehicles in the performance of the given intersection were studied. The research concluded that proportion of pedestrian's traffic at the Geda intersection in Jimma city was 61% of the entire traffic which was the root cause for the poor performance of the intersection. The volume occupied by tricycles was found to cover 61.91% of total vehicular traffic and thereby have a great influence on the performance of intersection. It had been concluded that number of tricycles should be controlled and the number other public transports like buses and minibuses should be increased to improve the performance of major intersections.

Datta (2020) studied delay and driver turning time evaluation for thirteen uncontrolled intersections (both 3-legged and 4-legged) from northern, eastern, western, and central parts of India based on videographic surveying. Performance parameters affecting service delay of uncontrolled intersections were evaluated through microscopic simulation. Data were collected for typical 5 to 7 hours within weekdays 15 comprising of both morning and evening peak periods. The paper attempted to assess driver waiting time before turning initiation (i.e., service delay), the time required to merge with the conflicting flow (i.e. driver turning time) and queue length at uncontrolled multimodal intersections under complex and diverse traffic scenario.

Pradhananga et al. (2021) studied effectiveness of Reversible Lane Systems (RLS) in Kathmandu Valley taking a case study of Jadibuti – Koteswor section to improve traffic at morning and evening peak hours using travel time and queue length as indicators. A micro –

simulation model was developed using VISSIM. The paper revealed that introduction of RLS at the section can reduce the queue lengths by more than 50% and improve the travel times by 11% on average during the morning and evening peak hours.

Marsani and Shrestha (2017) conducted micro-simulation at New Baneshwor intersection to evaluate the alternative scenarios introducing flyover and U-turn to relieve congestion. Among the scenarios, three phases signal planning with flyover by providing U-turn could effectively decrease delay and travel time by 81.92% and 80.1% in morning and evening peak time respectively. Additionally, travel time and delay could be decreased by 60% in Maitighar, Tinkune, Old Baneshwor and Shankhamul in morning and evening peak hours.

Marsani & Acharya (2020) used VISSIM combined with SSAM to predict vehicular interactions at New Baneshwor Intersection. Number of potential crossing, lane changing and rear-end crashes that are likely to occur per day were found to be 1, 9 and 945 respectively. The relationship between the simulated and observed conflicts was found to be statistically significant with a R-squared value of 0.8545, 0.7474, 0.8677 and 0.9138 for crossing, lane-changing, rear-end and total conflicts respectively. It was found that if the traffic signals are designed as per changing traffic volume rather than implementing the same fixed time traffic signal, the number of crossing, lane-changing and rear-end conflicts can be decreased by a maximum of 88%, 40% and 39% respectively. This study suggested that this method can be used for locating vehicular conflicts so as to reduce their number by the improvement of intersections thereby enhancing their traffic safety.

Tiwari et. al. (2023) addresses traffic congestion at two critical intersections, Shital Nivas and Kanti Children's Hospital, in Kathmandu Valley, Nepal. Through surveying and simulation using SIDRA software, signal coordination strategies were evaluated. Results demonstrate significant reductions in average delay time and maximum queue length at both intersections. While this study focused on two intersections, it highlighted the efficiency of signal coordination in alleviating urban congestion network-wide.

Dhungel et al. (2023) studied the operational performance of two nearby intersections, Keshar Mahal and Durbar Marg in Kathmandu, Nepal using the SIDRA INTERSECTION software. It found that the current traffic management system caused long queues, spillback, and significant delays at both intersections. Simulations were run to test different phase

configurations and signal timing strategies under both isolated and coordinated settings for pre-timed and actuated signals. The results showed that pre-timed signal coordination with an optimized signal cycle was the most effective approach reducing total travel time by 33.4%, total control delay by 48.8% and average control delay by 49.2%. This strategy also improved intersection performance, cutting the 95th percentile queue length by 62.1% at Keshar Mahal and 13.9% at Durbar Marg. The study compared these results to the current system, demonstrating the proposed strategy's potential to enhance traffic flow and reduce delays at both intersections.

Mistry et al. (2022) focused on enhancing traffic flow and safety at the Kamrej intersection in Surat, India, by employing a micro-simulation approach. It proposes traffic management measures and geometric modifications to improve intersection efficiency. PTV VISSIM software is used to evaluate the effectiveness of these strategies. The findings indicate that delays for straight and right turns can be significantly reduced, improving overall traffic performance. The most effective measures include a redesigned central island, free left turns, road widening and a four-phase signal control, upgrading the intersection from LOS F to LOS C according to national standards.

Manandhar and Pradhananga (2023) explored micro-simulation models for unsignalized intersections in developing countries, where traffic is often diverse and complex. Due to the challenges of analyzing such traffic and calibrating microsimulation models, their use in countries like Nepal has mainly been limited to research. The study suggested a methodology for developing these models using VISSIM, a behavior-based simulation tool. To address the calibration difficulties, the study used Latin Hypercube Sampling (LHS) and one-way ANOVA testing to identify key parameters. Initially, 12 calibration parameters were selected from previous research, which were then reduced to 9 based on their influence on traffic flow. The study concludes that prioritizing these sensitive parameters can greatly streamline the model calibration process, saving time and effort.

Pandey & Shrestha (2023) investigated the impact of vehicle restriction policies on urban intersections during peak hours, focusing on the New Baneshwor Intersection as a case study. Data was collected during morning peak hours (9:00–11:00 AM) and evening peak hours (4:00–6:00 PM) through video surveys and the information was analyzed using VISSIM simulations. Six scenarios based on land use plans and four scenarios based on vehicle

restriction strategies, including mode shifts were created to evaluate traffic performance. The study found that Scenario 9, which involved an odd-even vehicle restriction was the most effective in reducing travel time and delays. Under Scenario 9, travel time and delay decreased by 27.92% and 36.39%, respectively, for through traffic on the Tinkune main lane, and queue lengths dropped by 72.01%. For through traffic on the Tinkune service lane, travel time and delay decreased slightly by 1.07% and 1.90%, though queues increased by 1.13%.

Shrestha & Budhathoki (2024) evaluated the operational performance of the Pepsicola Intersection. Data were collected through videographic surveying and fed into PTV VISSIM to represent field conditions. Currently, the intersection had a Level of Service (LOS) rating of C, with an average total delay of 18.62 seconds. The movement from Jadibuti to Sanothimi showed the best performance, with a Level of Service of B compared to other movements at the intersection. The maximum queue length recorded was 16.32 meters. They recommend signal phase design or coordination with nearby intersections could be implemented to improve the intersection's performance.

Luitel & Tiwari (2023) conducted a study to improve traffic flow at the Buspark intersection in Birgunj Metropolitan City. Traffic volume data was collected for 72 hours, along with the intersection's geometrical characteristics. Using this data, an existing model of the intersection was developed in the 'SIDRA Intersection 8.0' software. The model was validated by comparing observed and simulated queue lengths for each approach, followed by an evaluation of the intersection's current performance. Two solutions were proposed to improve the performance of the Buspark Junction. The first option (Alternative I) involved optimizing signal timing by adjusting the cycle lengths, while the second option (Alternative II) focused on controlling the continuous left-turn movement within the signal timing. As a result of these changes, the intersection's Level of Service (LOS) improved from E to D. The modifications led to reductions in average delay by 34.7% and 38.8%, and the Back of Queue (BOQ) decreased by 34.7% and 40% respectively.

Chen et al. (2013) found out that for the large intersection and high volume of traffic, VISSIM is more appropriate simulation software than CORSIM. Furthermore, VISSIM is also more appropriate than CORSIM to calculate the average control delay at the intersection.

Kunwar & Pradhananga (2023) conduct a research to identify alternatives to improve the traffic operation and safety performance of the Dhalkebar three-legged roundabout, focusing on capacity, delay, operational speed, Level of Service (LOS) and traffic conflicts. A VISSIM microsimulation model was developed, calibrated, and validated against current traffic conditions to assess the roundabout's operational performance. Additionally, the Surrogate Safety Assessment Model (SSAM) was employed to evaluate traffic conflicts. The microsimulation was utilized to analyze three proposed improvement alternatives: Alternative I (geometric improvements), Alternative II (metering concept), and Alternative III (turbo roundabout). Evaluations were conducted for both current and projected traffic conditions over the next ten years. For the current traffic scenario, a comparative analysis revealed that Alternative III was the most effective, leading to reductions in delay, conflicts, and increases in capacity values—34.55 seconds, 1044 conflicts, and 604 PCU/hour, respectively—while improving the LOS to B. The average operational speed for this alternative was also higher than the others. For the forecasted traffic scenario, Alternative III again emerged as the best option achieving a reduction in delay of 44.58 seconds, conflicts down to 5776 and an increase in capacity to 1074 PCU/hour, with the LOS improving to C. Overall, Alternative III demonstrated the best performance in terms of both safety and operational measures under both current and projected traffic conditions.

Sharma et al. (2019) examined gap acceptance and lateral placement of vehicles to analyze U-turn behavior at unsignalized median openings in urban areas. They studied nine median openings in Varanasi and Jabalpur, India. The study found that critical gap was the key factor in gap acceptance, while critical position indicated vehicle location during a U-turn. Median openings provided access to opposing traffic without major conflicts, but turning was complex due to high-speed opposing vehicles. Most median openings were uncontrolled, requiring vehicles to accept time gaps for safe U-turns.

# CHAPTER 3: METHODOLOGY

## 3.1 Research Design

For the proposed study, all the relevant literatures were thoroughly assessed to identify the important variables to be considered. A model framework was prepared by keeping in mind the purpose of study and types of variables considered for the research followed by choosing suitable location for the study. Following this, the data collection process was conducted by video-graphic surveying. All relevant information's was extracted from the recordings. Simulation model was developed and validated to support the chosen research topic.

The methodology used for the research is illustrated in Figure 3.1 below.

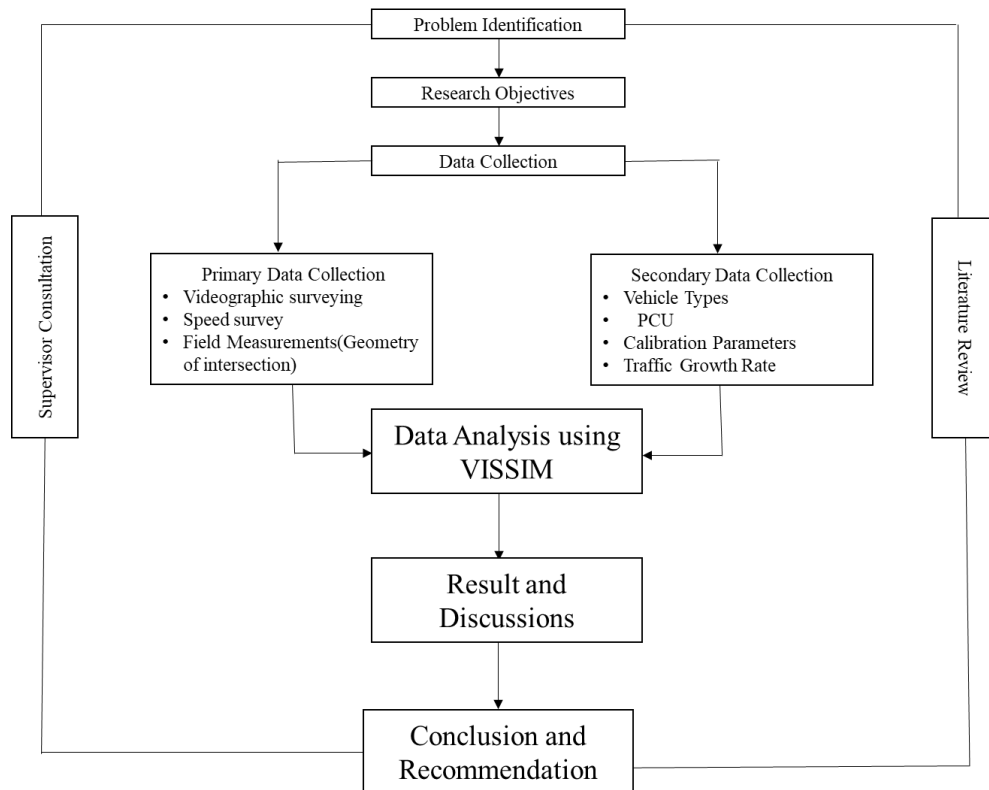


Figure 3.1 Framework of Research Methodology

### 3.2 Study Area

Several literatures have been studied regarding performance evaluation and the way how the study area have been selected were found to be quite similar. The unsignalized intersection at Ekantakuna, Lalitpur was chosen for this study. Ekantakuna is a significant intersection located in the southern part of Kathmandu, Nepal, specifically in the Lalitpur district. It served as a crucial junction connecting various parts of the Kathmandu Valley. The intersection was part of the Kathmandu Ring Road which encircled the Kathmandu Valley and connected major areas. It is a four legged intersection connecting Jawalakhel to north, Satdobato in east, Balkhu in west and Bhaisepati in south. Figure 3.2 and Figure 3.3 shows the general layout and geometry of Ekantakuna Intersection.



Source: Google Earth (2023)

Figure 3.2 Ekantakuna Intersection

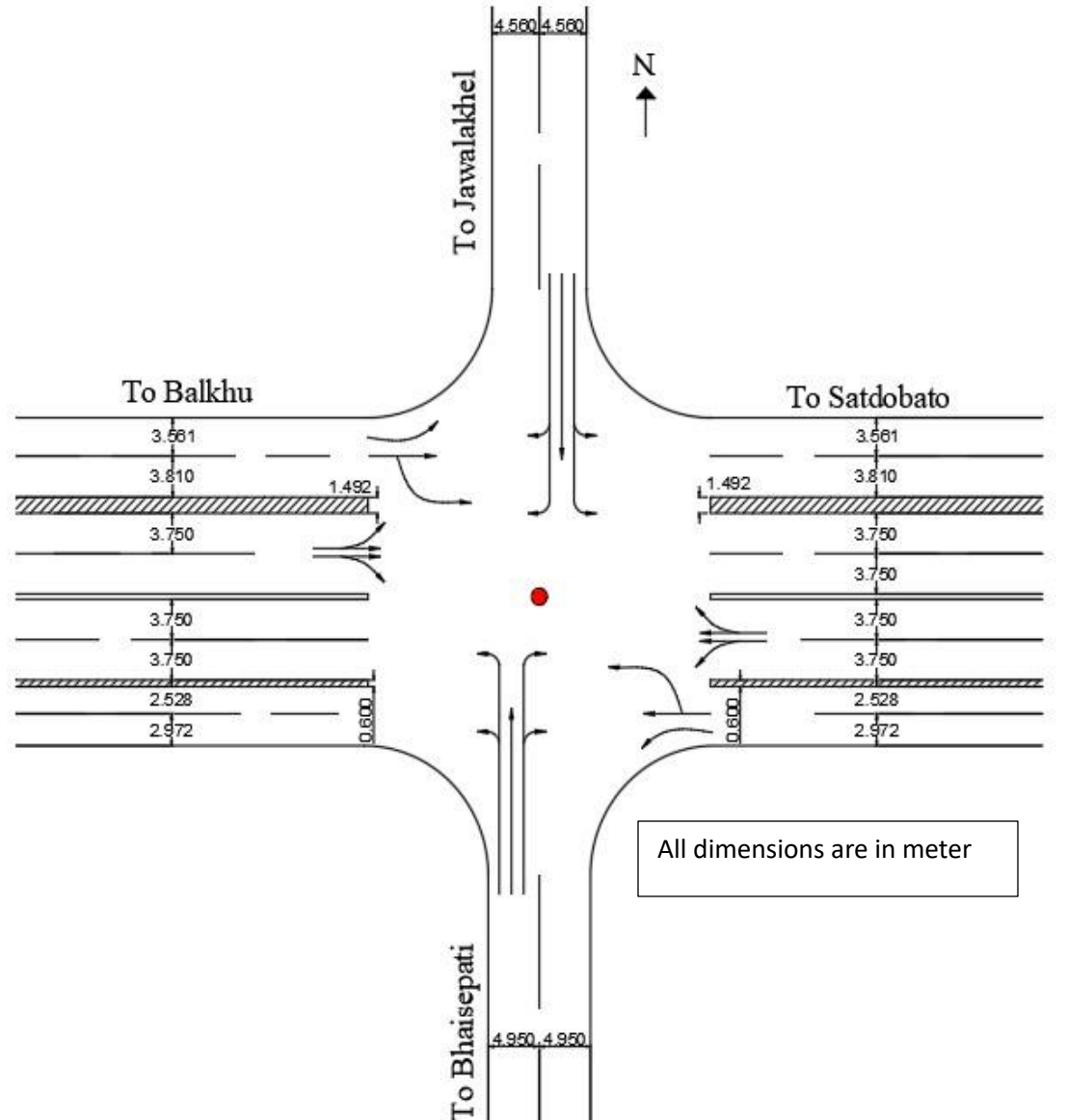


Figure 3.3 Geometry of Ekantakuna Intersection (Not to Scale)

### 3.3 Data Collection

Primarily, the study relied on primary data which included traffic data and road geometry. The traffic data has been gathered to support perform the study. Videographic surveying and field measurements were carried out in field. The videos were taken for morning and evening peak hours for three days (Monday, Tuesday and Wednesday) from 15<sup>th</sup> to 17<sup>th</sup> August, 2022. The videographic survey was conducted at two different times in a day - 9 AM to 11 AM in the

morning and 4 PM to 6 PM in the evening using GoPro as shown in figure 3.4. The secondary datas such as PCU factors (DOR 2013), Standard values of traffic operational performance (Indo-HCM), google image (Google Earth,2023) and traffic growth rate for forecasted year (DOR: SSRN) were also taken during the analysis.



Figure 3.4 Videographic Surveying using GoPro

### 3.4 Data Processing

The obtained videos were played several times so as to conduct a classified count. The vehicle types were considered similarly those used by Department of Roads, Nepal as shown in Table 3.1. The vehicles volumes were recorded for each group of vehicles and subsequent model development and analysis proceeded.

Table 3.1 Vehicle Types and Equivalency Factors

S.N.	Vehicle Type	Equivalency Factor
1	Bicycle, Motorcycle	0.5
2	Car, Auto Rickshaw, SUV, Light Van and Pick Up	1.0
3	Light (Mini) Truck, Tractor, Rickshaw	1.5
4	Truck, Bus, Minibus, Tractor with trailer	3.0
5	Non-motorized carts	6.0

Source: (Department of Roads, 2013)

The non-motorized carts, rickshaw and tractor have not been considered during classified count of total vehicles since their frequency is relatively low compared to other vehicle types. All the directional movements involving left turn, through movements and right turns from four intersection legs were also obtained from the video. The sample of the data collected has been shown in APPENDIX A: Classified Volume Count.

### 3.5 Traffic Projection

The alternative analysis may not be suitable for future traffic count. The future growth rate of traffic is to be calculated. The study was carried out for quantifying the existing and future operational traffic performance of intersection (Forecasted 10 years). The traffic data was predicted using equation 3.1.

$$F = P (1 + r)^n \dots\dots\dots \text{Equation 3.1}$$

Where,

F =Future traffic in n years

P = Current or present traffic

r = Compound growth rate

And n = Number of years

The average growth rate of traffic for each vehicle category were determined through an analysis of past data obtained from the Department of Roads: Statistics of Strategic Road Networks (DOR: SSRN). The adopted growth rates for motorcycles, cars, mini trucks and buses were 8.97%, 5.22%, 2.71%, and 3.59% respectively.

### 3.6 Microscopic simulation Model Development, Calibration and Validation

#### 3.6.1 Model Development

Links were created using connector to represent road segments that carry them through movements and general curvature of the roadway. PTV VISSIM was used for the development

of the model. Following data were used as input for VISSIM such that the model prepared reflects the existing field condition.

- Vehicle Types
- Classified Vehicle Count
- Directional movement of vehicles
- Relative flows for static vehicle routing

The vehicle input in VISSIM was given as vehicle per hour. The node was defined to gather the results from the intersection Queue counters were positioned just before the signal head to measure the queue length. The model of Ekantakuna Intersection in VISSIM is shown in figure 3.5.



Figure 3.5 Modeling of Ekantakuna Intersection in VISSIM

### 3.6.2 Model Calibration

Calibration is the process of comparing output of PTV VISSIM Software with the real-world data by changing driving behavior parameters inside VISSIM Model so that the model realistically represents the real-world traffic environment. With Calibration, the discrepancy

between model results and measurement or observations from the field is minimized. The input data discussed in chapter 3.6.1 were fed to VISSIM. Calibration of traffic volume was done using GEH statistics as mentioned in Equation 2.1. The simulation was repeatedly run, adjusting the driver behavior parameters each time, until the GEH value for all vehicle volumes falls below 5, indicating an acceptable fit. Additionally, the model was calibrated for queue length and speed using RMSNE index until the value falls below 15% as mentioned in equation 2.2.

### **3.6.3 Model Validation**

The calibrated model was used for validation, changing the volume data while keeping all other parameters constant. After gathering and extracting traffic count data, the data from Day 1 and Day 2 was used for model calibration, while Day 3 traffic data was employed to validate the model using the calibrated parameters from the first two days under similar conditions at the same location. Queue length and speed was also used to validate the model. The overall strategy for evaluation of operational performance using VISSIM is shown in figure 3.6.

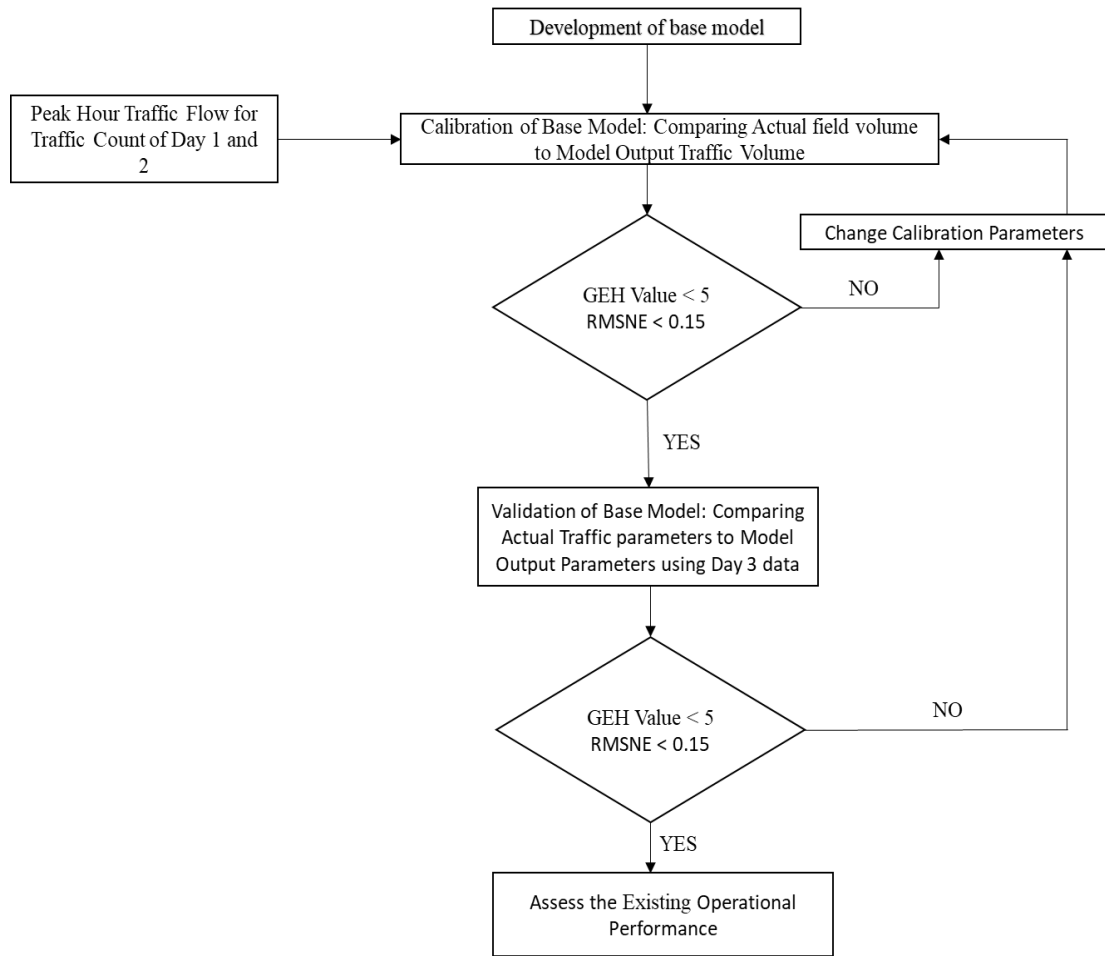


Figure 3.6 Flowchart for evaluation of operational performance using VISSIM

### 3.7 Analysis of alternatives for improvement

Once the model was calibrated and validated, a scenario analysis was conducted to identify the most appropriate alternative for reducing congestion at the intersection. The prevailing traffic flow conditions at intersection is shown in figure 3.7.

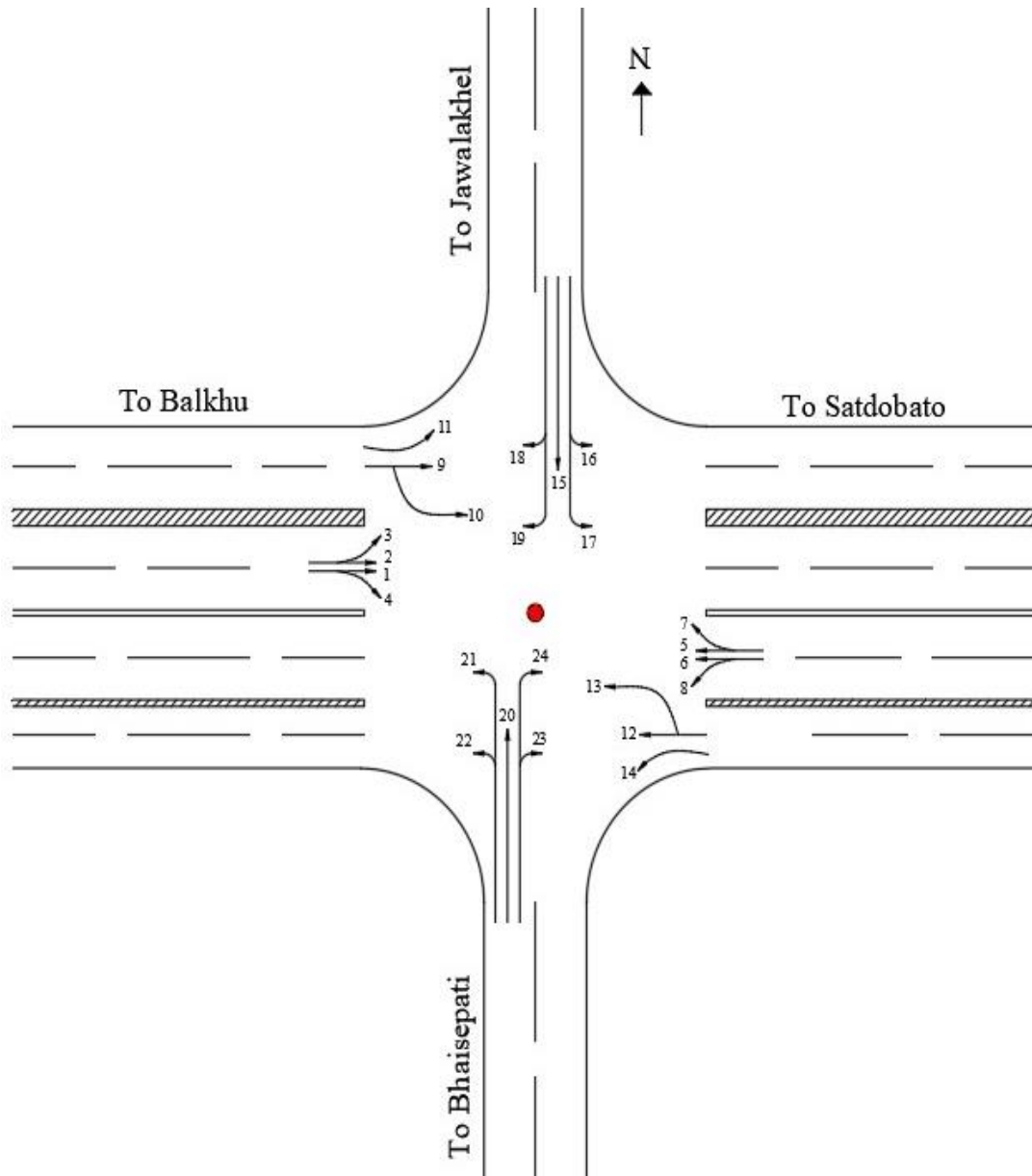


Figure 3.7 Prevailing Traffic Movement in the Intersection

The movement directions of vehicles at the Ekantakuna Intersection from the adjacent lanes are indicated as follows:

- 1 - Balkhu Main lane to Satdobato main lane
- 2 - Balkhu Main lane to Satdobato service lane
- 3 - Balkhu Main lane to Jawalakhel lane

- 4 - Balkhu Main lane to Bhaisepati lane
- 5 - Satdobato Main lane to Balkhu Main lane
- 6 - Satdobato Main lane to Balkhu Service lane
- 7 - Satdobato Main lane to Jawalakhel lane
- 8 - Satdobato Main lane to Bhaisepati lane
- 9 - Balkhu Service lane to Satdobato Service lane
- 10 - Balkhu Service lane to Satdobato Main lane
- 11 - Balkhu Service lane to Jawalkhel lane
- 12 - Satdobato Service lane to Balkhu Service lane
- 13 - Satdobato Service lane to Balkhu Main lane
- 14 - Satdobato Service lane to Bhaisepati lane
- 15 - Jawalakhel lane to Bhaisepati lane
- 16 - Jawalakhel lane to Satdobato Service lane
- 17 - Jawalakhel lane to Satdobato Main lane
- 18 - Jawalakhel lane to Balkhu Main lane
- 19 - Jawalakhel lane to Balkhu Service lane
- 20 - Bhaisepati lane to Jawalakhel lane
- 21 - Bhaisepati lane to Balkhu Main lane
- 22 - Bhaisepati lane to Balkhu Service lane
- 23 - Bhaisepati lane to Satdobato Main lane
- 24 - Bhaisepati lane to Satdobato Service lane

The alternative applied to this intersection were as follows:

### Alternative 1: Restriction of traffic movement from service lane to main lane

Alternative 1 involved lane restrictions where vehicles from the Balkhu and Satdobato service lanes are limited to their respective service lanes and restricted from accessing the main lane. The vehicles from Balkhu service lane had been allowed to move only in the Satdobato service lane and the vehicles from the Satdobato service lane had been allowed to move only in the Balkhu service lane. The traffic movements at the intersection following the implementation of alternative 1 are shown in figure 3.8. Movements 9 and 10 from the Balkhu service lane had been combined as have movements 12 and 13 from the Satdobato service lane.

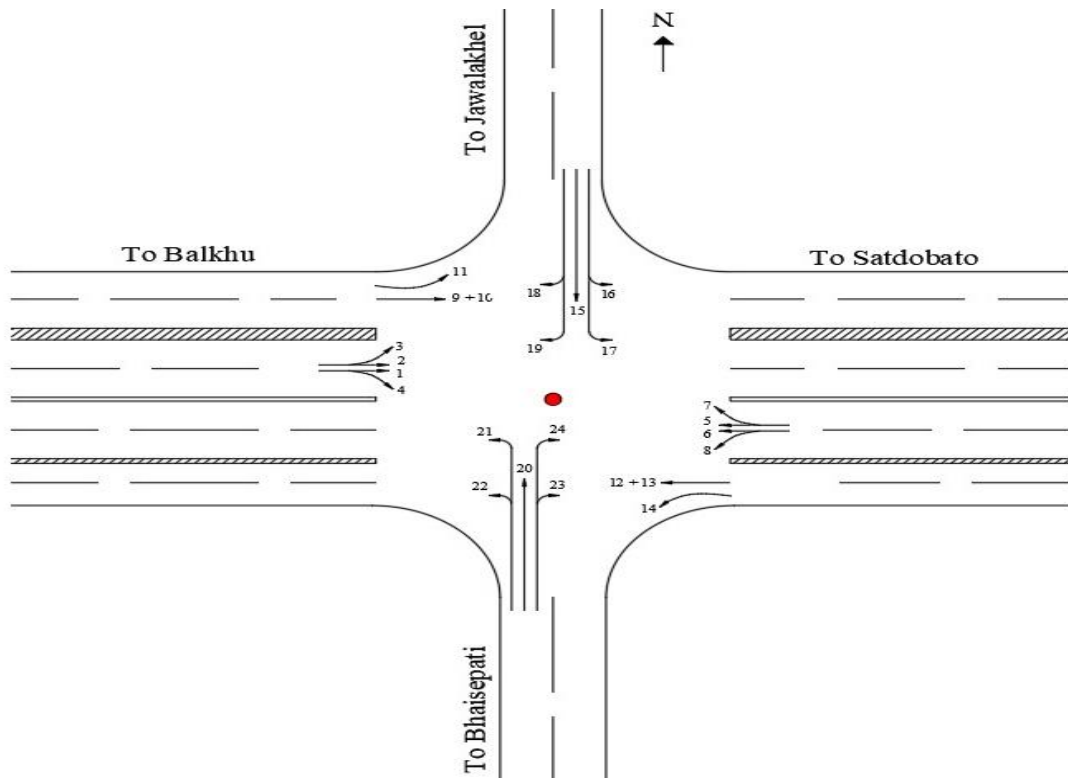


Figure 3.8 Movements with Alternative 1

### Alternative 2: Restriction of left turning traffic movement from main lane

Alternative 2 involved lane restrictions where left-turning traffic from the main lane had been restricted. The left-turning traffic from the main lane had been diverted at a distance 200 meters ahead of the intersection. The traffic movements at the intersection after implementing

alternative 2 were shown in Figure 3.9. Movements 3 and 11 from the Balkhu main lane and Balkhu service lane had been merged and allowed to move in Balkhu service lane before taking left turn towards Jawalakhel. Similarly, movements 8 and 14 from the Satdobato main lane and Satdobato service lane had been merged and allowed to move in Satdobato service lane before taking left turn towards Bhaisepati.

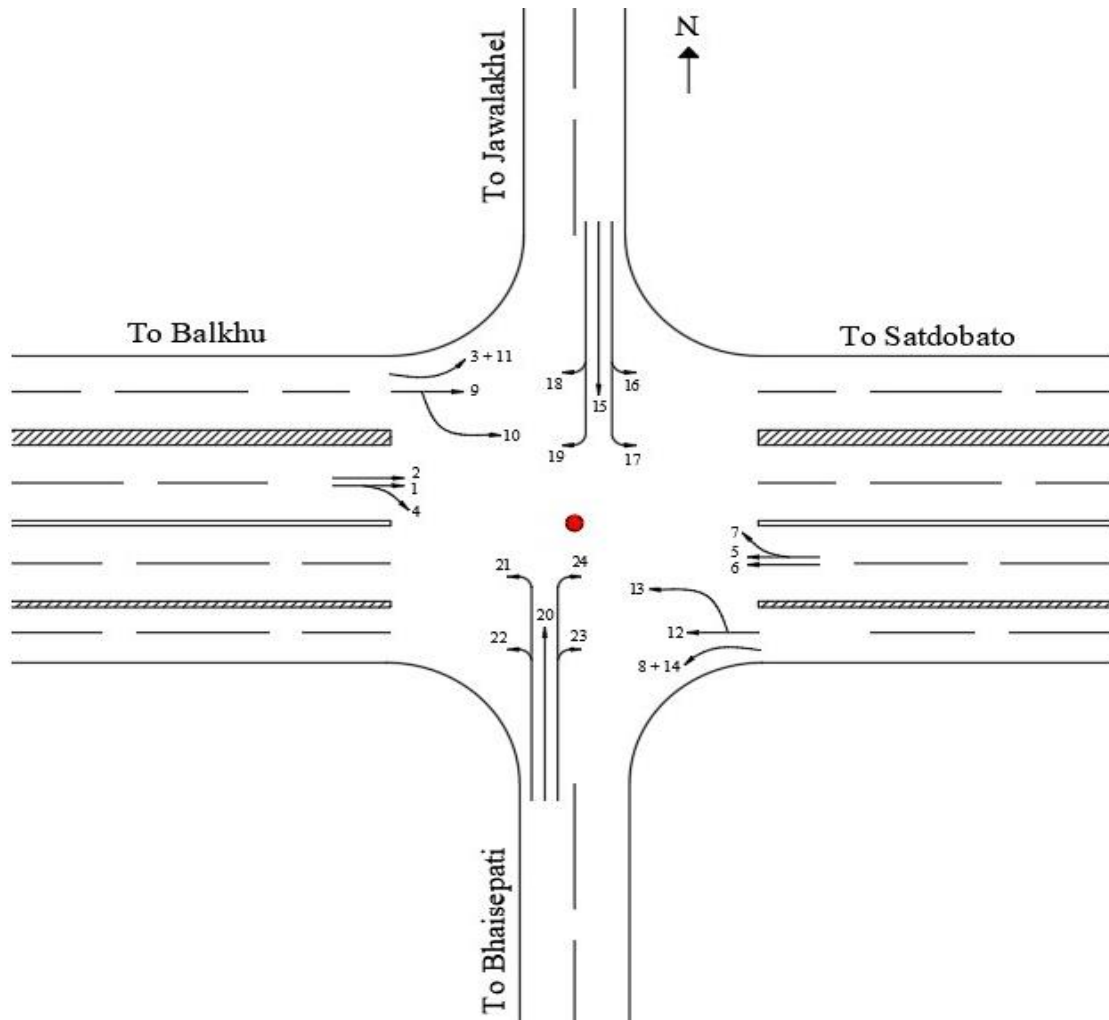


Figure 3.9 Movements with Alternative 2

### Alternative 3: Combined Scenario

Alternative 3 involved lane restrictions where the lane restrictions from both alternative 1 and alternative 2 were implemented to assess the combined effect of both alternatives. The traffic movement had been restricted both from the service lane to the main lane and for left-turning

traffic from the main lane, with left-turning vehicles being diverted to pass 200 meters ahead of the intersection. The movements 3 and 11 and movements 9 and 10 had been merged from the Balkhu approach. Similarly, movements 8 and 14, and movements 12 and 13 had been merged from the Satdobato approach. The traffic movements at the intersection following the implementation of alternative 3 are shown in figure 3.10.

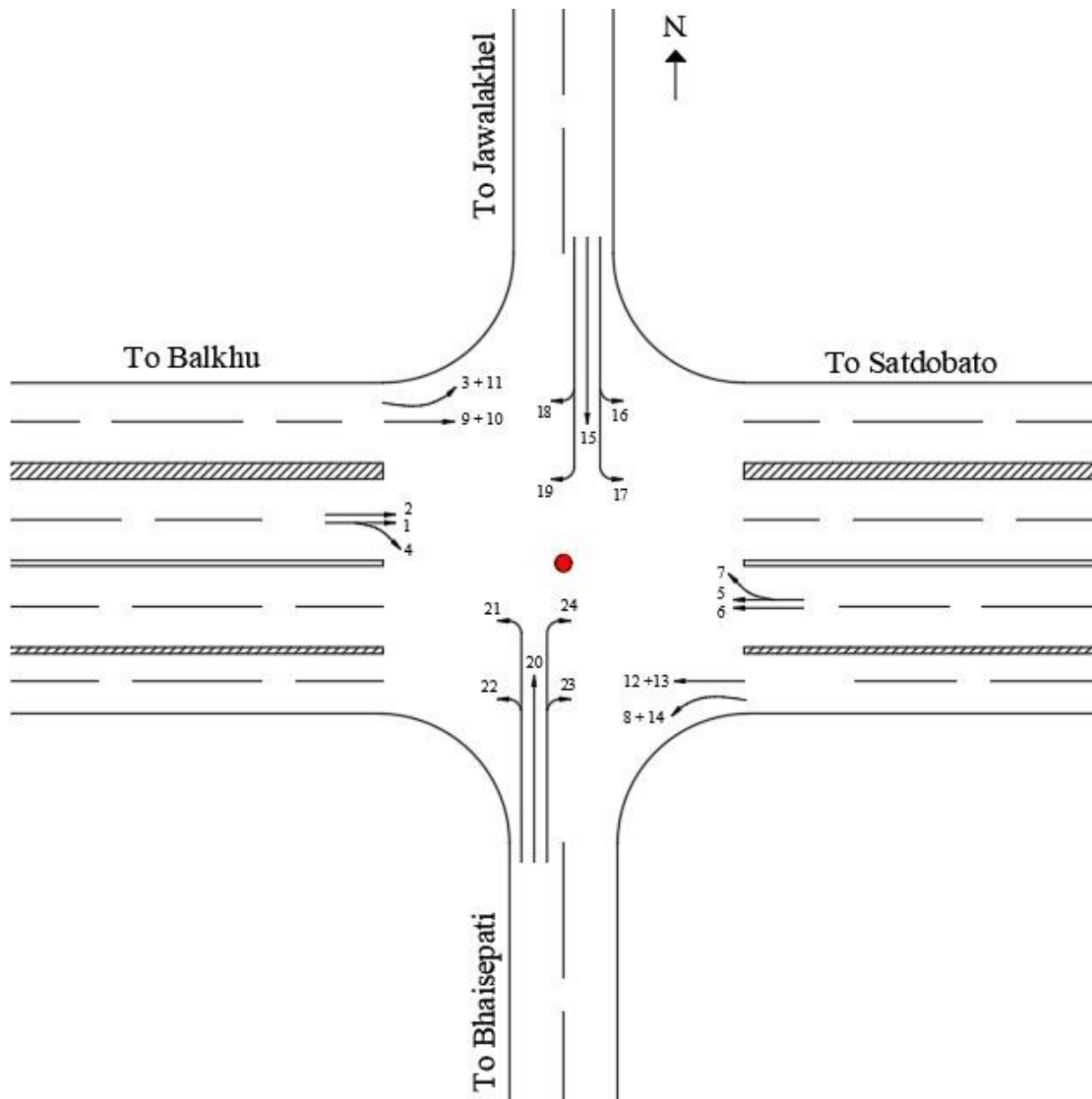


Figure 3.10 Movements with Alternative 3

**Alternative 4: Restriction of right turning traffic movement from main lane**

Alternative 4 involved lane restrictions where right-turning vehicles from the Balkhu and Satdobato main lanes (Movements 4 and 7) were restricted. This alternative facilitated U-turn

movements of restricted traffic from Balkhu main and Satdobato main approaches. The right-turning traffic movement from Balkhu main lane to Bhaisepati (Movement 4) had been restricted. Consequently, the restricted traffic was allowed to move towards Satdobato main lane (Combined with movement 1) and take a U-turn at a distance 200 meters ahead of the intersection. This diverted traffic then mixed with the traffic from the Satdobato main lane (Movement 8) before taking a left turn towards Bhaisepati.

Similarly, the right-turning traffic movement from Satdobato main lane to Jawalakhel (Movement 7) had been restricted. The restricted traffic was then allowed to move towards Balkhu main lane (Combined with movement 5) and take a U-turn at a distance 200 meters ahead of the intersection. This diverted traffic mixed with the traffic from the Balkhu main lane (Movement 3) before taking a left turn towards Jawalakhel. The traffic movements at the intersection following the implementation of alternative 4 and intersection sketch are shown in figure 3.11 and figure 3.12.

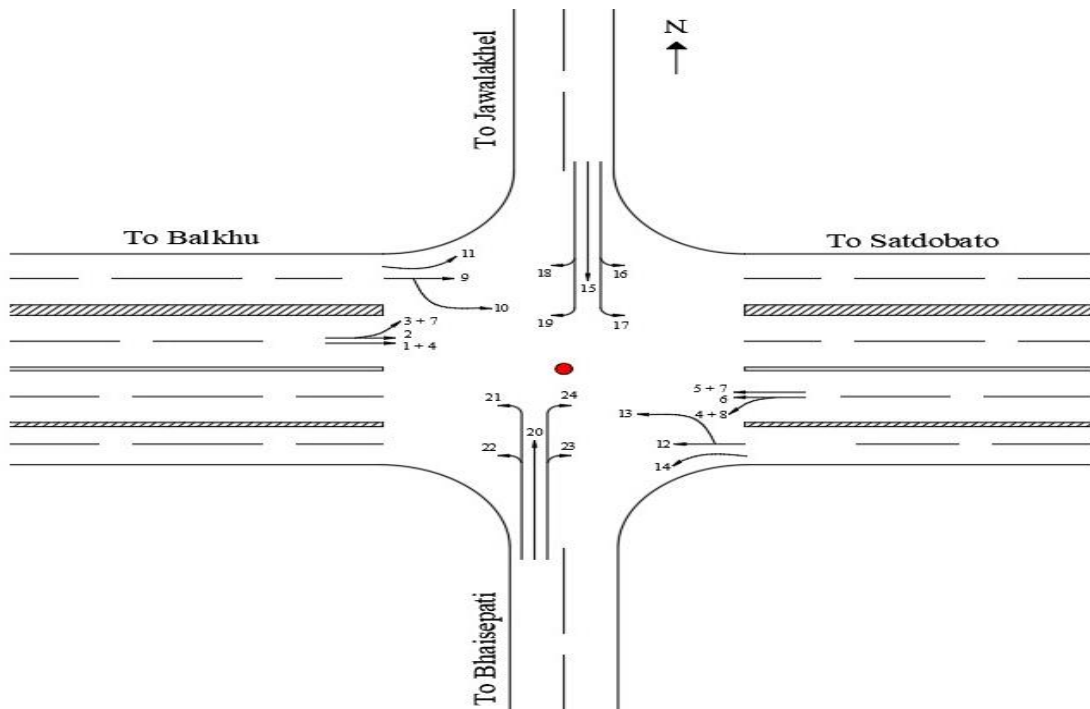


Figure 3.11 Movements with Alternative 4

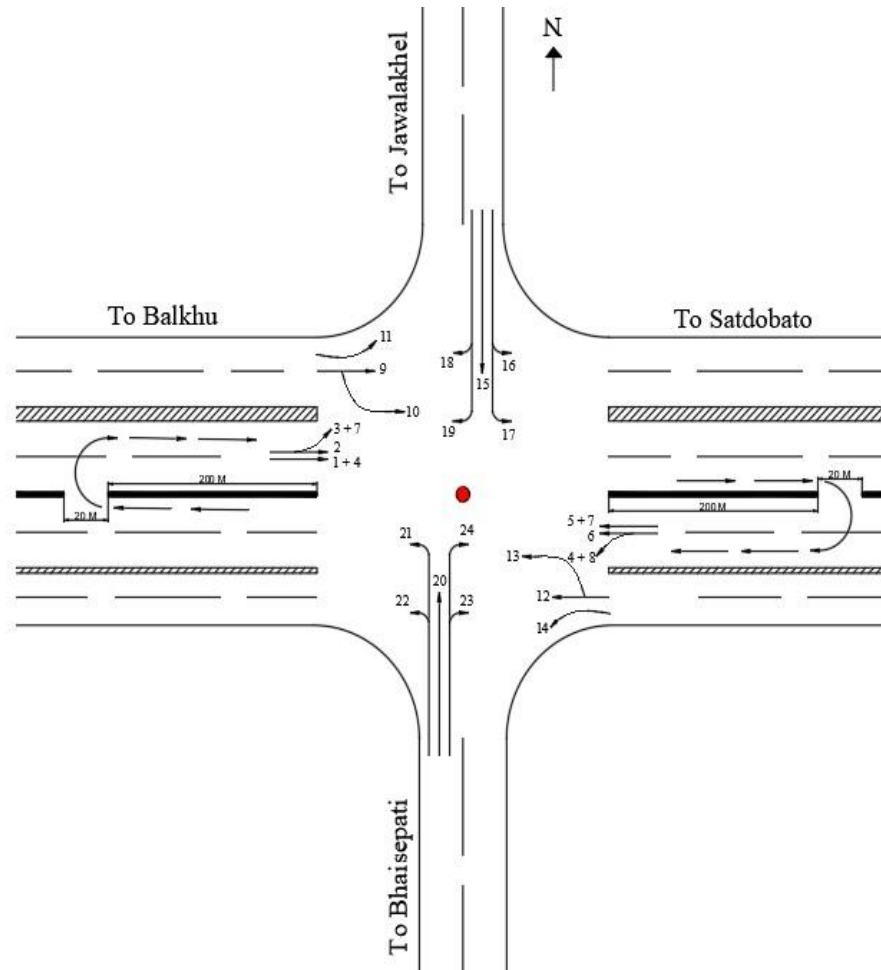


Figure 3.12 Intersection Sketch with alternative 4

**Alternative 5: Conversion of Unsignalized Intersection into Grade-Separated Signalized Intersection**

Alternative 5 involved the conversion of the unsignalized Ekantakuna Intersection into a grade-separated intersection by introducing an underpass along the Balkhu-Satdobato road section. The study aimed to assess the effect of introducing a four-lane underpass (Two lanes in each direction) in the design to ease traffic congestion at the intersection. The underpass was analyzed based on the criteria provided in the IRC SP: 84-2019 code for grade-separated intersections. According to this code, the minimum vertical clearance for highways should be 5.5m. The underpass was analyzed with a vertical clearance of 8m and maintained at a slope of 1:20 (V: H) with a 50m straight reach along the Jawalakhel–Bhaisepati road section. This included the through movement of vehicles from Balkhu Main to Satdobato Main lanes and

vice versa. Based on the vehicle flow rates, a three-phase signal design was carried out and the optimum cycle length was found to be 150 seconds. The routes were re-defined and traffic volumes were adjusted accordingly.

The movement directions of vehicles at the Ekantakuna Intersection following the implementation of alternative 5 are indicated as follows:

- Balkhu Service lane to Jawalakhel lane (Left turning traffic)
- Balkhu Service lane to Bhaisepati lane (Right turning traffic)
- Balkhu Main lane to Satdobato Main Lane (Through traffic)
- Satdobato Main lane to Balkhu Main Lane (Through traffic)
- Satdobato Service lane to Bhaisepati lane ( Left turning traffic)
- Satdobato Service lane to Jawalakhel lane ( Right turning traffic)
- Jawalakhel lane to Satdobato Service lane ( Left turning traffic )
- Jawalakhel lane to Bhaisepati lane ( Through traffic )
- Jawalakhel lane to Balkhu Service lane ( Right turning traffic )
- Bhaisepati lane to Balkhu Service lane (Left turning traffic )
- Bhaisepati lane to Jawalakhel lane (Through traffic )
- Bhaisepati lane to Satdobato Service lane (Right turning traffic )

The traffic movements at the intersection following the implementation of alternative 5 and intersection sketch are shown in figure 3.13 and figure 3.14.

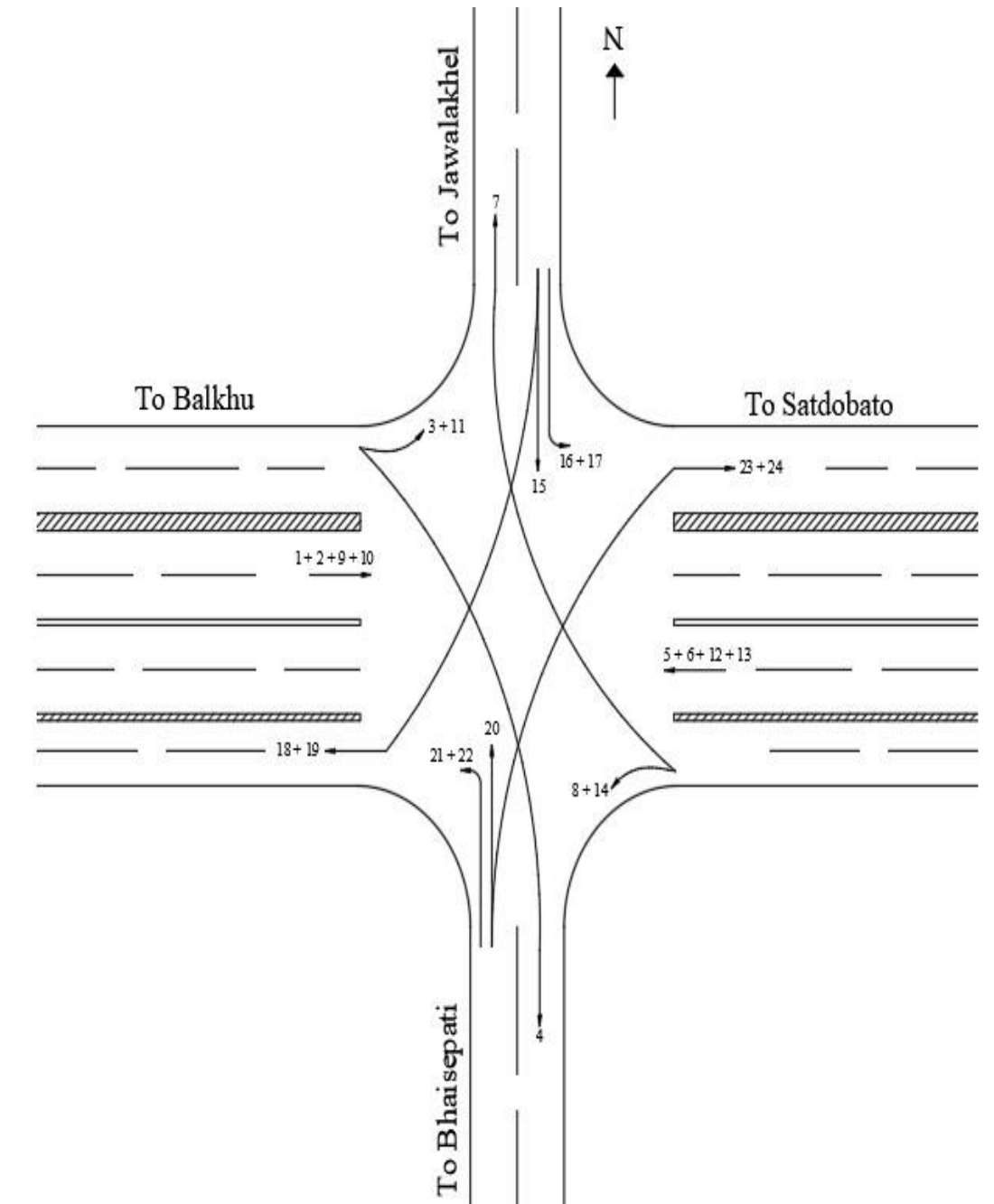


Figure 3.13 Movements with Alternative 5

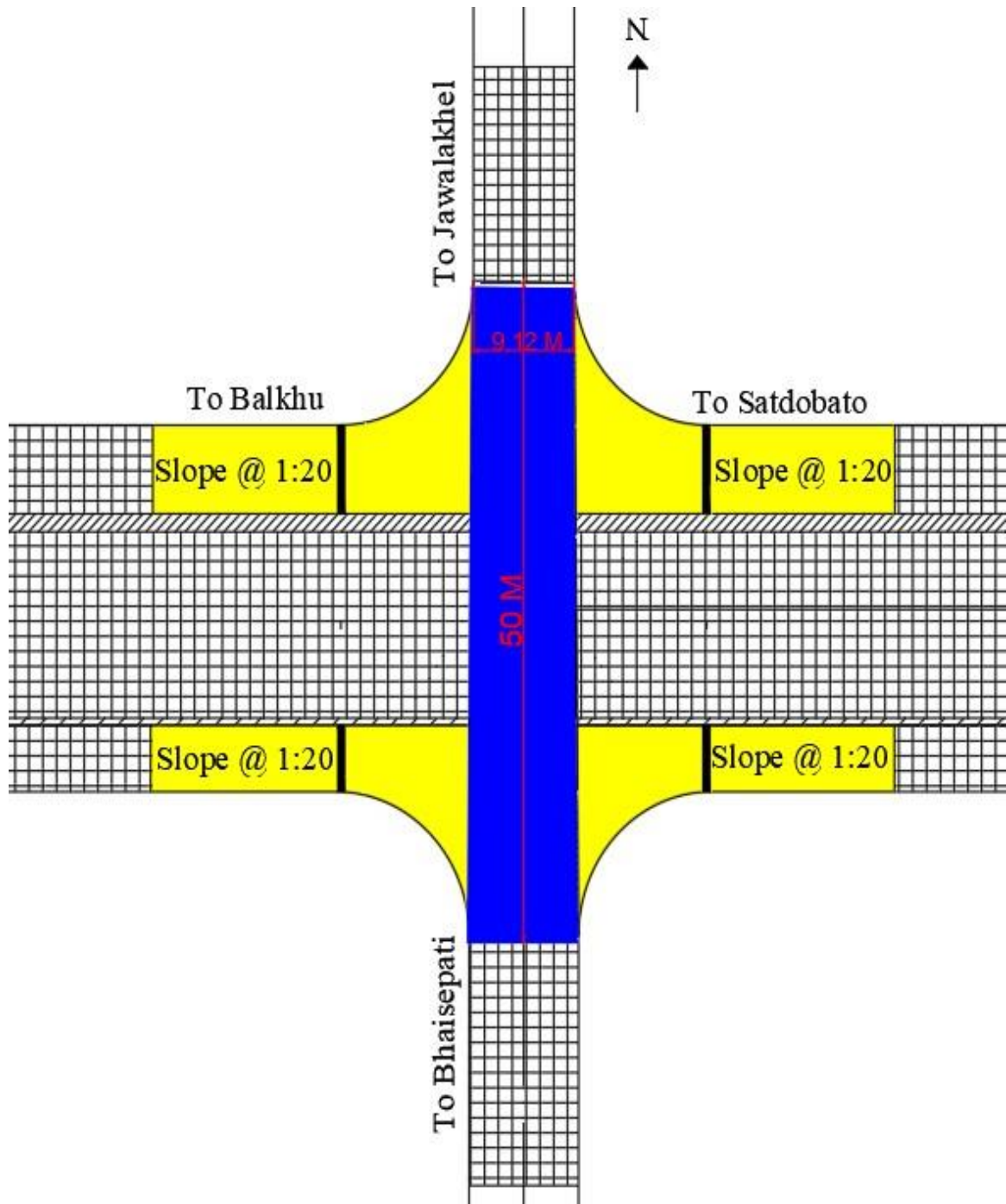


Figure 3.14 Intersection Sketch with Alternative 5

## CHAPTER 4: RESULTS AND DISCUSSIONS

### 4.1 Ekantakuna Intersection

The Ekantakuna Intersection located in Lalitpur is a four-legged crossroad where traffic is directed by police officers rather than functioning traffic lights. This intersection is formed by the convergence of roads coming from Jawalakhel, Balkhu, Satdobato and Bhaisepati. Table 4.1 shows the existing geometry of the intersection.

Table 4. 1 Existing Geometry of the Intersection

SN	Description	Width of Road(m)
1	Balkhu Main Lane	7.50
2	Balkhu Service Lane	7.371
3	Satdobato Main Lane	7.50
4	Satdobato Service Lane	5.5
5	Jawalakhel Lane	9.12
6	Bhaisepati Lane	9.90

### 4.2 Traffic Volume at Intersection

Traffic volume count using video-graphic survey was carried out to conduct a classified count of vehicles. The traffic volume count was done for morning and evening peak hours for three days (Monday, Tuesday and Wednesday) at two different times in a day - 9 AM to 11 AM in the morning and 4 PM to 6 PM in the evening.

Traffic count as presented in Table 4.2 showed that the total volume from Balkhu Main lane at Ekantakuna Intersection is 2361 PCU on Monday morning from 9:00 AM to 11:00 AM.

Table 4. 2 Total Traffic Volume from Balkhu Main Lane (Monday 9:00 - 11:00 AM)

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	156	106	0	10	17	289	250
9:15 - 9:30	228	121	0	15	9	373	285
9:30 - 9:45	243	120	2	19	13	397	311
9:45 - 10:00	232	125	0	14	20	391	322
10:00 - 10:15	225	134	0	7	19	385	314
10:15 - 10:30	261	130	1	11	18	421	332
10:30 - 10:45	228	103	0	13	17	361	288
10:45 - 11:00	241	112	0	4	7	364	260
Total	1814	951	3	93	120	2981	2361
Percentage (%)	60.852	31.902	0.10	3.119	4.0296		

Traffic count as presented in Table 4.3 showed that the total volume from Balkhu Service lane at Ekantakuna Intersection is 1225 PCU on Monday morning from 9:00 AM to 11:00 AM.

Table 4. 3 Total Traffic Volume from Balkhu Service Lane (Monday 9:00 - 11:00 AM)

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	63	31	2	3	39	138	186
9:15 - 9:30	58	31	2	4	19	114	125
9:30 - 9:45	45	20	0	3	24	92	119
9:45 - 10:00	72	28	2	9	24	135	152
10:00 - 10:15	61	46	0	6	33	146	185
10:15 - 10:30	63	32	1	2	33	131	167
10:30 - 10:45	61	26	1	2	27	117	142
10:45 - 11:00	47	26	1	3	32	109	151
Total	470	240	9	32	231	982	1225
Percentage (%)	48.304	24.439	0.916	3.368	23.523		

Traffic count as presented in Table 4.4 showed that the total volume from Satdobato Main lane at Ekantakuna Intersection is 2247 PCU on Monday morning from 9:00 AM to 11:00 AM.

Table 4. 4 Total Traffic Volume from Satdobato Main Lane (Monday 9:00 - 11:00 AM)

<b>Time</b>	<b>Motorcycl e</b>	<b>Car/SUV/Lig ht Van/Pickup, Jeep</b>	<b>Temp o</b>	<b>Mini Truc k</b>	<b>Truck,Bu s, Minibus</b>	<b>Tota l</b>	<b>PC U</b>
9:00 - 9:15	207	111	0	3	10	331	249
9:15 - 9:30	277	111	1	6	8	403	284
9:30 - 9:45	270	100	1	6	9	386	272
9:45 - 10:00	305	105	0	3	4	417	274
10:00 - 10:15	362	109	1	8	9	489	330
10:15 - 10:30	299	105	1	3	7	415	281
10:30 - 10:45	289	113	0	3	5	410	277
10:45 - 11:00	282	117	0	7	4	410	281
Total	2291	871	4	39	56	3261	2247
Percentage (%)	70.254	26.709	0.1227	1.216	1.717		

Traffic count as presented in Table 4.5 showed that the total volume from Satdobato Service lane at Ekantakuna Intersection is 1718 PCU on Monday morning from 9:00 AM to 11:00 AM.

Table 4. 5 Total Traffic Volume from Satdobato Service Lane (Monday 9:00 - 11:00 AM)

<b>Time</b>	<b>Motorcycl e</b>	<b>Car/SUV/Lig ht Van/Pickup, Jeep</b>	<b>Temp o</b>	<b>Mini Truc k</b>	<b>Truck,Bu s, Minibus</b>	<b>Tota l</b>	<b>PC U</b>
9:00 - 9:15	131	73	1	3	14	222	186
9:15 - 9:30	146	81	2	2	9	240	186
9:30 - 9:45	149	83	2	6	15	255	214
9:45 - 10:00	135	81	1	2	16	235	201
10:00 - 10:15	135	97	2	5	13	252	213
10:15 - 10:30	137	90	0	6	18	251	222
10:30 - 10:45	158	105	3	3	18	287	246
10:45 - 11:00	132	91	0	7	28	258	252
Total	1123	701	11	34	131	2000	1718
Percentage (%)	56.15	35.05	0.55	1.7	6.55		

Traffic count as presented in Table 4.6 showed that the total volume from Jawalakhel lane at Ekantakuna Intersection is 1459 PCU on Monday morning from 9:00 AM to 11:00 AM.

Table 4. 6 Total Traffic Volume from Jawalakhel Lane (Monday 9:00 - 11:00 AM)

<b>Time</b>	<b>Motorcycle</b>	<b>Car/SUV/Light Van/Pickup, Jeep</b>	<b>Tempo</b>	<b>Mini Truck</b>	<b>Truck,Bus, Minibus</b>	<b>Total</b>	<b>PCU</b>
9:00 - 9:15	132	77	0	0	11	220	176
9:15 - 9:30	124	84	0	2	5	215	164
9:30 - 9:45	140	81	0	4	14	239	199
9:45 - 10:00	137	96	0	2	6	241	186
10:00 - 10:15	153	93	0	1	7	254	192
10:15 - 10:30	143	97	0	2	8	250	196
10:30 - 10:45	130	84	0	0	10	224	179
10:45 - 11:00	119	77	0	1	10	207	168
<b>Total</b>	<b>1078</b>	<b>689</b>	<b>0</b>	<b>12</b>	<b>71</b>	<b>1850</b>	<b>1459</b>
<b>Percentage (%)</b>	<b>58.27</b>	<b>37.243</b>	<b>0</b>	<b>0.648</b>	<b>3.837</b>		

Traffic count as presented in Table 4.7 showed that the total volume from Bhaisepati lane at Ekantakuna Intersection is 1103 PCU on Monday morning from 9:00 AM to 11:00 AM.

Table 4.7 Total Traffic Volume from Bhaisepati Lane (Monday 9:00 - 11:00 AM)

<b>Time</b>	<b>Motorcycle</b>	<b>Car/SUV/Light Van/Pickup, Jeep</b>	<b>Tempo</b>	<b>Mini Truck</b>	<b>Truck,Bus, Minibus</b>	<b>Total</b>	<b>PCU</b>
9:00 - 9:15	315	5	0	0	1	321	166
9:15 - 9:30	276	9	0	2	0	287	150
9:30 - 9:45	237	6	0	1	2	246	132
9:45 - 10:00	256	8	0	2	0	266	139
10:00 - 10:15	306	9	0	1	0	316	164
10:15 - 10:30	210	11	0	1	0	222	118
10:30 - 10:45	220	3	0	0	0	223	113
10:45 - 11:00	224	7	0	0	1	232	122
<b>Total</b>	<b>2044</b>	<b>58</b>	<b>0</b>	<b>7</b>	<b>4</b>	<b>2113</b>	<b>1103</b>
<b>Percentage (%)</b>	<b>96.734</b>	<b>2.744</b>	<b>0</b>	<b>0.331</b>	<b>0.189</b>		

The traffic count data in tables 4.2 to 4.7 indicates a total volume of 10,113 PCU at the Ekantakuna Intersection on Monday morning from 9:00 AM to 11:00 AM. During the morning hours, the Balkhu Main Lane shows a higher traffic compared to other routes, likely due to the concentration of major business and commercial areas around Pulchowk, Sanepa, Jawalakhel Balkumari and Thapathali. In the evening, the traffic volume on Satdobato Main lane and Jawalakhel lane increased from 2247 PCU to 2634 PCU and 1459 PCU to 2351 PCU, respectively as people returned from these business and commercial zones. The morning and evening peak hours at the intersection were identified as 9:30 to 10:30 AM and 4:15 to 5:15 PM respectively.

### **4.3 Traffic Composition at Intersection**

The vehicles at the Ekantakuna Intersection included motorcycles, cars, tempos, minibuses, long buses, trucks, tractors and bicycles. Bicycles were excluded from the study and tractors were omitted due to their negligible volume. From the traffic volume count data presented in tables 4.2 to 4.7, it can be seen that motorcycle contributes maximum to the total traffic volume followed by cars. Figure 4.3 further illustrates that motorcycles hold the highest proportion of vehicle volume in both the Bhaisepati and Satdobato Main lanes. Conversely, trucks show a lower presence on this route, as heavy vehicles were restricted during office hours under specific time schedules. However, trucks transporting petroleum products and water tankers may occasionally use this route. The volume of tempos at the intersection was negligible and thus has minimal impact.

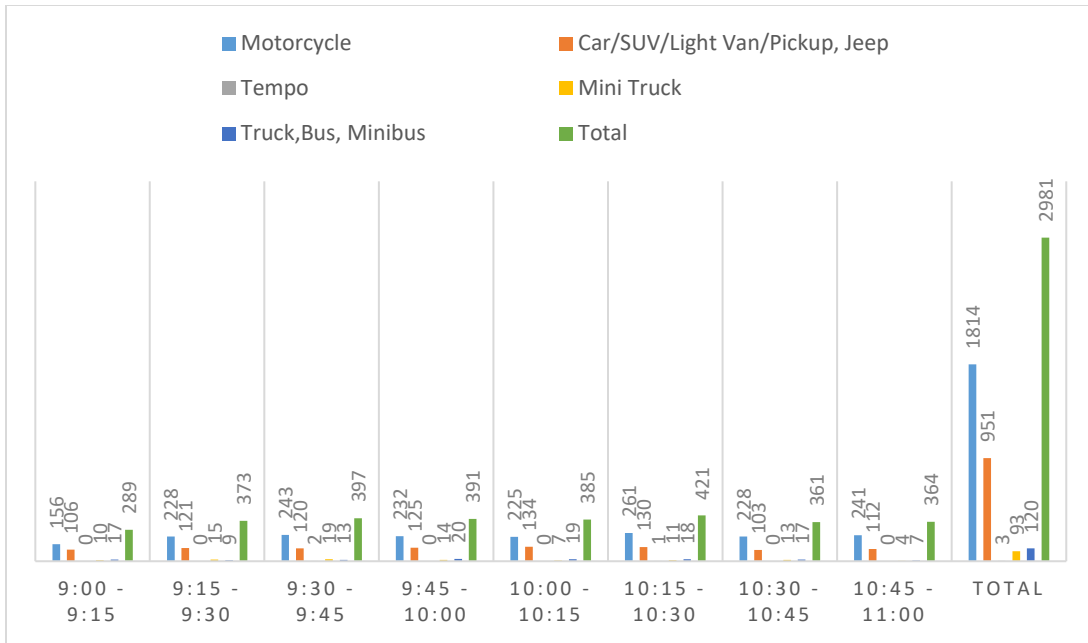


Figure 4.1 Traffic Volume on Balkhu Main Lane (Monday 9:00 - 11:00 AM)

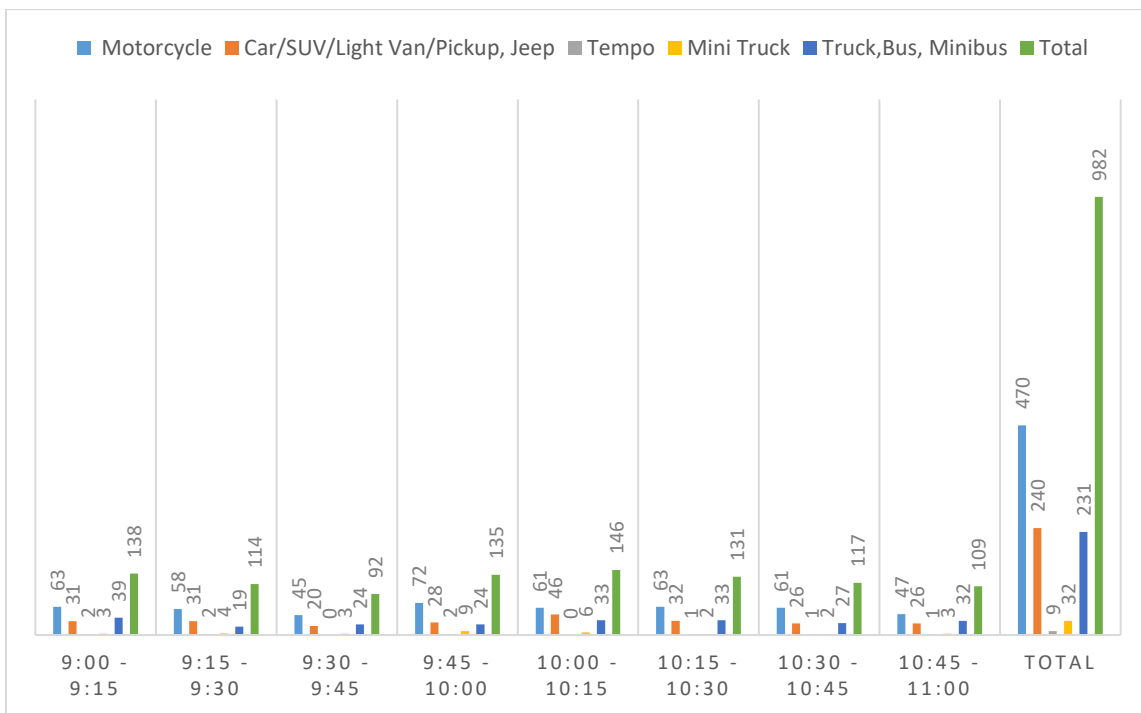


Figure 4. 2 Traffic Volume on Balkhu Service Lane (Monday 9:00 - 11:00 AM)

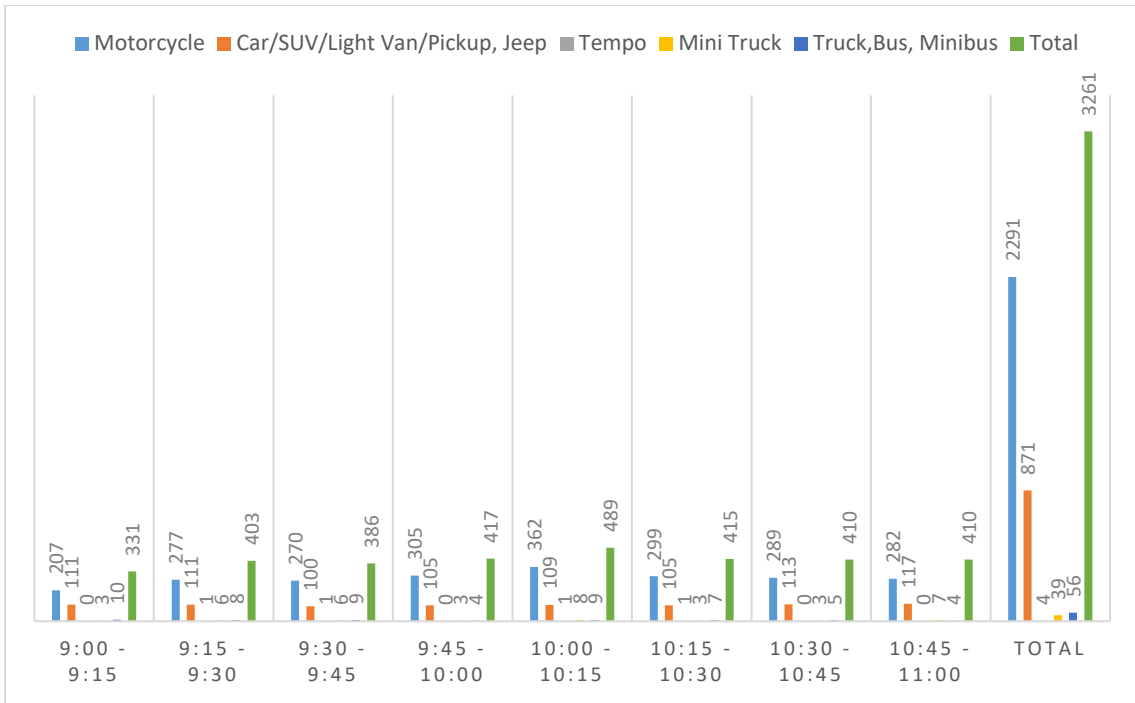


Figure 4.3 Traffic Volume on Satdobato Main Lane (Monday 9:00 - 11:00 AM)

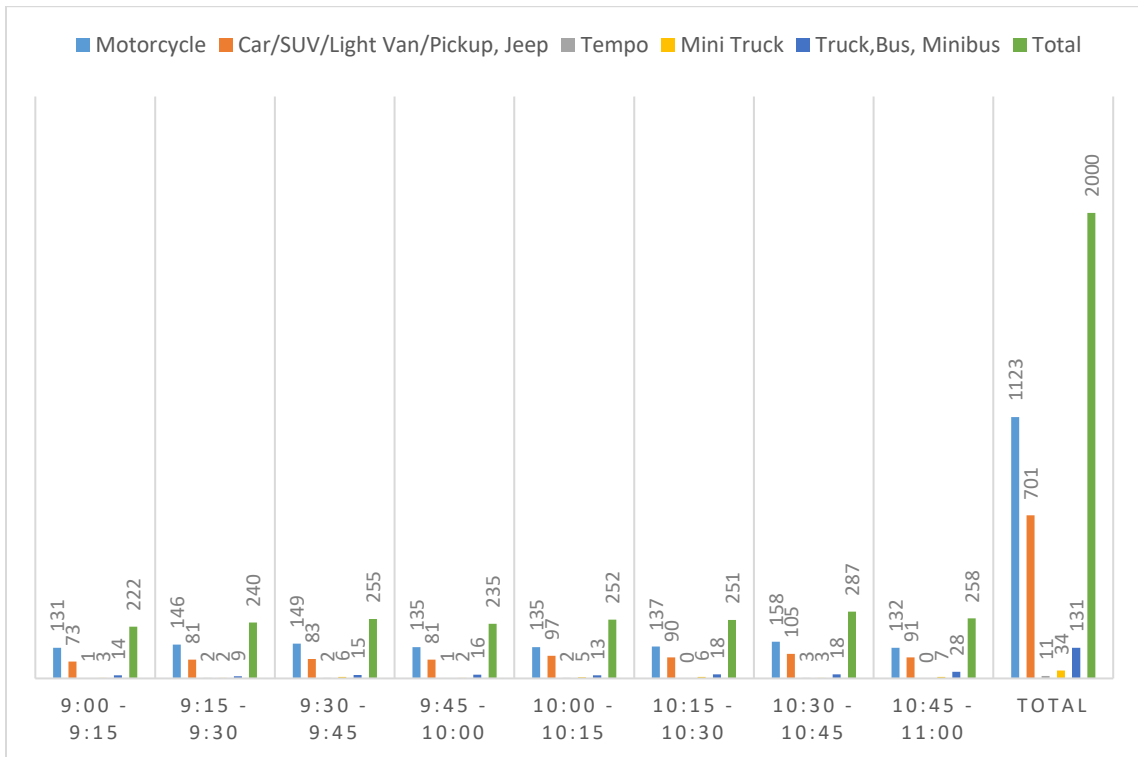


Figure 4.4 Traffic Volume on Satdobato Service Lane (Monday 9:00 - 11:00 AM)

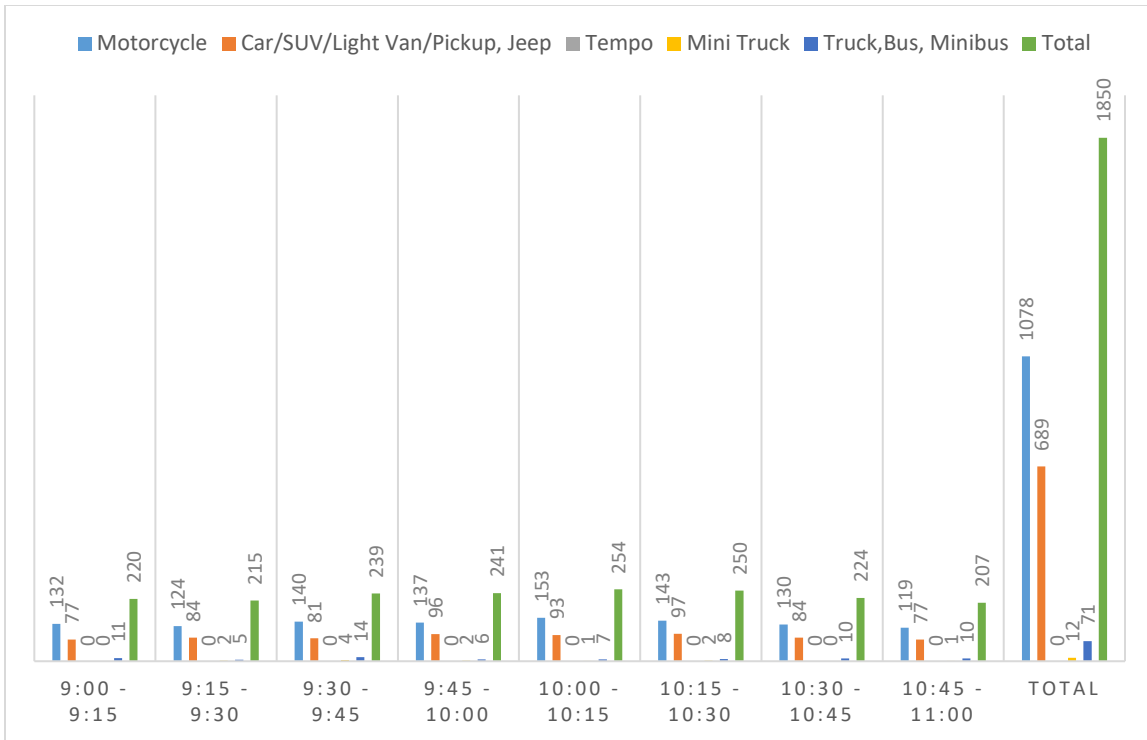


Figure 4.5 Traffic Volume on Jawalakhel Lane (Monday 9:00 - 11:00 AM)

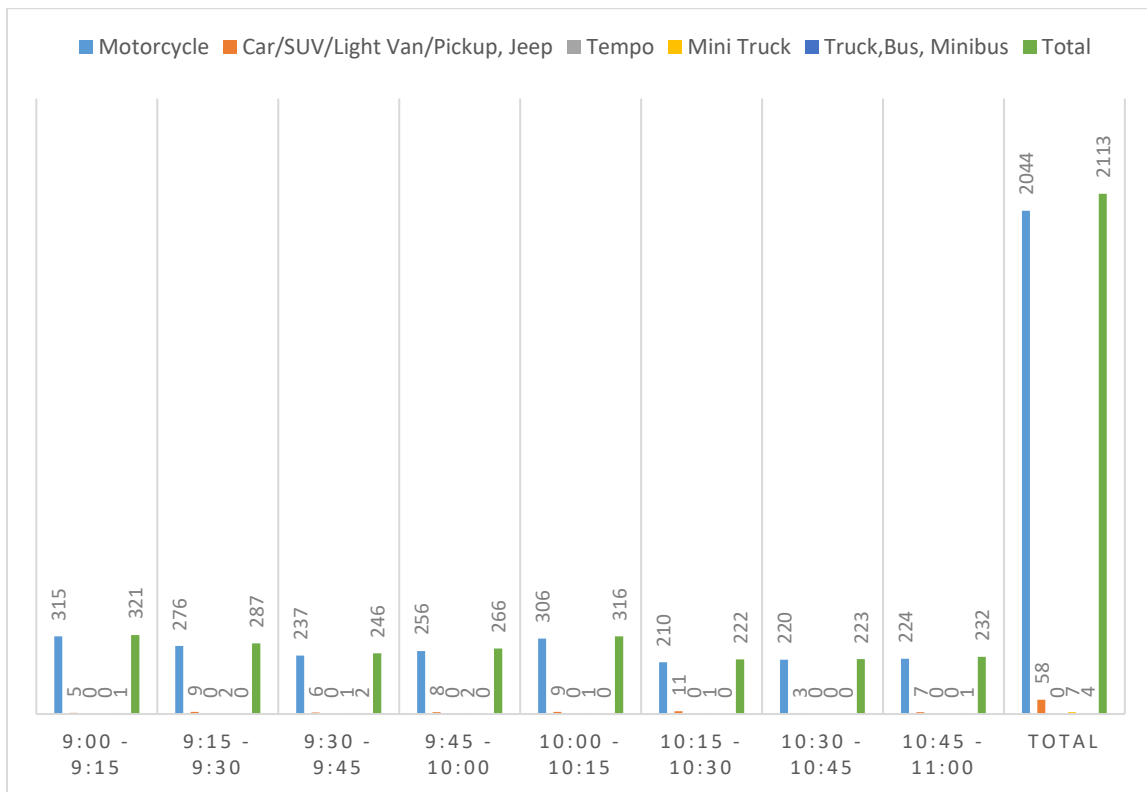


Figure 4.6 Traffic Volume on Bhaisepati Lane (Monday 9:00 - 11:00 AM)

#### 4.4 Relative Flows

Relative flow serves as a proportional factor applied to control and adjust traffic volumes on links and connectors in traffic simulations. The total volumes from Balkhu in the main lane was splitted towards Bhaisepati,Satdobato Main lane,Satdobato Service lane and Jawalakhel.Hence, a proportioning factor should be used to adjust traffic volume known as relative flow.A sample data of relative flows for Monday from Balkhu Main lane (9:00 to 11:00 AM) are shown in figures 4.7 to 4.10 as below:

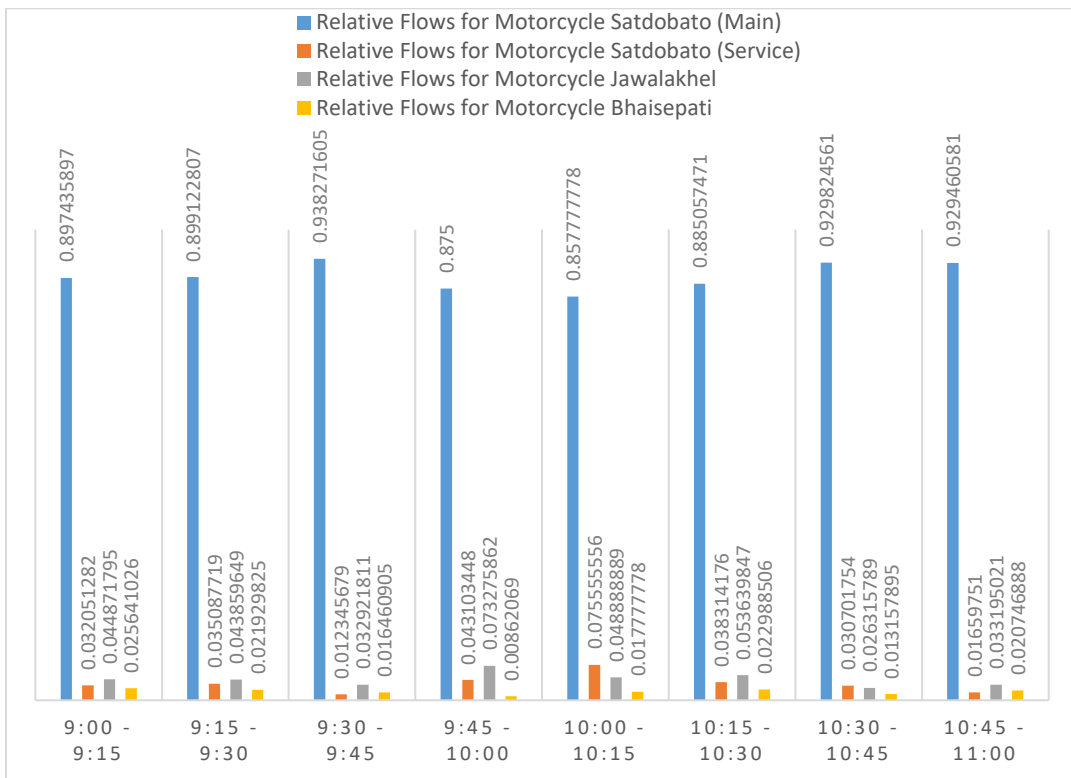


Figure 4.7 Relative flow for Motorcycles (Monday 9:00 to 11:00 AM)

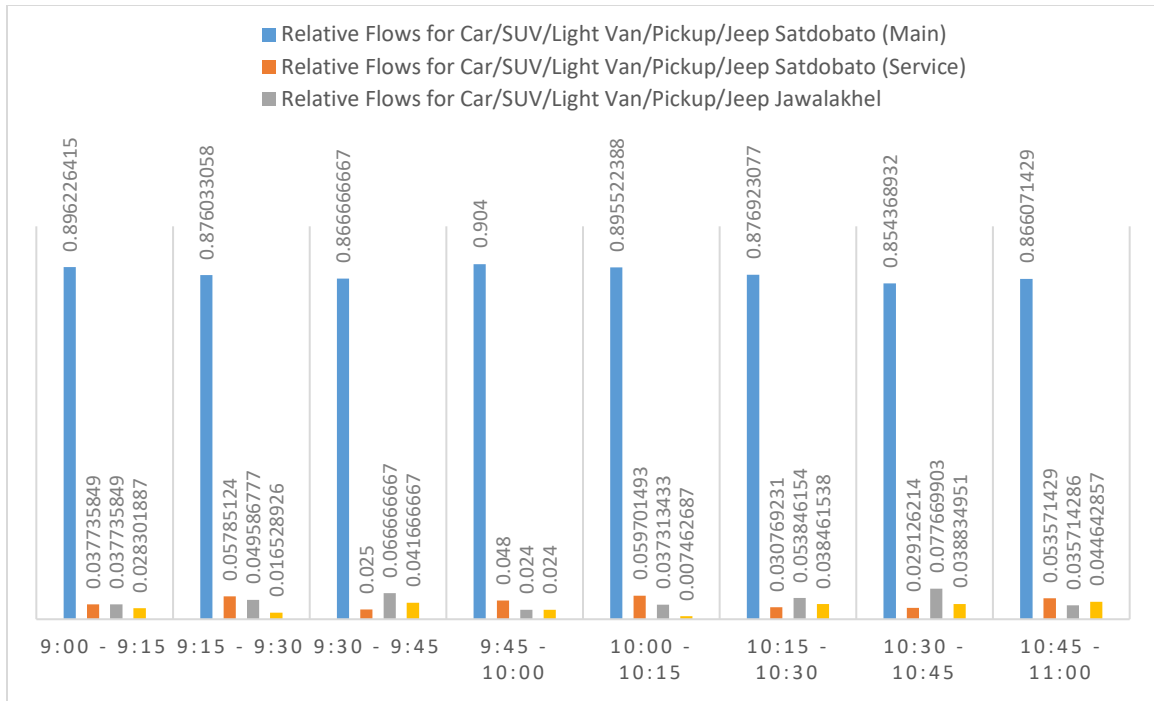


Figure 4.8 Relative flow for Car/SUV/Light Van/Pickup, Jeep (Monday 9:00 to 11:00AM)

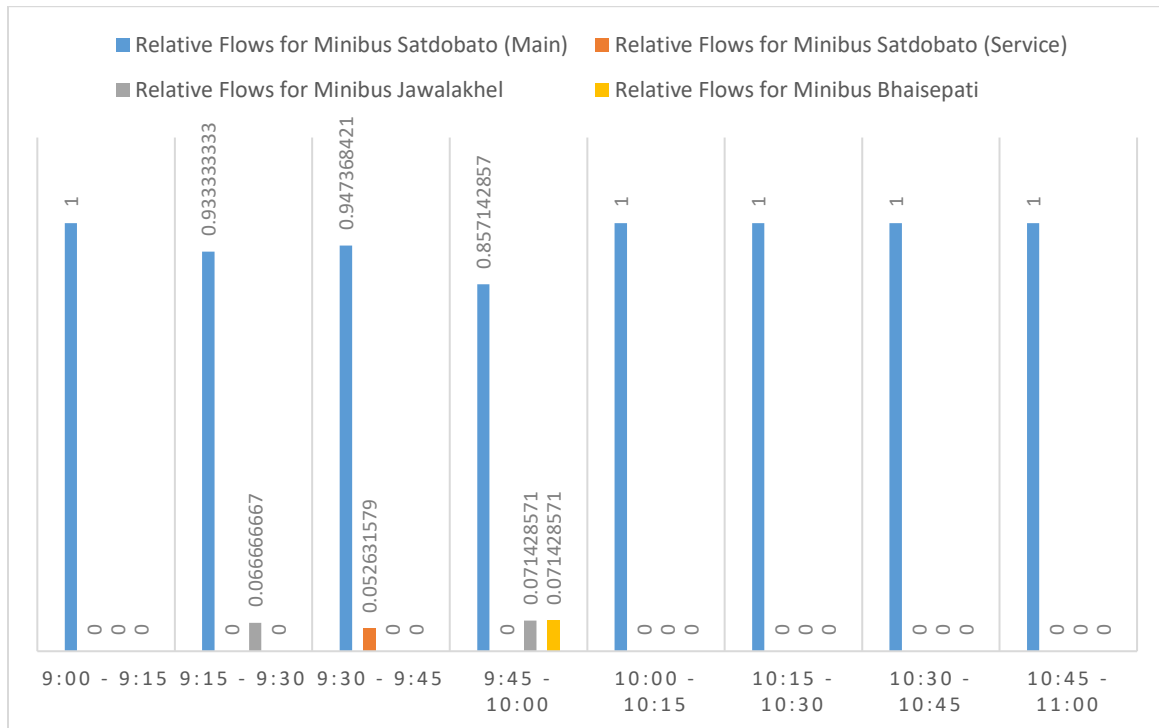


Figure 4.9 Relative flow for Minibus (Monday 9:00 to 11:00AM)

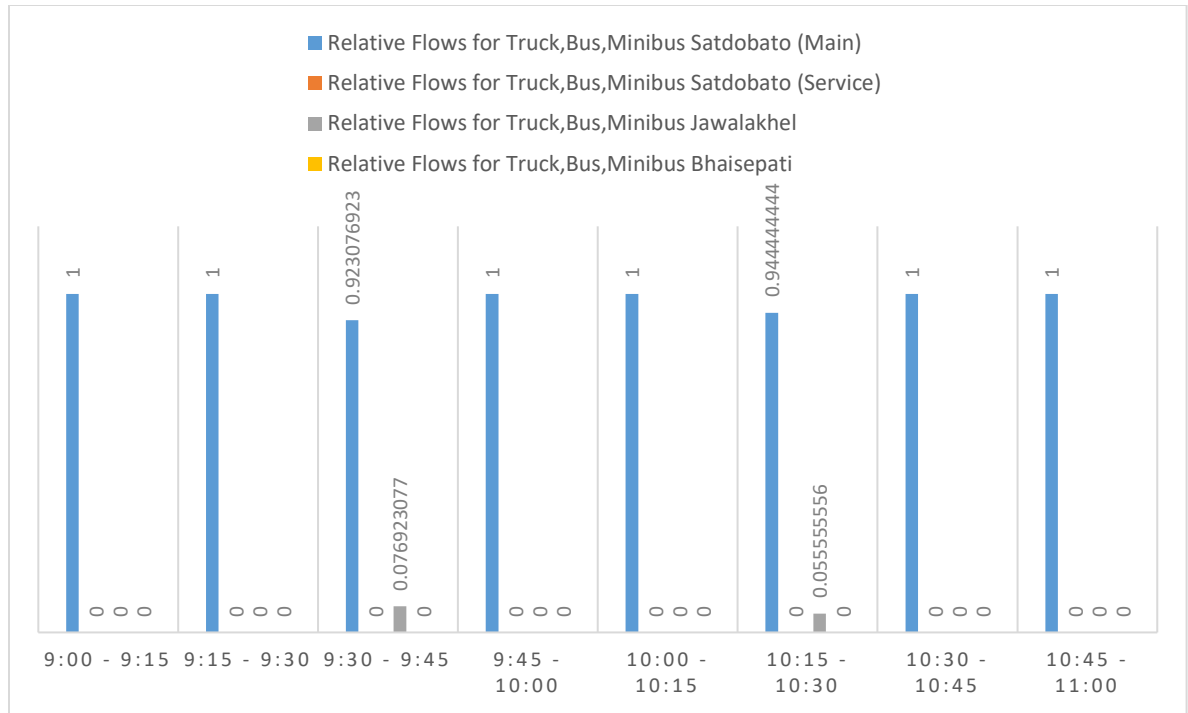


Figure 4.10 Relative flow for Truck, Bus, Minibus (Monday 9:00 to 11:00AM)

It has been seen that motorcycle contributes maximum to the total traffic volume. Relative flow for every 15-minute time intervals has been calculated for each of the lanes and a detailed sample of relative flow has been presented in APPENDIX B: Relative Flow.

#### 4.5 Calibration of Model

Calibration involved adjusting driving behavior parameters to ensure the model reliably reflects real traffic conditions. The objective of calibration was to develop a model that accurately reflects real world conditions. A trial-and-error approach was applied to determine the appropriate values for various driving behavior parameters specific to the study area.

Calibration had been done using traffic volume, queue length and speed distribution. For traffic volume, GEH statistics has been used and for queue length and speed distribution, RMSNE statistics was used to calibrate the developed model.

##### 4.5.1 Calibration of Driving Behavior Parameters

Field data collected on Monday and Tuesday (Day 1 and 2) was used as an input for calibrating the model. Driving behaviors were adjusted to align the output volume from VISSIM with the

input volume based on field data. The calibrated driving behavior parameters were presented in the table 4.8.

Table 4.8 Calibrated Driving Behavior Parameters

<b>Parameter</b>	<b>Value</b>
Look ahead distance-min	20.00m
Look back distance-min	18.00m
Average standstill distance	1.00m
Additive part of safety distance	0.20
Multiplicative part of safety distance	0.60
Minimum headway (front/rear)	0.55

#### **4.5.2 Calibration of Model for Traffic Volume**

The field data were entered into VISSIM with the required parameters and the simulation was run. The output volume was then compared to the input volume, and the GEH statistics was calculated for model calibration using Equation 2.1. Two days data had been used for calibration of the model. A trial-and-error approach has been used to calibrate the model.

Table 4.9 represents calibration of VISSIM model for traffic volume for two days data (Day 1 and 2). Calibration of volume was carried out with a trial-and-error method referencing to GEH value of less than 5 (WSDOT, 2021). It can be seen that for all movements, the value of GEH lies below 5 (i.e. within acceptable range).

Table 4.9 Calibration of Traffic Volume using GEH Statistics

SN	Movement	Code	Output Volume in VISSIM Model	Actual Volume in Field	GEH
1	Balkhu Main to Satdobato Main	BM-SM	2709	2952	4.567
2	Balkhu Main to Satdobato Service	BM-SS	125	144	1.638
3	Balkhu Main to Jawalakhel	BM-Ja	137	135	0.171
4	Balkhu Main to Bhaisepati	BM-Bh	74	81	0.795
5	Satdobato Main to Balkhu Main	SM-BM	2057	2257	4.306
6	Satdobato Main to Balkhu Service	SM-BS	173	181	0.601
7	Satdobato Main to Bhaisepati	SM-Bh	197	223	1.794
8	Satdobato Main to Jawalakhel	SM-Ja	842	791	1.785
9	Balkhu Service to Satdobato Main	BS-SM	238	247	0.578
10	Balkhu Service to Satdobato Service	BS-SS	326	358	1.730
11	Balkhu Service to Jawalakhel	BS-Ja	382	382	0.000
12	Satdobato Service to Balkhu Service	SS-BS	654	552	4.154
13	Satdobato Service to Balkhu Main	SS-BM	556	651	3.867
14	Satdobato Service to Bhaisepati	SS-Bh	832	744	3.135
15	Jawalakhel to Bhaisepati	Ja-Bh	1425	1620	4.998
16	Jawalakhel to Balkhu Main	Ja-BM	152	197	3.407
17	Jawalakhel to Balkhu Service	Ja-BS	89	142	4.932
18	Jawalakhel to Satdobato Service	Ja-SS	117	175	4.800
19	Jawalakhel to Satdobato Main	Ja-SM	423	457	1.621
20	Bhaisepati to Jawalakhel	Bh-Ja	1187	1023	4.934
21	Bhaisepati to Balkhu Main	Bh-BM	29	32	0.543
22	Bhaisepati to Balkhu Service	Bh-BS	20	20	0.000
23	Bhaisepati to Satdobato Main	Bh-SM	788	787	0.036
24	Bhaisepati to Satdobato Service	Bh-SS	142	120	1.922

As calculated GEH values are less than 5% as specified by Geoffrey E. Havers formula, the model is thus calibrated using traffic volume.

#### 4.5.3 Calibration of Model for Average Queue Length

The average queue length for each vehicle type was measured from the video footage. This observed average queue length was then compared with the average queue length generated

by the VISSIM simulation. The calibration of the model for Queue Length was performed using RMSNE statistics and has been presented in table 4.10.

Table 4.10 Calibration of Model for Average Queue Length using RMSNE Statistics

SN	Time in Seconds	Leg	Average Queue Length in VISSIM Output(m)	Average Queue Length in Field(m)	RMSNE
1	0-7200	Balkhu Main(BM)	45.860	46.774	0.134
2	0-7200	Balkhu Service(BS)	15.278	15.584	0.077
3	0-7200	Jawalakhel(Ja)	18.120	18.482	0.084
4	0-7200	Satdobato Service(SS)	18.639	19.011	0.085
5	0-7200	Satdobato Main(SM)	41.305	42.131	0.127
6	0-7200	Bhaisepati(Bh)	40.060	40.865	0.125

As calculated RMSNE values are less than 15%, the model is thus calibrated using queue length.

#### 4.5.4 Calibration of Model for Speed

The speed for each vehicle type was calculated. This observed speed of vehicles was then compared with the speed generated by the VISSIM simulation. Data collection included a minimum of fifty samples across all vehicle categories to determine the average speed for each type. A minimum of at least 50 vehicle samples are required for spot speed analysis (Mathew, 2019). The calibration of the model for speed was performed using RMSNE statistics and sample of calibration using speed has been presented in table 4.11.

Table 4.11 Calibration of model for speed using RMSNE Statistics

SN	Vehicle Category	Speed (Kmph)		RMSNE
		Simulated average speed	Field Measured average speed	
1	Motorcycle	34.886	35.565	0.1139
2	Car/SUV/Light Van/Pickup/Jeep	31.558	32.077	0.0916
3	Mini Truck	26.719	26.509	0.0408
4	Truck/Bus	21.606	21.12	0.1058

As calculated RMSNE values are less than 15% (0.15), the model is thus calibrated using speed.

#### 4.6 Validation of Model

Once the model was calibrated, it was validated for Day 3 traffic. The GEH statistics and RMSNE statistics were calculated for Day 3 traffic using a process similar to the calibration phase. The field data of day 3 were entered into VISSIM with the obtained calibration parameters and the simulation was run. The output volume was then compared to the input volume and the GEH statistics was calculated for model calibration using Equation 2.1.

Validation has been done using traffic volume, queue length and speed distribution. For traffic volume statistics has been used and for queue length and speed distribution, RMSNE statistics was used to validate the model.

##### 4.6.1 Validation of Model for Traffic Volume

Field data collected on Wednesday (Day 3) was used as input for validating the model. Table 4.12 represents validation of VISSIM model for traffic volume using Day 3 data. It can be seen that for all movements, the value of GEH lies below 5 (i.e. within acceptable range).

Table 4.12 Validation of Traffic Volume using GEH for Day 3 Data (9:00 to 11:00 AM)

SN	Movement	Code	Output Volume in VISSIM Model	Actual Volume in Field	GEH
1	Balkhu Main to Satdobato Main	BM-SM	2660	2680	0.387
2	Balkhu Main to Satdobato Service	BM-SS	108	108	0.000
3	Balkhu Main to Jawalakhel	BM-Ja	131	131	0.000
4	Balkhu Main to Bhaisepati	BM-Bh	58	62	0.516
5	Satdobato Main to Balkhu Main	SM-BM	2038	2049	0.243
6	Satdobato Main to Balkhu Service	SM-BS	148	151	0.245

SN	Movement	Code	Output Volume in VISSIM Model	Actual Volume in Field	GEH
7	Satdobato Main to Bhaisepati	SM-Bh	192	204	0.853
8	Satdobato Main to Jawalakhel	SM-Ja	851	857	0.205
9	Balkhu Service to Satdobato Main	BS-SM	236	237	0.065
10	Balkhu Service to Satdobato Service	BS-SS	335	343	0.435
11	Balkhu Service to Jawalakhel	BS-Ja	398	402	0.200
12	Satdobato Service to Balkhu Service	SS-BS	693	700	0.265
13	Satdobato Service to Balkhu Main	SS-BM	456	460	0.187
14	Satdobato Service to Bhaisepati	SS-Bh	832	840	0.277
15	Jawalakhel to Bhaisepati	Ja-Bh	953	1022	2.196
16	Jawalakhel to Balkhu Main	Ja-BM	140	152	0.993
17	Jawalakhel to Balkhu Service	Ja-BS	89	93	0.419
18	Jawalakhel to Satdobato Service	Ja-SS	122	133	0.974
19	Jawalakhel to Satdobato Main	Ja-SM	430	450	0.953
20	Bhaisepati to Jawalakhel	Bh-Ja	1182	1177	0.146
21	Bhaisepati to Balkhu Main	Bh-BM	21	21	0.000
22	Bhaisepati to Balkhu Service	Bh-BS	18	15	0.739
23	Bhaisepati to Satdobato Main	Bh-SM	734	761	0.988
24	Bhaisepati to Satdobato Service	Bh-SS	145	139	0.504

As calculated GEH values are less than 5% as specified by Geoffrey E. Havers Formula, the model is thus validated using traffic volume.

#### 4.6.2 Validation of Model for Average Queue Length

The validation of the model for Queue Length was performed using RMSNE statistics and has been presented in table 4.13.

Table 4.13 Validation of Model for Average Queue Length using RMSNE Statistics

S.N	Time in Seconds	Leg	Average Queue Length in Vissim Model (m)	Average Queue Length in Field(m)	RMSNE
1	0-7200	Balkhu Main(BM)	33.735	34.411	0.115
2	0-7200	Balkhu Service(BS)	6.623	6.755	0.051
3	0-7200	Jawalakhel(Ja)	15.365	15.672	0.078
4	0-7200	Satdobato Service(SS)	5.401	5.509	0.046
5	0-7200	Satdobato Main(SM)	37.312	38.056	0.101
6	0-7200	Bhaisepati(Bh)	39.917	40.715	0.125

As calculated RMNSE values are less than 15%, the model is thus validated using queue length.

#### 4.6.3 Validation of Model for Speed

The speed for each vehicle type was determined, and this observed speed was then compared with the speed generated by the VISSIM simulation. Model validation for speed was conducted using RMSNE statistics, with a sample of the validation results shown in table 4.14.

Table 4.14 Validation of model for speed using RMSNE Statistics

SN	Vehicle Category	Speed (Kmph)		RMSNE
		Simulated average speed	Field Measured average speed	
1	Motorcycle	35.643	36.277	0.10526
2	Car/SUV/Light Van/Pickup/Jeep	32.386	33.214	0.14367
3	Mini Truck	26.782	27.211	0.08224
4	Truck/Bus	23.416	23.977	0.11457

As calculated RMNSE values are less than 15% (0.15), the model is thus validated using speed.

#### 4.7 Operational Performance of the Intersection in Present

After calibrating and validating VISSIM model for the intersection, the operational performance was evaluated in terms of delay and level of service taking the average of the evening peak data from days 1, 2 and 3 since the evening peak flow was found to be greater than the morning peak flow. The intersection achieved an overall Level of Service (LOS) of D with an average delay of 25.104 seconds. The maximum average queue length was obtained to be 45.924 meters. This demonstrated the potential for congestion at the intersection which can be explained by high demand relative to the intersection's capacity. Table 4.15 showed the route-wise operational performance of the intersection in present.

Table 4.15 Route-wise operational performance of the intersection in present

Time in Second	Routes	Vehicular Delay in Seconds	LOS
0-7200	BS-SS	25.932	D
0-7200	BS-SM	26.391	D
0-7200	BS-Ja	2.744	A
0-7200	BM-SS	27.122	D
0-7200	BM-SM	31.980	D
0-7200	BM-Ja	29.277	D
0-7200	BM-Bh	25.430	D
0-7200	SM-BM	17.710	C
0-7200	SM-BS	15.946	C
0-7200	SM-Ja	28.904	D
0-7200	SM-Bh	19.764	C
0-7200	SS-BM	21.999	C
0-7200	SS-BS	16.313	C
0-7200	SS-Bh	7.215	A
0-7200	Bh-SS	53.034	F
0-7200	Bh-SM	42.899	E
0-7200	Bh-BM	39.301	E

<b>Time in Second</b>	<b>Routes</b>	<b>Vehicular Delay in Seconds</b>	<b>LOS</b>
0-7200	Bh-BS	37.203	E
0-7200	Bh-Ja	47.905	E
0-7200	Ja-SS	9.01	A
0-7200	Ja-SM	14.162	B
0-7200	Ja-BM	15.904	C
0-7200	Ja-BS	28.129	D
0-7200	Ja-Bh	18.213	C
Overall Delay in Seconds		25.104	D

Table 4.16 showed the approach-wise operational performance of the intersection in present.

Table 4.16 Approach-wise LOS of the intersection in present

<b>Approaches</b>	<b>North (Jawalakhel)</b>	<b>East (Satdobato)</b>		<b>West(Balkhu)</b>		<b>South(Bhaise pati)</b>
		<b>Main Lane</b>	<b>Service Lane</b>	<b>Main Lane</b>	<b>Service Lane</b>	
LOS	C	C	C	D	C	E

#### 4.8 Operational Performance of the Intersection in Future

The calibrated and validated model was also used in the evaluation of intersection performance in terms of delay and level of service for the forecasted year (10 Years). The intersection achieved an overall Level of Service (LOS) of F with an average delay of 50.031 seconds. The maximum average queue length was obtained to be 89.661 meters. This emphasized the critical traffic conditions and the potential for congestion at the intersection, which could be explained by the high demand surpassing the intersection's capacity. Table 4.17 showed the route-wise operational performance of the intersection for forecasted 10 years.

Table 4.17 Route-wise operational performance of the intersection for forecasted year

<b>Time in Second</b>	<b>Routes</b>	<b>Vehicular Delay in Seconds</b>	<b>LOS</b>
0-7200	BS-SS	49.457	E
0-7200	BS-SM	50.254	F

<b>Time in Second</b>	<b>Routes</b>	<b>Vehicular Delay in Seconds</b>	<b>LOS</b>
0-7200	BS-Ja	11.458	B
0-7200	BM-SS	73.101	F
0-7200	BM-SM	69.595	F
0-7200	BM-Ja	53.626	F
0-7200	BM-Bh	49.256	E
0-7200	SM-BM	42.258	E
0-7200	SM-BS	36.698	E
0-7200	SM-Ja	49.597	E
0-7200	SM-Bh	43.884	E
0-7200	SS-BM	48.698	E
0-7200	SS-BS	29.966	D
0-7200	SS-Bh	15.554	C
0-7200	Bh-SS	97.868	F
0-7200	Bh-SM	70.642	F
0-7200	Bh-BM	74.018	F
0-7200	Bh-BS	63.212	F
0-7200	Bh-Ja	71.084	C
0-7200	Ja-SS	22.352	C
0-7200	Ja-SM	30.294	D
0-7200	Ja-BM	38.759	E
0-7200	Ja-BS	56.128	F
0-7200	Ja-Bh	52.976	F
Overall Delay in Seconds		50.031	F

Table 4.18 showed the approach-wise operational performance of the intersection for forecasted 10 years.

Table 4.18 Approach-wise LOS of the intersection for forecasted year

<b>Approaches</b>	<b>North (Jawalakhel)</b>	<b>East (Satdobato)</b>		<b>West(Balkhu)</b>		<b>South(Bhaise pati)</b>
		<b>Main Lane</b>	<b>Service Lane</b>	<b>Main Lane</b>	<b>Service Lane</b>	
LOS	E	E	D	F	E	F

#### **4.9 Improvement alternatives of Intersection in present**

To enhance the operational performance of the intersection, five improvement alternatives were evaluated. The analysis was conducted for both current traffic conditions and projected traffic volumes over the next 10 years. Under existing conditions, the intersection operated at LOS D with a delay of 25.104 seconds and maximum average queue length of 45.924 meters. However, for the forecasted traffic volume in 10 years, the LOS deteriorated to F with a significantly higher delay of 50.031 seconds and maximum average queue length of 89.661 meters. A comparative analysis of the traffic performance parameters for both current and future traffic conditions revealed that all key operational performance indicators declined over time.

The variations in traffic performance measures and the observations following the implementation of alternatives in present are outlined as follows:

##### **Alternative 1: Restriction of traffic movement from service lane to main lane**

From the simulation of alternative 1, it was observed that the average queue length and delay decreased by 5.935% and 12.268%, respectively along the Balkhu Main Lane to Bhaisepati Lane. However, the average queue length and delay drastically increased by 59.639% and 21%, respectively along the Satdobato Service Lane to Balkhu Service Lane. Furthermore, neutral routes like the Bhaisepati approach and Jawalakhel to Bhaisepati Lane experienced minimal changes in queue length and delay. The restriction of traffic movement from the service lane to the main lane did not bring significant changes in queue length and delay for most lanes. Details of the output from alternative 1 were presented in APPENDIX D: Scenario Analysis.

##### **Alternative 2: Restriction of left turning traffic movement from main lane**

From the simulation of alternative 2, it was observed that the average queue length and delay decreased most significantly by 18.285% and 8.559% respectively along the Balkhu Main Lane to Bhaisepati Lane followed by decrease in average queue length and delay by 18.285% and 1.818% respectively along Balkhu Main Lane to Satdobato Service lane. However, the average queue length and delay increased by 21.1% and 23.069%, respectively along the Balkhu Service Lane to Jawalakhel Lane. Furthermore, Bhaisepati approach experienced

minimal changes in queue length and delay whereas Jawalakhel approach showed mixed results. Overall, the restriction of left turning traffic movement from main lanes did not bring significant changes in queue length and delay for most lanes.

### **Alternative 3: Combined Scenario**

Upon obtaining the results from restriction scenarios 1 and 2, the combined scenario 3 which integrates both restriction scenarios 1 and 2 was implemented to analyze the result. From the simulation of alternative 3, it was observed that the average queue length and delay decreased most significantly by 34.723% and 25.657% respectively along the Balkhu Main Lane to Satdobato Service Lane followed by decrease in average queue length and delay by 33.035% and 23.11% respectively along Balkhu Main Lane to Bhaisepati Lane. However, the average queue length and delay drastically increased by 84.875% and 24.135% respectively along the Balkhu Service Lane to Jawalakhel Lane. Overall, the combined restriction decreased queue and delay by 4.948% and 4.117% respectively in average.

### **Alternative 4: Restriction of right turning traffic movement from main lane**

From the simulation of alternative 4, it was observed that the average queue length and delay decreased by significant margins. It can be seen that the average queue length and delay significantly decreased by 83.049% and 93.775% along Balkhu Main Lane to Satdobato Service Lane followed by decrease in corresponding values by 63.432% and 89.024% respectively along Jawalakhel Lane to Bhaisepati Lane. Moreover, the routes from Jawalakhel to Balkhu Service Lane and Balkhu Main Lane, and Satdobato Main Lane to Balkhu Service Lane had achieved substantial decrease in queue and delay. Furthermore, it can be seen that the average queue length and delay increased by 47.627% and 19.279% respectively along the Balkhu Service Lane to Satdobato Service Lane. No major changes can be seen in Bhaisepati Lanes. Overall, the alternative 4 decreased queue and delay by 8.103% and 7.388% respectively in average. Details of the output from alternative 4 were presented in APPENDIX D: Scenario Analysis.

## **Alternative 5: Conversion of Unsignalized Intersection into Grade-Separated Signalized Intersection**

From the simulation of alternative 5, it was observed that the average queue length and delay decreased by significant margins and thereby improving level of service. It can be seen that the queue and delay along Balkhu Main Lane to Satdobato Main Lane route and vice-versa had been reduced to zero. This is because of introduction of underpass along these routes. Moreover, after the implementation of alternative 5, the overall level of service of intersection had improved from D to B. Overall, the alternative 5 decreased queue and delay by 33.789% and 39.060% respectively in average. Details of the output from alternative 5 were presented in APPENDIX D: Scenario Analysis.

### **4.10 Improvement alternatives of Intersection for Forecasted 10 Years**

The variations in traffic performance measures and the observations following the implementation of alternatives for forecasted 10 years are outlined as follows:

#### **Alternative 1: Restriction of traffic movement from service lane to main lane**

From the simulation of alternative 1, it was observed that both the average queue length and delay decreased by 6.797% and 13.507% respectively along the Balkhu Main Lane to Satdobato Service Lane. The average queue length and delay also decreased by 4.408% and 14.043% respectively along the Balkhu Main Lane to Bhaisepati Lane. However, the average queue length and delay drastically increased by 40.211% and 36.926%, respectively along the Satdobato Service Lane to Balkhu Service Lane. The restriction of traffic movement from the service lane to the main lane did not bring significant changes in queue length and delay for most lanes. Details of the output from alternative 1 were presented in APPENDIX D: Scenario Analysis.

#### **Alternative 2: Restriction of left turning traffic movement from main lane**

From the simulation of alternative 2, it was observed that both the average queue length and delay decreased significantly by 13.660% and 16.291% respectively along the Balkhu Main Lane to Satdobato Main Lane. Moreover, it can be seen that average queue length and delay decreased significantly by 15.665% and 5.500% respectively along the Balkhu Main Lane to

Bhaisepati Lane. However, the average queue length and delay drastically increased by 32.901% and 30.285%, respectively along the Balkhu Service Lane to Jawalakhel Lane. Overall, the restriction of left turning traffic movement from main lanes did not bring significant changes in queue length and delay for most lanes.

### **Alternative 3: Combined Scenario**

Upon obtaining the results from restriction scenarios 1 and 2, the combined scenario 3 which integrates both restriction scenarios 1 and 2 was implemented to analyze the result. From the simulation of alternative 3, it was observed that the average queue length and delay decreased by 22.885% and 15.226% respectively along Balkhu Main Lane to Satdobato Service Lane respectively. Similarly significant reductions in delay and queue can be seen along Balkhu Main Lane to Satdobato Main Lane and Bhaisepati Lane. However, the average queue length and delay drastically increased by 52.150% and 38.803% respectively along the Balkhu Service Lane to Jawalakhel Lane. Significant increase in delay and queue can be seen along Balkhu Service and Satdobato Service approaches. No major changes can be seen in Bhaisepati Lanes. Overall, the combined restriction decreased queue and delay by 1.551% and 3.488% respectively in average.

### **Alternative 4: Restriction of right turning traffic movement from main lane**

From the simulation of alternative 4, it was observed that the average queue length and delay decreased by significant margins. It can be seen that the average queue length and delay significantly decreased by 80.112% and 91.557% along Balkhu Main Lane to Satdobato Service Lane followed by decrease in corresponding values by 71.694% and 88.782% respectively along Jawalakhel Lane to Bhaisepati Lane. Similarly, significant delay in queue and delay can be observed along the routes Jawalakhel to Balkhu Service and Balkhu Main Lanes. Furthermore, it can be seen that the average queue length and delay increased by 56.592% and 22.041% respectively along the Balkhu Service Lane to Satdobato Service Lane. Overall, the alternative 4 decreased queue and delay by 10.574% and 11.450% respectively in average. Details of the output from alternative 4 were presented in APPENDIX D: Scenario Analysis.

### **Alternative 5: Conversion of Unsignalized Intersection into Grade-Separated Signalized Intersection**

From the simulation of alternative 5, it was observed that the average queue length and delay decreased by significant margins. It can be seen that the queue and delay along Balkhu Main Lane to Satdobato Main Lane route and vice-versa had been reduced to zero. This is because of introduction of underpass along these routes. The LOS of routes had been deteriorated due to increase in vehicular volume. Moreover, after the implementation of alternative 5, the overall level of service of intersection had improved from F to D. Overall, the alternative 5 decreased queue and delay by 39.340% and 42.243% respectively in average. Details of the output from alternative 5 were presented in APPENDIX D: Scenario Analysis.

## CHAPTER 5: CONCLUSION AND RECOMMENDATION

### 5.1 Conclusion

This study evaluated the performance of delay, queue length and Level of Service (LOS) at Ekantakuna Intersection and aims to suggest improvement alternatives for managing both present and forecasted traffic scenarios for 10-year period. A field survey was conducted to collect geometric data of the intersection while a video-graphic survey was carried out over three days to record traffic counts for each directional vehicle movements. A base model of the intersection was developed using PTV VISSIM software and calibrated and validated against the base traffic conditions so that the model realistically represents the real-world traffic environment. The calibration and validation process involved traffic volume, maximum queue length and average speed assessments using GEH and RMSNE statistical measures. Five alternative improvement scenarios were considered: Alternative 1(Restriction of traffic movement from service lane to main lane), Alternative 2(Restriction of left turning traffic movement from main lane), Alternative 3(Combined Scenario), Alternative 4(Restriction of right turning traffic movement from main lane) and Alternative 5(Conversion of Unsignalized Intersection into Grade-Separated Signalized Intersection).

The major findings of the study are:

1. The four-legged intersection of Ekantakuna is currently unsignalized and controlled manually operated by traffic police resulting in Level of Service (LOS) rating of 'D' with average delay of 25.104 seconds and maximum average queue length of 45.924m. This demonstrated the potential for congestion at the intersection which can be explained by high demand relative to the intersection's capacity.
2. For the base year traffic, restricting traffic movements from service lanes or main lanes (Alternatives 1, 2 and 3) led to localized improvements but also caused increased congestion in some lanes. Among these, the combined scenario (Alternative 3) showed moderate improvements by reducing overall queue length and delay by 4.948% and 4.117%, respectively. The restriction of right-turning traffic from main lanes with

provision of U-turn (Alternative 4) resulted in significant improvements in certain lanes, reducing overall queue length and delay by 8.103% and 7.388%, respectively. The most effective solution was the conversion of the unsignalized intersection into a grade-separated signalized intersection (Alternative 5) which significantly improved traffic flows. The introduction of an underpass along main lanes eliminated delays along key routes, improving the intersection's LOS from D to B while reducing overall queue length and delay by 33.789% and 39.060%, respectively.

3. For forecasted 10 years traffic, the intersection LOS had been projected to be F with an average vehicle delay of 50.031 seconds and maximum average queue length of 89.661m. Among the alternatives, Alternative 5 had been the most effective solution to reduce queue and delay in the intersection which significantly reduced queue length by 39.340% and vehicular delay by 42.243% while improving the overall Level of Service (LOS) from F to D. It also eliminated congestion on key routes by introducing an underpass.

## **5.2 Recommendations for further study**

The following recommendations were suggested for further study:

1. The current analysis of the intersection was conducted in isolation without considering the effects of nearby intersections. A network-level analysis is recommended to improve the accuracy and depth of future studies.
2. Pedestrian data were not included and their movement was not prioritized in the simulation. A pedestrian study should be conducted to account for delays caused by pedestrian activity.
3. Signal coordination of existing intersection with neighboring intersections can be used for effective queue management and delay control.

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## **APPENDICES**

## **APPENDIX A: Classified Volume Count**

**Monday Morning Base Year (09:00 to 11:00 AM)**

Route: Balkhu (Main) to Satdobato (Main)

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	140	95	0	10	17	262	231
9:15 - 9:30	205	106	0	14	9	334	257
9:30 - 9:45	228	104	0	18	12	362	281
9:45 - 10:00	203	113	0	12	20	348	293
10:00 - 10:15	193	120	0	7	19	339	284
10:15 - 10:30	231	114	0	11	17	373	297
10:30 - 10:45	212	88	0	13	17	330	265
10:45 - 11:00	224	97	0	4	7	332	236
<b>Total</b>	<b>1636</b>	<b>837</b>	<b>0</b>	<b>89</b>	<b>118</b>	<b>2680</b>	<b>2143</b>

Route: Balkhu (Main) to Satdobato (Service)

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	5	4	0	0	0	9	7
9:15 - 9:30	8	7	0	0	0	15	11
9:30 - 9:45	3	3	1	1	0	8	7
9:45 - 10:00	10	6	0	0	0	16	11
10:00 - 10:15	17	8	0	0	0	25	17
10:15 - 10:30	10	4	1	0	0	15	10
10:30 - 10:45	7	3	0	0	0	10	7
10:45 - 11:00	4	6	0	0	0	10	8
<b>Total</b>	<b>64</b>	<b>41</b>	<b>2</b>	<b>1</b>	<b>0</b>	<b>108</b>	<b>77</b>

Route: Balkhu (Main) to Jawalakhel

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck,Bus, Minibus	Total	PCU
9:00 - 9:15	7	4	0	0	0	11	8
9:15 - 9:30	10	6	0	1	0	17	13
9:30 - 9:45	8	8	1	0	1	18	16
9:45 - 10:00	17	3	0	1	0	21	13
10:00 - 10:15	11	5	0	0	0	16	11
10:15 - 10:30	14	7	0	0	1	22	17
10:30 - 10:45	6	8	0	0	0	14	11
10:45 - 11:00	8	4	0	0	0	12	8
Total	81	45	1	2	2	131	96

Route: Balkhu (Main) to Bhaisepati

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck,Bus, Minibus	Total	PCU
9:00 - 9:15	4	3	0	0	0	7	5
9:15 - 9:30	5	2	0	0	0	7	5
9:30 - 9:45	4	5	0	0	0	9	7
9:45 - 10:00	2	3	0	1	0	6	6
10:00 - 10:15	4	1	0	0	0	5	3
10:15 - 10:30	6	5	0	0	0	11	8
10:30 - 10:45	3	4	0	0	0	7	6
10:45 - 11:00	5	5	0	0	0	10	8
Total	33	28	0	1	0	62	46

Total traffic from Balkhu Main

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck,Bus, Minibus	Total	PCU
9:00 - 9:15	156	106	0	10	17	289	250
9:15 - 9:30	228	121	0	15	9	373	285
9:30 - 9:45	243	120	2	19	13	397	311
9:45 - 10:00	232	125	0	14	20	391	322
10:00 - 10:15	225	134	0	7	19	385	314
10:15 - 10:30	261	130	1	11	18	421	332
10:30 - 10:45	228	103	0	13	17	361	288
10:45 - 11:00	241	112	0	4	7	364	260
Total	1814	951	3	93	120	2981	2361

Route: Satdobato (Main) to Balkhu (Main)

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck,Bus, Minibus	Total	PCU
9:00 - 9:15	126	55	0	3	9	193	150
9:15 - 9:30	200	49	0	4	8	261	179
9:30 - 9:45	168	52	1	3	9	233	169
9:45 - 10:00	202	47	0	2	4	255	163
10:00 - 10:15	265	44	1	5	8	323	209
10:15 - 10:30	203	50	0	2	7	262	176
10:30 - 10:45	193	51	0	3	5	252	167
10:45 - 11:00	206	54	0	6	4	270	178
Total	1563	402	2	28	54	2049	1390

Route: Satdobato (Main) to Balkhu (Service)

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	9	4	0	0	0	13	8.5
9:15 - 9:30	5	5	1	0	0	11	8.5
9:30 - 9:45	7	2	0	2	0	11	8.5
9:45 - 10:00	17	3	0	0	0	20	11.5
10:00 - 10:15	17	9	0	3	0	29	22
10:15 - 10:30	18	8	1	0	0	27	18
10:30 - 10:45	14	5	0	0	0	19	12
10:45 - 11:00	15	5	0	1	0	21	14
Total	102	41	2	6	0	151	103

Route: Satdobato (Main) to Jawalakhel

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	53	47	0	0	1	101	77
9:15 - 9:30	58	50	0	2	0	110	82
9:30 - 9:45	73	42	0	0	0	115	79
9:45 - 10:00	68	47	0	1	0	116	83
10:00 - 10:15	51	48	0	0	1	100	77
10:15 - 10:30	55	39	0	1	0	95	68
10:30 - 10:45	63	51	0	0	0	114	83
10:45 - 11:00	51	55	0	0	0	106	81
Total	472	379	0	4	2	857	627

Route: Satdobato (Main) to Bhaisepati

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Buses, Minibus	Total	PCU
9:00 - 9:15	19	5	0	0	0	24	15
9:15 - 9:30	14	7	0	0	0	21	14
9:30 - 9:45	22	4	0	1	0	27	17
9:45 - 10:00	18	8	0	0	0	26	17
10:00 - 10:15	29	8	0	0	0	37	23
10:15 - 10:30	23	8	0	0	0	31	20
10:30 - 10:45	19	6	0	0	0	25	16
10:45 - 11:00	10	3	0	0	0	13	8
Total	154	49	0	1	0	204	128

Total traffic from Satdobato Main

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Buses, Minibus	Total	PCU
9:00 - 9:15	207	111	0	3	10	331	249
9:15 - 9:30	277	111	1	6	8	403	284
9:30 - 9:45	270	100	1	6	9	386	272
9:45 - 10:00	305	105	0	3	4	417	274
10:00 - 10:15	362	109	1	8	9	489	330
10:15 - 10:30	299	105	1	3	7	415	281
10:30 - 10:45	289	113	0	3	5	410	277
10:45 - 11:00	282	117	0	7	4	410	281
Total	2291	871	4	39	56	3261	2247

Route: Balkhu (Service) to Satdobato (Service)

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	15	9	1	1	25	51	94
9:15 - 9:30	12	12	2	0	14	40	62
9:30 - 9:45	8	4	0	1	17	30	61
9:45 - 10:00	17	7	1	2	18	45	74
10:00 - 10:15	13	18	0	1	23	55	95
10:15 - 10:30	10	12	1	0	17	40	69
10:30 - 10:45	9	9	0	1	19	38	72
10:45 - 11:00	17	8	1	0	18	44	72
Total	101	79	6	6	151	343	598

Route: Balkhu (Service) to Satdobato (Main)

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	13	8	1	2	6	30	37
9:15 - 9:30	9	11	0	2	2	24	25
9:30 - 9:45	10	4	0	2	3	19	21
9:45 - 10:00	17	6	1	6	4	34	37
10:00 - 10:15	13	9	0	5	7	34	44
10:15 - 10:30	19	11	0	2	9	41	51
10:30 - 10:45	14	5	1	1	4	25	27
10:45 - 11:00	12	9	0	2	7	30	39
Total	107	63	3	22	42	237	279

Route: Balkhu (Service) to Jawalakhel

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck,Bus, Minibus	Total	PCU
9:00 - 9:15	35	14	0	0	8	57	56
9:15 - 9:30	37	8	0	2	3	50	39
9:30 - 9:45	27	12	0	0	4	43	38
9:45 - 10:00	38	15	0	1	2	56	42
10:00 - 10:15	35	19	0	0	3	57	46
10:15 - 10:30	34	9	0	0	7	50	47
10:30 - 10:45	38	12	0	0	4	54	43
10:45 - 11:00	18	9	0	1	7	35	41
Total	262	98	0	4	38	402	349

Total traffic from Balkhu Service

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck,Bus, Minibus	Total	PCU
9:00 - 9:15	63	31	2	3	39	138	186
9:15 - 9:30	58	31	2	4	19	114	125
9:30 - 9:45	45	20	0	3	24	92	119
9:45 - 10:00	72	28	2	9	24	135	152
10:00 - 10:15	61	46	0	6	33	146	185
10:15 - 10:30	63	32	1	2	33	131	167
10:30 - 10:45	61	26	1	2	27	117	142
10:45 - 11:00	47	26	1	3	32	109	151
Total	470	240	9	32	231	982	1225

Route: Satdobato (Service) to Balkhu (Service)

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	52	11	1	1	14	79	82
9:15 - 9:30	57	13	2	0	9	81	71
9:30 - 9:45	58	21	2	2	15	98	100
9:45 - 10:00	52	8	1	0	16	77	83
10:00 - 10:15	62	12	2	0	13	89	84
10:15 - 10:30	52	11	0	1	18	82	93
10:30 - 10:45	57	16	3	0	18	94	102
10:45 - 11:00	52	17	0	3	28	100	132
Total	442	109	11	7	131	700	745

Route: Satdobato (Service) to Balkhu (Main)

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	27	28	0	0	0	55	42
9:15 - 9:30	33	32	0	1	0	66	50
9:30 - 9:45	29	27	0	0	0	56	42
9:45 - 10:00	13	26	0	0	0	39	33
10:00 - 10:15	16	36	0	0	0	52	44
10:15 - 10:30	28	33	0	2	0	63	50
10:30 - 10:45	28	34	0	0	0	62	48
10:45 - 11:00	30	37	0	0	0	67	52
Total	204	253	0	3	0	460	360

Route: Satdobato (Service) to Bhaisepati

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	52	34	0	2	0	88	63
9:15 - 9:30	56	36	0	1	0	93	66
9:30 - 9:45	62	35	0	4	0	101	72
9:45 - 10:00	70	47	0	2	0	119	85
10:00 - 10:15	57	49	0	5	0	111	85
10:15 - 10:30	57	46	0	3	0	106	79
10:30 - 10:45	73	55	0	3	0	131	96
10:45 - 11:00	50	37	0	4	0	91	68
Total	477	339	0	24	0	840	614

Total traffic from Satdobato Service

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	131	73	1	3	14	222	186
9:15 - 9:30	146	81	2	2	9	240	186
9:30 - 9:45	149	83	2	6	15	255	214
9:45 - 10:00	135	81	1	2	16	235	201
10:00 - 10:15	135	97	2	5	13	252	213
10:15 - 10:30	137	90	0	6	18	251	222
10:30 - 10:45	158	105	3	3	18	287	246
10:45 - 11:00	132	91	0	7	28	258	252
Total	1123	701	11	34	131	2000	1718

Route: Jawalakhel to Bhaisepati

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck,Bus, Minibus	Total	PCU
9:00 - 9:15	72	38	0	0	8	118	98
9:15 - 9:30	78	42	0	0	5	125	96
9:30 - 9:45	81	44	0	2	11	138	121
9:45 - 10:00	80	48	0	0	4	132	100
10:00 - 10:15	83	45	0	1	3	132	97
10:15 - 10:30	74	38	0	0	7	119	96
10:30 - 10:45	80	46	0	0	10	136	116
10:45 - 11:00	76	38	0	1	7	122	99
Total	624	339	0	4	55	1022	822

Route: Jawalakhel to Satdobato (Service)

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck,Bus, Minibus	Total	PCU
9:00 - 9:15	15	3	0	0	0	18	11
9:15 - 9:30	8	5	0	1	0	14	11
9:30 - 9:45	13	5	0	0	0	18	12
9:45 - 10:00	17	2	0	0	0	19	11
10:00 - 10:15	18	3	0	0	0	21	12
10:15 - 10:30	9	6	0	0	0	15	11
10:30 - 10:45	13	5	0	0	0	18	12
10:45 - 11:00	9	1	0	0	0	10	6
Total	102	30	0	1	0	133	83

Route: Jawalakhel to Satdobato (Main)

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	24	22	0	0	1	47	37
9:15 - 9:30	30	25	0	0	0	55	40
9:30 - 9:45	38	22	0	1	2	63	49
9:45 - 10:00	35	23	0	0	0	58	41
10:00 - 10:15	38	24	0	0	2	64	49
10:15 - 10:30	40	29	0	1	0	70	51
10:30 - 10:45	29	22	0	0	0	51	37
10:45 - 11:00	22	19	0	0	1	42	33
Total	256	186	0	2	6	450	335

Route: Jawalakhel to Balkhu (Main)

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	6	11	0	0	0	17	14
9:15 - 9:30	5	7	0	1	0	13	11
9:30 - 9:45	4	8	0	0	1	13	13
9:45 - 10:00	3	17	0	2	0	22	22
10:00 - 10:15	9	18	0	0	2	29	29
10:15 - 10:30	12	16	0	1	0	29	24
10:30 - 10:45	3	7	0	0	0	10	9
10:45 - 11:00	6	12	0	0	1	19	18
Total	48	96	0	4	4	152	138

Route: Jawalakhel to Balkhu (Service)

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	15	3	0	0	2	20	17
9:15 - 9:30	3	5	0	0	0	8	7
9:30 - 9:45	4	2	0	1	0	7	6
9:45 - 10:00	2	6	0	0	2	10	13
10:00 - 10:15	5	3	0	0	0	8	6
10:15 - 10:30	8	8	0	0	1	17	15
10:30 - 10:45	5	4	0	0	0	9	7
10:45 - 11:00	6	7	0	0	1	14	13
Total	48	38	0	1	6	93	82

Total traffic from Jawalakhel

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	132	77	0	0	11	220	176
9:15 - 9:30	124	84	0	2	5	215	164
9:30 - 9:45	140	81	0	4	14	239	199
9:45 - 10:00	137	96	0	2	6	241	186
10:00 - 10:15	153	93	0	1	7	254	192
10:15 - 10:30	143	97	0	2	8	250	196
10:30 - 10:45	130	84	0	0	10	224	179
10:45 - 11:00	119	77	0	1	10	207	168
Total	1078	689	0	12	71	1850	1459

Route: Bhaisepati to Jawalakhel

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck,Bus, Minibus	Total	PCU
9:00 - 9:15	202	1	0	0	1	204	105
9:15 - 9:30	166	2	0	1	0	169	87
9:30 - 9:45	135	0	0	0	2	137	74
9:45 - 10:00	142	3	0	2	0	147	77
10:00 - 10:15	166	0	0	0	0	166	83
10:15 - 10:30	111	1	0	1	0	113	58
10:30 - 10:45	118	0	0	0	0	118	59
10:45 - 11:00	119	3	0	0	1	123	66
Total	1159	10	0	4	4	1177	608

Route: Bhaisepati to Balkhu (Main)

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck,Bus, Minibus	Total	PCU
9:00 - 9:15	1	0	0	0	0	1	1
9:15 - 9:30	2	0	0	0	0	2	1
9:30 - 9:45	1	1	0	0	0	2	2
9:45 - 10:00	3	0	0	0	0	3	2
10:00 - 10:15	5	1	0	0	0	6	4
10:15 - 10:30	1	2	0	0	0	3	3
10:30 - 10:45	2	0	0	0	0	2	1
10:45 - 11:00	2	0	0	0	0	2	1
Total	17	4	0	0	0	21	13

Route: Bhaisepati to Balkhu (Service)

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	1	0	0	0	0	1	1
9:15 - 9:30	0	0	0	1	0	1	2
9:30 - 9:45	2	0	0	0	0	2	1
9:45 - 10:00	0	0	0	0	0	0	0
10:00 - 10:15	1	1	0	0	0	2	2
10:15 - 10:30	3	0	0	0	0	3	2
10:30 - 10:45	1	0	0	0	0	1	1
10:45 - 11:00	4	1	0	0	0	5	3
Total	12	2	0	1	0	15	10

Route: Bhaisepati to Satdobato (Main)

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	95	3	0	0	0	98	51
9:15 - 9:30	83	5	0	0	0	88	47
9:30 - 9:45	83	4	0	1	0	88	47
9:45 - 10:00	88	2	0	0	0	90	46
10:00 - 10:15	111	6	0	0	0	117	62
10:15 - 10:30	82	7	0	0	0	89	48
10:30 - 10:45	91	3	0	0	0	94	49
10:45 - 11:00	95	2	0	0	0	97	50
Total	728	32	0	1	0	761	398

Route: Bhaisepati to Satdobato (Service)

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	16	1	0	0	0	17	9
9:15 - 9:30	25	2	0	0	0	27	15
9:30 - 9:45	16	1	0	0	0	17	9
9:45 - 10:00	23	3	0	0	0	26	15
10:00 - 10:15	23	1	0	1	0	25	14
10:15 - 10:30	13	1	0	0	0	14	8
10:30 - 10:45	8	0	0	0	0	8	4
10:45 - 11:00	4	1	0	0	0	5	3
Total	128	10	0	1	0	139	76

Total traffic from Bhaisepati

Time	Motorcycle	Car/SUV/Light Van/Pickup, Jeep	Tempo	Mini Truck	Truck, Bus, Minibus	Total	PCU
9:00 - 9:15	315	5	0	0	1	321	166
9:15 - 9:30	276	9	0	2	0	287	150
9:30 - 9:45	237	6	0	1	2	246	132
9:45 - 10:00	256	8	0	2	0	266	139
10:00 - 10:15	306	9	0	1	0	316	164
10:15 - 10:30	210	11	0	1	0	222	118
10:30 - 10:45	220	3	0	0	0	223	113
10:45 - 11:00	224	7	0	0	1	232	122
Total	2044	58	0	7	4	2113	1103

## **APPENDIX B: Relative Flow**

**Monday Morning (09:00 to 11:00 AM)**

**Balkhu Main Lane**

Relative Flows for Motorcycle

Time	Satdobato (Main)	Satdobato (Service)	Jawalakhel	Bhaisepati	Check
9:00 - 9:15	0.897	0.032	0.045	0.026	1
9:15 - 9:30	0.899	0.035	0.044	0.022	1
9:30 - 9:45	0.938	0.012	0.033	0.016	1
9:45 - 10:00	0.875	0.043	0.073	0.009	1
10:00 - 10:15	0.858	0.076	0.049	0.018	1
10:15 - 10:30	0.885	0.038	0.054	0.023	1
10:30 - 10:45	0.930	0.031	0.026	0.013	1
10:45 - 11:00	0.929	0.017	0.033	0.021	1
Total	0.901	0.035	0.045	0.018	1

Relative Flows for Car/SUV/Light Van/Pickup/Jeep

Time	Satdobato (Main)	Satdobato (Service)	Jawalakhel	Bhaisepati	Check
9:00 - 9:15	0.8962	0.0377	0.0377	0.0283	1
9:15 - 9:30	0.8760	0.0579	0.0496	0.0165	1
9:30 - 9:45	0.8667	0.0250	0.0667	0.0417	1
9:45 - 10:00	0.9040	0.0480	0.0240	0.0240	1
10:00 - 10:15	0.8955	0.0597	0.0373	0.0075	1
10:15 - 10:30	0.8769	0.0308	0.0538	0.0385	1
10:30 - 10:45	0.8544	0.0291	0.0777	0.0388	1
10:45 - 11:00	0.8661	0.0536	0.0357	0.0446	1
Total	0.8795	0.0427	0.0478	0.0300	1

### Relative Flows for Tempo

Time	Satdobato (Main)	Satdobato (Service)	Jawalakhel	Bhaisepati	Check
9:00 - 9:15	-	-	-	-	-
9:15 - 9:30	-	-	-	-	-
9:30 - 9:45	0	0.5	0.5	0	1
9:45 - 10:00	-	-	-	-	-
10:00 - 10:15	-	-	-	-	-
10:15 - 10:30	0	1	0	0	1
10:30 - 10:45	-	-	-	-	-
10:45 - 11:00	-	-	-	-	-
Total	-	-	-	-	-

### Relative Flows for Minibus

Time	Satdobato (Main)	Satdobato (Service)	Jawalakhel	Bhaisepati	Check
9:00 - 9:15	1.0000	0.0000	0.0000	0.0000	1
9:15 - 9:30	0.9333	0.0000	0.0667	0.0000	1
9:30 - 9:45	0.9474	0.0526	0.0000	0.0000	1
9:45 - 10:00	0.8571	0.0000	0.0714	0.0714	1
10:00 - 10:15	1.0000	0.0000	0.0000	0.0000	1
10:15 - 10:30	1.0000	0.0000	0.0000	0.0000	1
10:30 - 10:45	1.0000	0.0000	0.0000	0.0000	1
10:45 - 11:00	1.0000	0.0000	0.0000	0.0000	1
Total	0.9672	0.0066	0.0173	0.0089	1

Relative Flows for Truck, Bus, Minibus

Time	Satdobato (Main)	Satdobato (Service)	Jawalakhel	Bhaisepati	Check
9:00 - 9:15	1.000	0	0.0000	0	1
9:15 - 9:30	1.000	0	0.0000	0	1
9:30 - 9:45	0.923	0	0.0769	0	1
9:45 - 10:00	1.000	0	0.0000	0	1
10:00 - 10:15	1.000	0	0.0000	0	1
10:15 - 10:30	0.944	0	0.0556	0	1
10:30 - 10:45	1.000	0	0.0000	0	1
10:45 - 11:00	1.000	0	0.0000	0	1
<b>Total</b>	<b>0.983</b>	<b>0</b>	<b>0.0166</b>	<b>0</b>	<b>1</b>

## **APPENDIX C: VISSIM Input and Output**

## Network Modeled in VISSIM



## Static Vehicle Route

Start Page Network Editor

Static Vehicle Routing Decisions / Static vehicle routes

Static vehicle rout

Number: 6	No	Name	Link	Pos	AllVehTypes	VehClasses	Route
1	1		1: Balkhu(Service) to Satdoba...	1.547	<input checked="" type="checkbox"/>		Static
2	2		2: Balkhu (Main) to Satdobato	1.721	<input checked="" type="checkbox"/>		Static
3	3		12: Jawalkel towards Bhaisipati	3.136	<input checked="" type="checkbox"/>		Static
4	4		9: Bhaisipati towards Jawalkhel	7.179	<input checked="" type="checkbox"/>		Static
5	5		7: SS towards Balkhu	5.084	<input checked="" type="checkbox"/>		Static
6	6		5: SM towards Balkhu	2.880	<input checked="" type="checkbox"/>		Static

Number: 3	No	Name	Formula	DestLink	DestPos	RelFlow(0-MAX)
1	1			15: Jawalkhel from Bhaisipati	108.954	356.000
2	2			3: Balkhu to Satdobato ( Servi...	204.363	383.000
3	3			4: Balkhu to Satdobato ( Main)	202.994	307.000

Vehicle Inputs / Vehicle volumes by time interval Static Vehicle Routing Decisions / Static vehicle routes

Delay Measurements from VISSIM

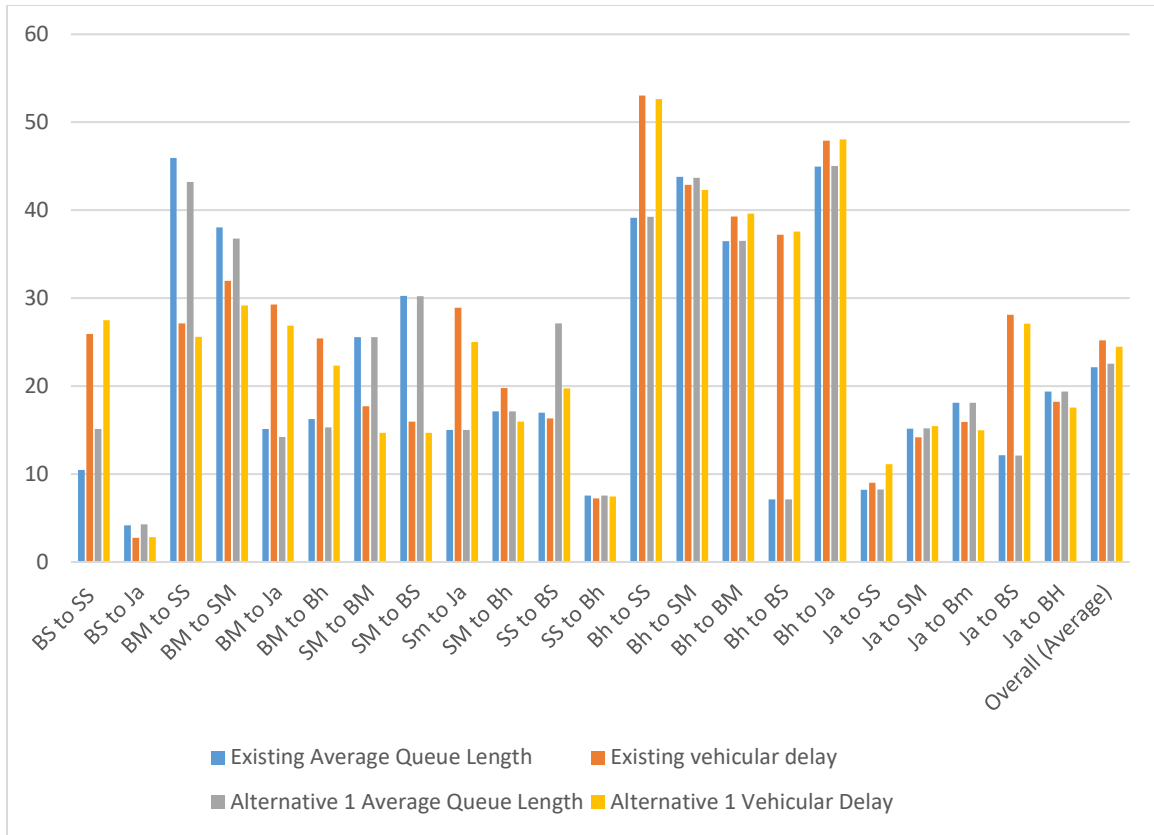
Delay Results				
Number: 216	SimRun	TimeInt	DelayMeasurement	VehDelay(All)
121	Average	0-7200	1: BM-SS	27.12
122	Average	0-7200	2: BM-SM	31.98
123	Average	0-7200	3: BM-Ja	29.28
124	Average	0-7200	4: BM-Bh	25.43
125	Average	0-7200	5: BS-SS	25.93
126	Average	0-7200	6: BS-SM	26.39
127	Average	0-7200	7: BS-Ja	2.74
128	Average	0-7200	8: SM-BM	17.71
129	Average	0-7200	9: SM-BS	15.95
130	Average	0-7200	10: SM-Bh	19.76
131	Average	0-7200	11: SM-Ja	28.90
132	Average	0-7200	12: SS-BS	16.21

Desir... | Vehic... | Static... | Vehic... | Signa... | Sign... | 2D/3... | Links... | Driv

## **APPENDIX D: Scenario Analysis**

**Scenario with Alternative 1 for base year**

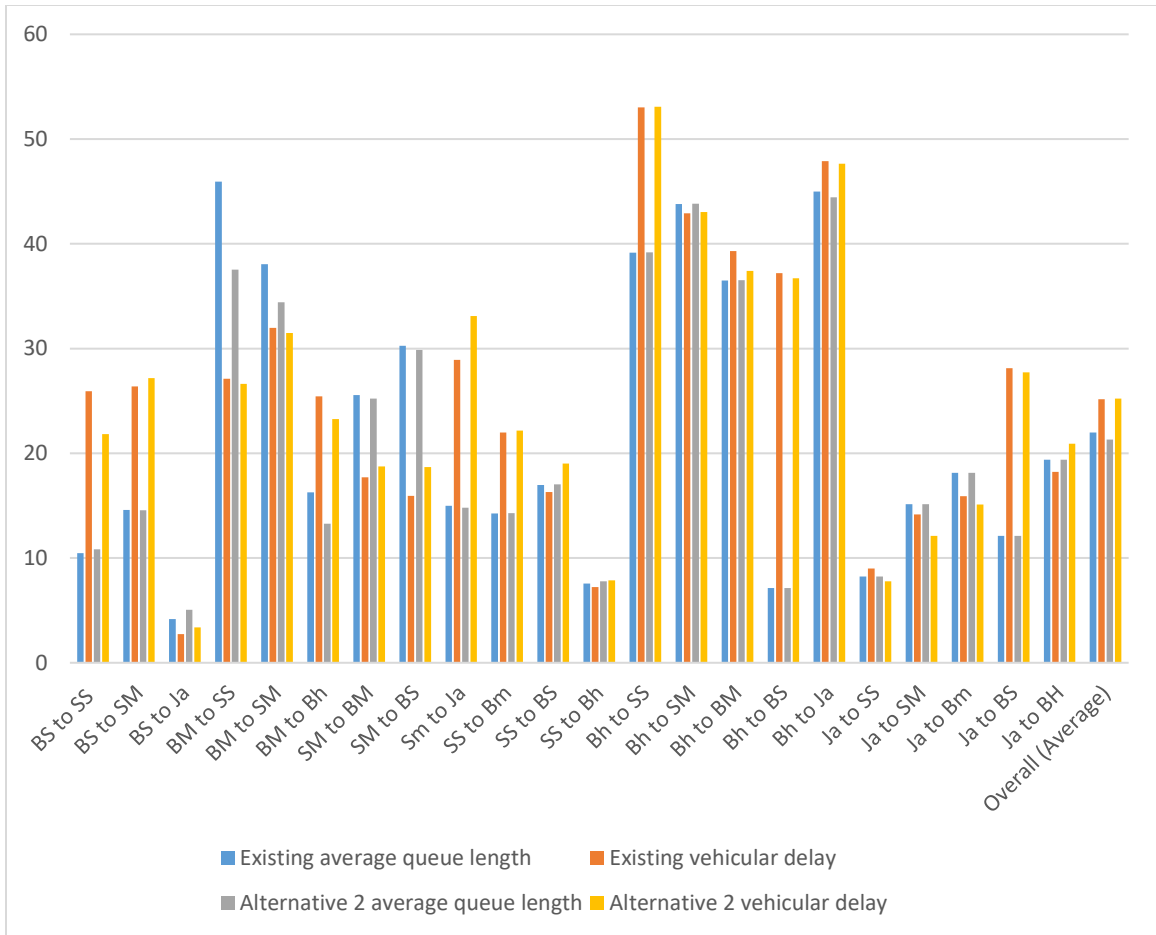
MOVEMENT	Existing average queue length	Existing vehicular delay	Alternative 1 average queue length	Alternative 1 vehicular delay	% Change in average queue length	% Change in vehicular delay
BS to SS	10.471	25.932	15.121	27.492	44.408	6.017
BS to Ja	4.171	2.744	4.285	2.811	2.733	2.442
BM to SS	45.924	27.122	43.199	25.612	-5.935	-5.567
BM to SM	38.04	31.98	36.770	29.152	-3.339	-8.843
BM to Ja	15.121	29.277	14.224	26.882	-5.935	-8.179
BM to Bh	16.258	25.43	15.293	22.310	-5.935	-12.268
SM to BM	25.568	17.71	25.557	14.703	-0.044	-16.980
SM to BS	30.25	15.946	30.237	14.699	-0.044	-7.820
SM to Ja	15.002	28.904	14.995	25.005	-0.044	-13.490
SM to Bh	17.12	19.764	17.113	15.952	-0.044	-19.287
SS to BS	16.985	16.313	27.115	19.739	59.639	21.000
SS to Bh	7.556	7.215	7.566	7.460	0.133	3.398
Bh to SS	39.149	53.034	39.229	52.653	0.205	-0.719
Bh to SM	43.796	42.899	43.697	42.290	-0.227	-1.420
Bh to BM	36.483	39.301	36.532	39.608	0.135	0.780
Bh to BS	7.124	37.203	7.134	37.555	0.135	0.946
Bh to Ja	44.977	47.905	45.038	48.051	0.135	0.305
Ja to SS	8.225	9.01	8.262	11.135	0.450	23.585
Ja to SM	15.146	14.162	15.211	15.437	0.426	9.000
Ja to BM	18.12	15.904	18.111	14.969	-0.052	-5.882
Ja to BS	12.123	28.129	12.117	27.079	-0.052	-3.731
Ja to BH	19.382	18.213	19.372	17.565	-0.052	-3.556
Overall (Average)	22.136	25.186	22.553	24.462	1.886	-2.876



Graphical representation of comparison of queue and delay for alternative 1 for base year

**Scenario with Alternative 2 for base year**

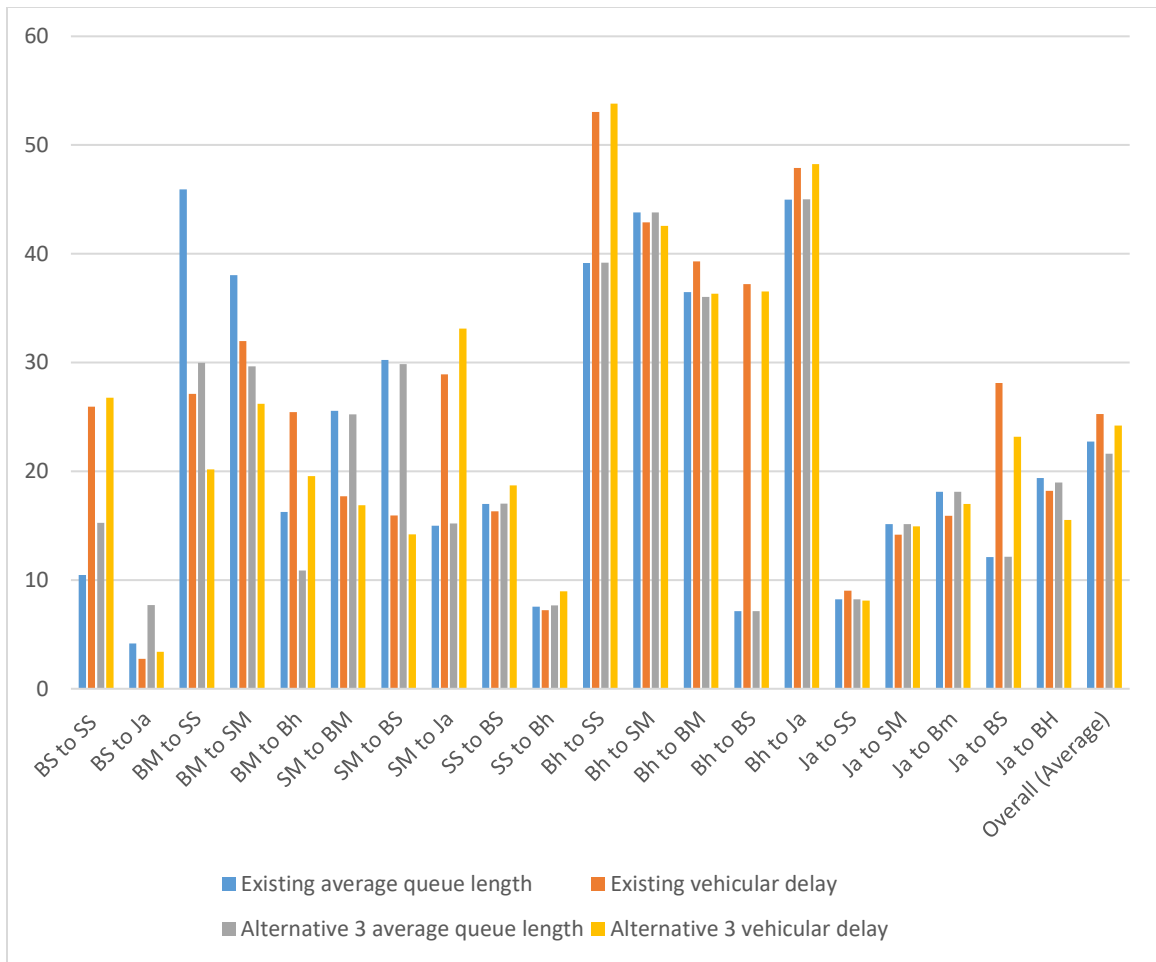
MOVEMENT	Existing average queue length	Existing vehicular delay	Alternative 2 average queue length	Alternative 2 vehicular delay	% Change in average queue length	% Change in vehicular delay
BS to SS	10.471	25.932	10.827	21.839	3.400	-15.785
BS to SM	14.591	26.391	14.547	27.181	-0.300	2.993
BS to Ja	4.171	2.744	5.051	3.377	21.100	23.069
BM to SS	45.924	27.122	37.527	26.629	-18.285	-1.818
BM to SM	38.04	31.98	34.410	31.480	-9.544	-1.564
BM to Bh	16.258	25.43	13.285	23.253	-18.285	-8.559
SM to BM	25.568	17.71	25.237	18.759	-1.293	5.923
SM to BS	30.25	15.946	29.859	18.683	-1.293	17.166
SM to Ja	15.002	28.904	14.808	33.090	-1.293	14.484
SS to Bm	14.252	21.999	14.287	22.158	0.244	0.724
SS to BS	16.985	16.313	17.024	19.031	0.232	16.660
SS to Bh	7.556	7.215	7.774	7.873	2.891	9.124
Bh to SS	39.149	53.034	39.193	53.085	0.113	0.095
Bh to SM	43.796	42.899	43.829	43.027	0.075	0.297
Bh to BM	36.483	39.301	36.512	37.405	0.080	-4.824
Bh to BS	7.124	37.203	7.130	36.698	0.089	-1.357
Bh to Ja	44.977	47.905	44.427	47.662	-1.222	-0.508
Ja to SS	8.225	9.01	8.230	7.784	0.055	-13.612
Ja to SM	15.146	14.162	15.154	12.101	0.055	-14.554
Ja to BM	18.12	15.904	18.130	15.101	0.055	-5.048
Ja to BS	12.123	28.129	12.130	27.737	0.055	-1.393
Ja to BH	19.382	18.213	19.393	20.919	0.055	14.859
Overall (Average)	21.981	25.156	21.307	25.221	-3.066	0.258



Graphical representation of comparison of queue and delay for alternative 2 for base year

**Scenario with Alternative 3 for base year**

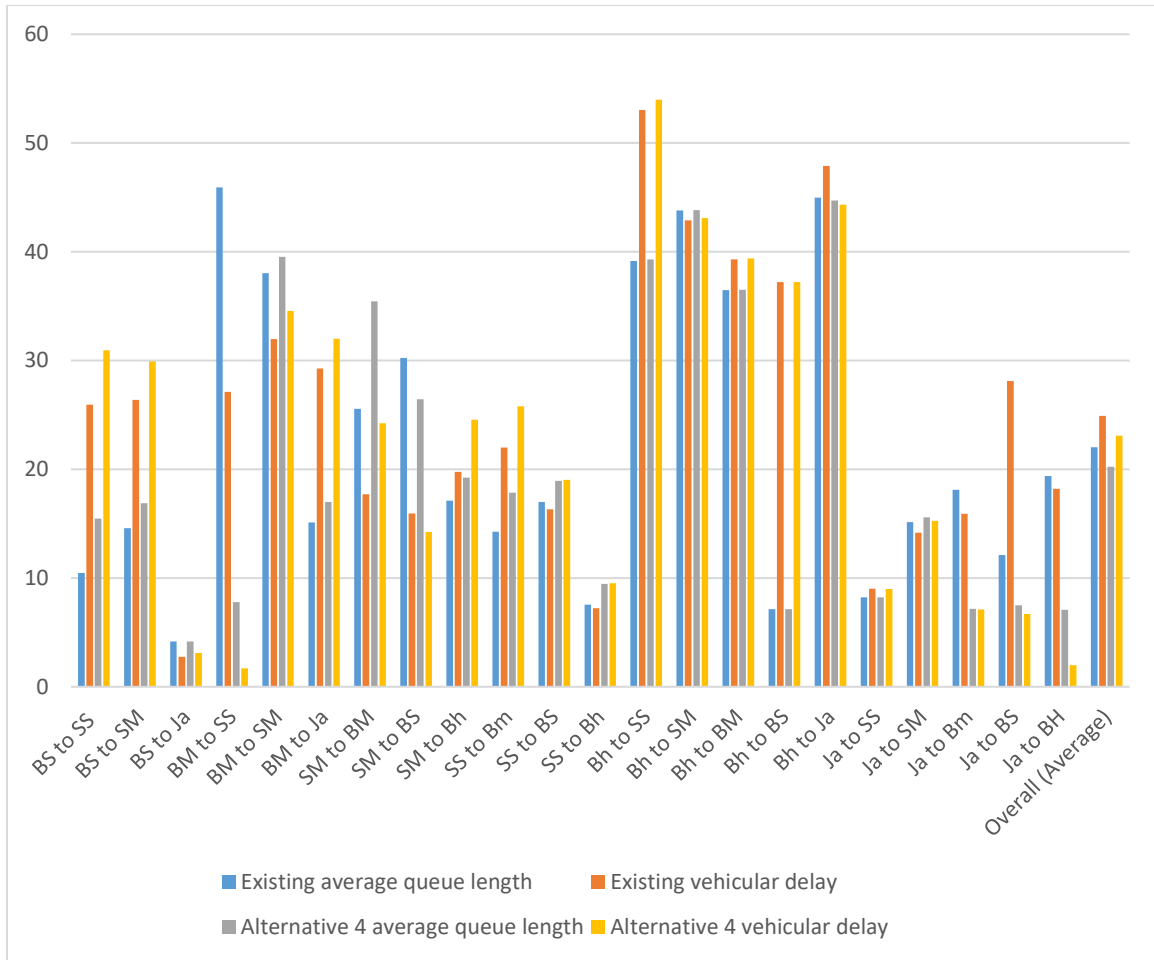
MOVEMENT	Existing average queue length	Existing vehicular delay	Alternative 3 average queue length	Alternative 3 vehicular delay	% Change in average queue length	% Change in vehicular delay
BS to SS	10.471	25.932	15.267	26.777	45.800	3.258
BS to Ja	4.171	2.744	7.711	3.406	84.875	24.135
BM to SS	45.924	27.122	29.978	20.163	-34.723	-25.657
BM to SM	38.04	31.98	29.657	26.215	-22.038	-18.028
BM to Bh	16.258	25.43	10.887	19.553	-33.035	-23.110
SM to BM	25.568	17.71	25.225	16.878	-1.341	-4.697
SM to BS	30.25	15.946	29.844	14.206	-1.341	-10.915
SM to Ja	15.002	28.904	15.207	33.127	1.366	14.612
SS to BS	16.985	16.313	17.027	18.711	0.248	14.698
SS to Bh	7.556	7.215	7.675	8.953	1.572	24.091
Bh to SS	39.149	53.034	39.179	53.802	0.078	1.447
Bh to SM	43.796	42.899	43.819	42.575	0.052	-0.755
Bh to BM	36.483	39.301	36.029	36.341	-1.245	-7.530
Bh to BS	7.124	37.203	7.129	36.548	0.066	-1.762
Bh to Ja	44.977	47.905	45.000	48.253	0.052	0.726
Ja to SS	8.225	9.01	8.227	8.112	0.027	-9.969
Ja to SM	15.146	14.162	15.152	14.923	0.039	5.370
Ja to BM	18.12	15.904	18.128	16.999	0.045	6.883
Ja to BS	12.123	28.129	12.128	23.181	0.039	-17.590
Ja to BH	19.382	18.213	18.980	15.539	-2.076	-14.682
Overall (Average)	22.737	25.253	21.612	24.213	-4.948	-4.117



Graphical representation of comparison of queue and delay for alternative 3 for base year

**Scenario with Alternative 4 for base year**

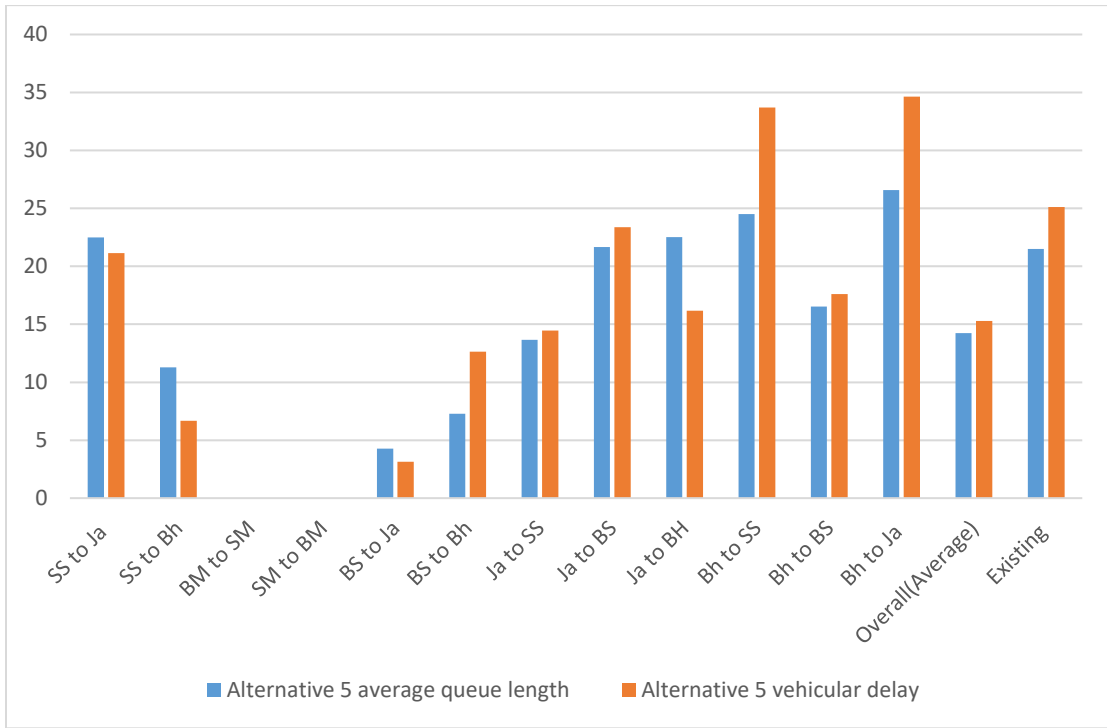
MOVEMENT	Existing average queue length	Existing vehicular delay	Alternative 4 average queue length	Alternative 4 vehicular delay	% Change in average queue length	% Change in vehicular delay
BS to SS	10.471	25.932	15.458	30.931	47.627	19.279
BS to SM	14.591	26.391	16.889	29.910	15.749	13.336
BS to Ja	4.171	2.744	4.177	3.112	0.144	13.411
BM to SS	45.924	27.122	7.784	1.688	-83.049	-93.775
BM to SM	38.04	31.98	39.542	34.569	3.948	8.096
BM to Ja	15.121	29.277	17.001	32.005	12.433	9.318
SM to BM	25.568	17.71	35.456	24.228	38.673	36.804
SM to BS	30.25	15.946	26.451	14.225	-12.560	-10.793
SM to Bh	17.12	19.764	19.227	24.558	12.307	24.256
SS to Bm	14.252	21.999	17.858	25.786	25.299	17.216
SS to BS	16.985	16.313	18.931	19.026	11.457	16.628
SS to Bh	7.556	7.215	9.475	9.531	25.400	32.101
Bh to SS	39.149	53.034	39.300	53.998	0.386	1.818
Bh to SM	43.796	42.899	43.830	43.102	0.078	0.473
Bh to BM	36.483	39.301	36.511	39.401	0.078	0.254
Bh to BS	7.124	37.203	7.130	37.217	0.078	0.038
Bh to Ja	44.977	47.905	44.721	44.323	-0.568	-7.478
Ja to SS	8.225	9.01	8.224	8.990	-0.007	-0.227
Ja to SM	15.146	14.162	15.572	15.252	2.815	7.697
Ja to BM	18.12	15.904	7.181	7.104	-60.368	-55.329
Ja to BS	12.123	28.129	7.503	6.700	-38.106	-76.183
Ja to BH	19.382	18.213	7.088	1.999	-63.432	-89.024
Overall (Average)	22.026	24.916	20.241	23.075	-8.103	-7.388



Graphical representation of comparison of queue and delay for alternative 4 for base year

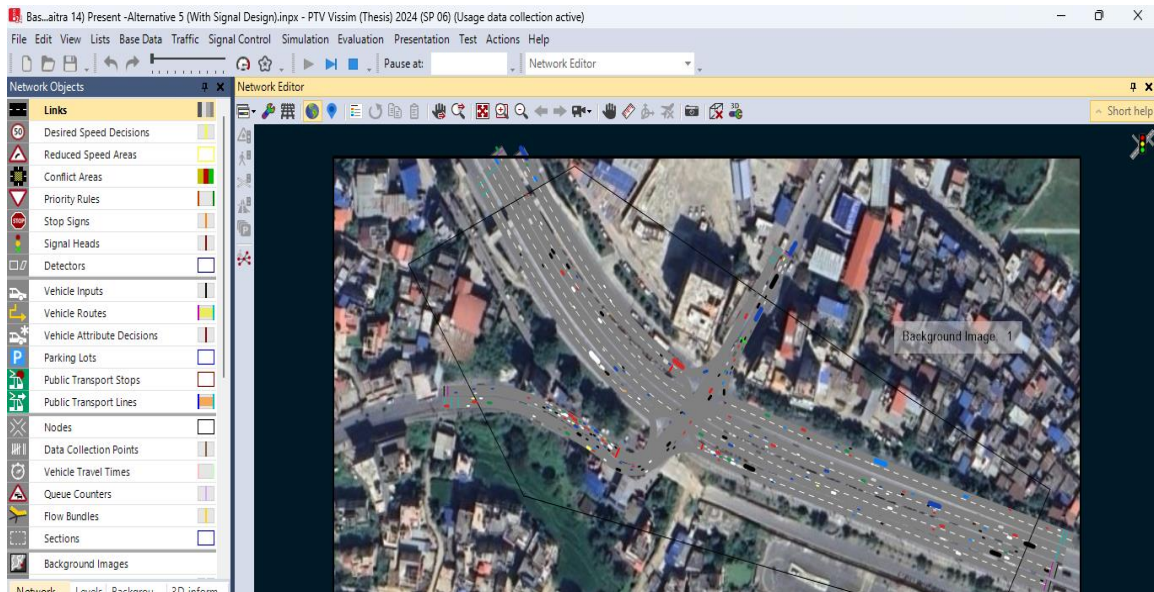
**Scenario with Alternative 5 for base year**

MOVEMENT	Alternative 5 average queue length	Alternative 5 vehicular delay	LOS
SS to Ja	22.48	21.15	C
SS to Bh	11.28	6.68	A
BM to SM	0	0	A
SM to BM	0	0	A
BS to Ja	4.26	3.15	A
BS to Bh	7.28	12.64	B
Ja to SS	13.67	14.47	B
Ja to BS	21.67	23.38	C
Ja to BH	22.51	16.17	C
Bh to SS	24.52	33.7	D
Bh to BS	16.52	17.61	C
Bh to Ja	26.58	34.63	D
Overall(Average)	14.231	15.298	B
Existing	21.493	25.104	
% change	33.789	39.060	

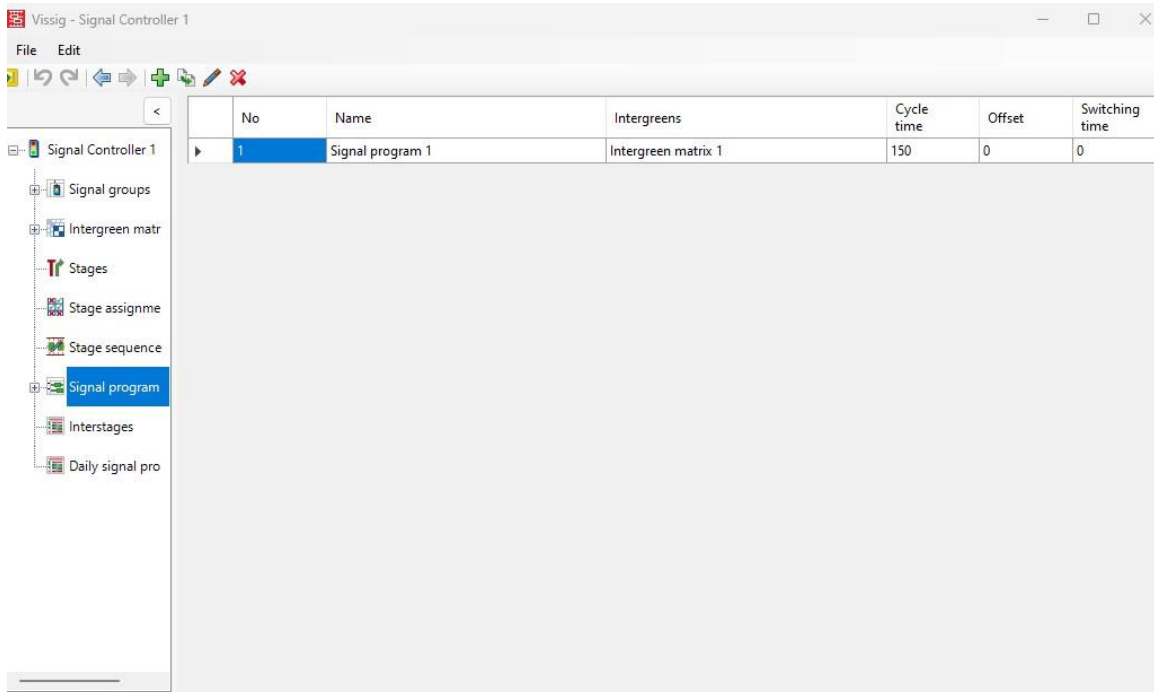


Graphical representation of comparison of queue and delay for alternative 5 for base year

## Simulation with Alternative 5 for base year



## Signal Program for Alternative 5 for base year



## Signal Design for Alternative 5 for base year

Number	No	Name	Type	CycTm	CycTmIsVar	Supply/File1
1	1	Signal Design	Fixed Time	0	<input type="checkbox"/>	vissig.config

Number	No	Name	Type
1	1	Signal group 1	Normal
2	2	Signal group 2	Normal
3	3	Signal group 3	Normal

## Signal Program Design for Alternative 5 for base year

Signal Controller 1

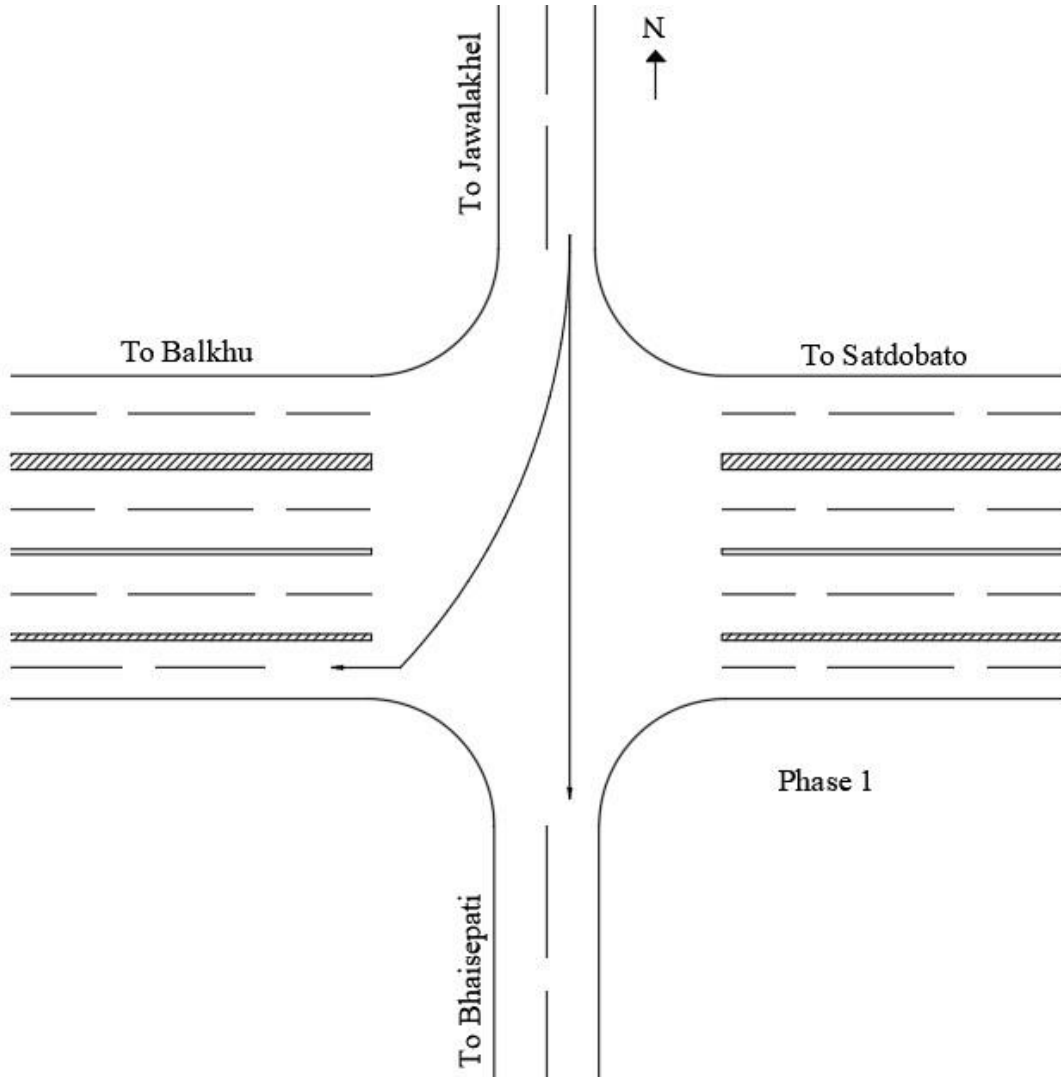
Name: Signal program 1

Intergreens: Cycle time: 150, Offset: 0, Switching time: 0

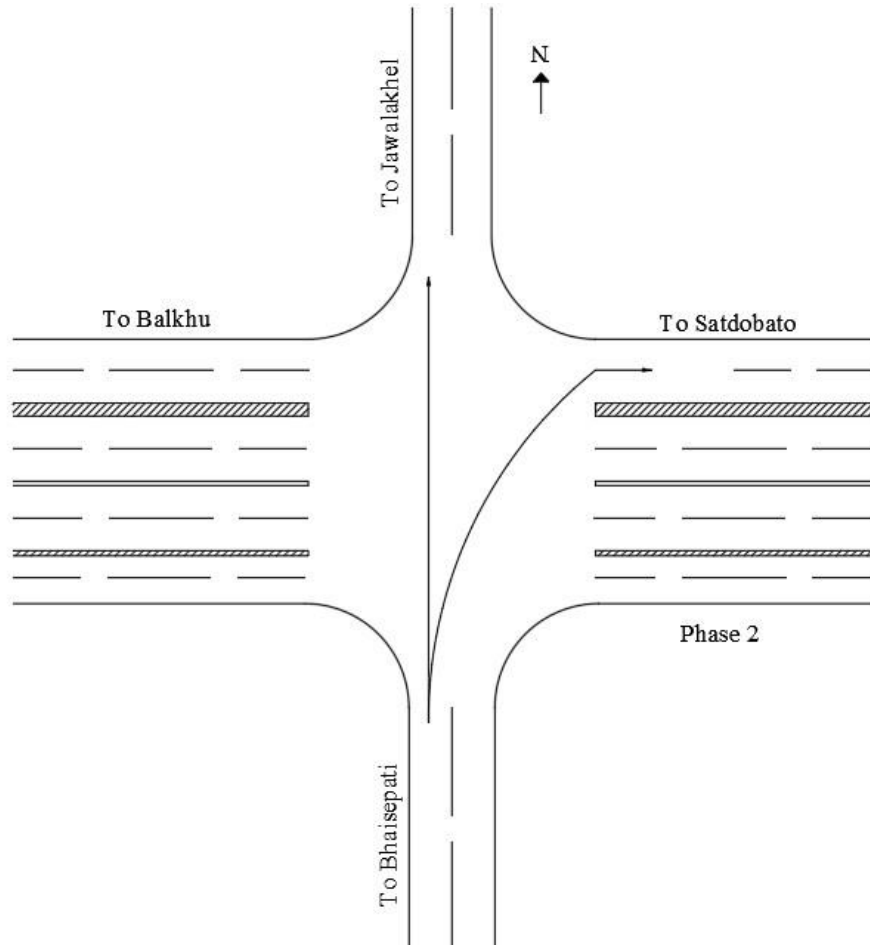
1: Intergreen matrix 1

No	Signal group	Signal sequence	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150			
1	Signal group 1	Red-Green-Amber	0						60									0	60		
2	Signal group 2	Red-Green-Amber								64				114					64	114	
3	Signal group 3	Red-Green-Amber																118	146	118	146

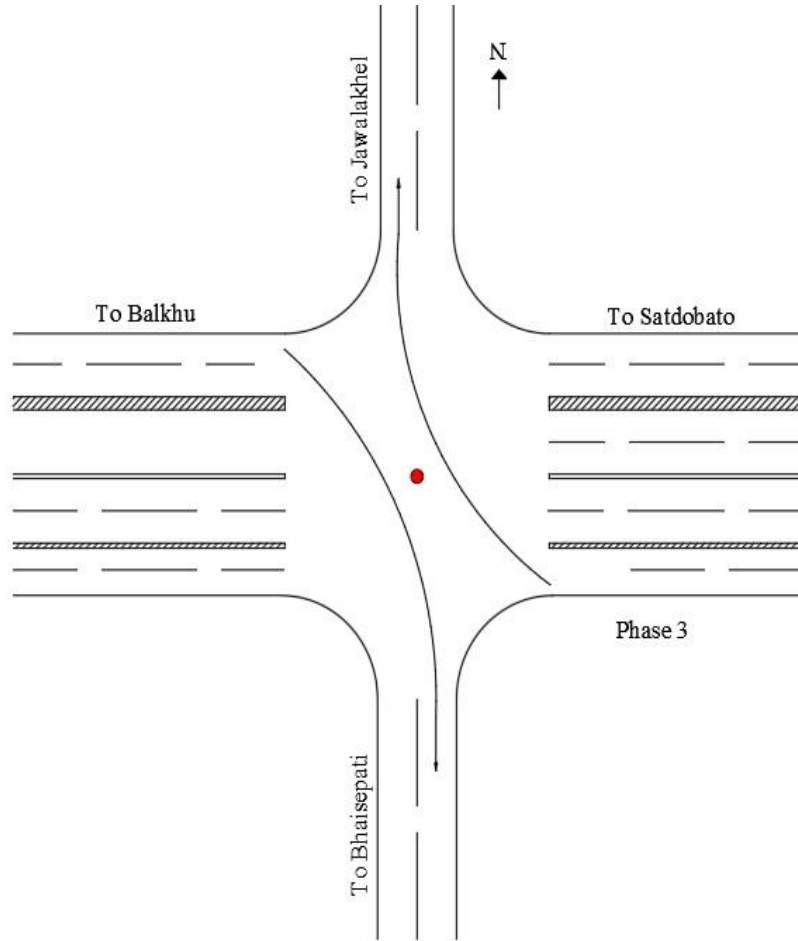
**Phase 1 for Alternative 5**



## Phase 2 for Alternative 5



### Phase 3 for Alternative 5



**Scenario with Alternative 1 for forecasted 10 years**

Movement	Existing average queue length	Existing vehicular delay	Alternative 1 average queue length	Alternative 1 vehicular delay	% Change in average queue length	% Change in vehicular delay
BS to SS	20.552	49.457	30.557	52.587	48.681	6.329
BS to Ja	18.255	11.458	19.005	12.112	4.108	5.708
BM to SS	89.661	73.101	83.567	63.227	-6.797	-13.507
BM to SM	73.099	69.595	69.994	68.112	-4.248	-2.131
BM to Ja	29.361	53.626	28.121	48.521	-4.223	-9.520
BM to Bh	31.490	49.256	30.102	42.339	-4.408	-14.043
SM to BM	48.991	42.258	48.921	39.854	-0.143	-5.689
SM to BS	62.274	36.698	61.024	34.458	-2.007	-6.104
SM to Ja	25.628	49.597	24.852	42.968	-3.029	-13.366
SM to Bh	39.013	43.884	38.855	41.247	-0.405	-6.009
SS to BS	32.200	29.966	45.148	41.031	40.211	36.926
SS to Bh	21.147	15.554	21.503	18.875	1.683	21.351
Bh to SS	79.580	97.868	81.021	99.557	1.811	1.726
Bh to SM	72.120	70.642	71.897	68.147	-0.309	-3.532
Bh to BM	68.711	74.018	69.015	75.127	0.442	1.498
Bh to BS	13.104	63.212	13.183	63.351	0.602	0.220
Bh to Ja	85.207	71.084	86.012	72.058	0.945	1.370
Ja to SS	19.352	22.352	20.053	23.832	3.622	6.621
Ja to SM	33.808	30.294	33.979	31.122	0.504	2.733
Ja to BM	44.161	38.759	43.707	36.557	-1.028	-5.681
Ja to BS	27.209	56.128	27.201	52.276	-0.029	-6.863
Ja to BH	59.998	52.976	58.014	49.668	-3.307	-6.244
Overall (Average)	45.224	50.081	45.715	48.956	1.087	-2.247

**Scenario with Alternative 2 for forecasted 10 years**

Movement	Existing average queue length	Existing vehicular delay	Alternative 2 average queue length	Alternative 2 vehicular delay	% Change in average queue length	% Change in vehicular delay
BS to SS	20.552	49.457	21.273	51.251	3.508	3.627
BS to SM	28.745	50.254	27.797	49.965	-3.298	-0.575
BS to Ja	18.255	11.458	24.261	14.928	32.901	30.285
BM to SS	89.661	73.101	88.718	72.197	-1.052	-1.237
BM to SM	73.099	69.595	63.114	58.257	-13.660	-16.291
BM to Bh	31.490	49.256	26.557	46.547	-15.665	-5.500
SM to BM	48.991	42.258	46.987	41.559	-4.090	-1.654
SM to BS	62.274	36.698	61.965	37.557	-0.496	2.341
SM to Ja	25.628	49.597	24.879	48.576	-2.924	-2.059
SS to BM	31.997	48.698	32.058	49.042	0.192	0.706
SS to BS	32.200	29.966	33.228	31.415	3.192	4.835
SS to Bh	21.147	15.554	22.961	16.028	8.578	3.047
Bh to SS	79.580	97.868	80.862	98.523	1.612	0.669
Bh to SM	72.120	70.642	72.446	71.960	0.453	1.866
Bh to BM	68.711	74.018	67.963	74.614	-1.089	0.805
Bh to BS	13.104	63.212	13.163	63.298	0.449	0.136
Bh to Ja	85.207	71.084	84.018	71.073	-1.395	-0.015
Ja to SS	19.352	22.352	20.012	21.423	3.411	-4.156
Ja to SM	33.808	30.294	33.764	29.386	-0.132	-2.997
Ja to BM	44.161	38.759	43.967	37.937	-0.439	-2.121
Ja to BS	27.209	56.128	26.756	55.406	-1.665	-1.286
Ja to BH	59.998	52.976	61.338	57.297	2.233	8.157
Overall (Average)	44.877	50.147	44.459	49.920	-0.932	-0.452

**Scenario with Alternative 3 for forecasted 10 years**

Movement	Existing average queue length	Existing vehicular delay	Alternative 3 average queue length	Alternative 3 vehicular delay	% Change in average queue length	% Change in vehicular delay
BS to SS	20.552	49.457	30.767	53.012	49.703	7.188
BS to Ja	18.255	11.458	27.775	15.904	52.150	38.803
BM to SS	89.661	73.101	69.143	61.971	-22.885	-15.226
BM to SM	73.099	69.595	66.554	56.667	-8.954	-18.576
BM to Bh	31.490	49.256	26.330	38.697	-16.388	-21.437
SM to BM	48.991	42.258	46.954	38.106	-4.158	-9.825
SM to BS	62.274	36.698	61.495	35.661	-1.251	-2.826
SM to Ja	25.628	49.597	24.866	48.225	-2.977	-2.766
SS to BS	32.200	29.966	45.831	41.032	42.332	36.929
SS to Bh	21.147	15.554	23.816	19.847	12.621	27.601
Bh to SS	79.580	97.868	72.188	96.247	-9.288	-1.656
Bh to SM	72.120	70.642	72.232	70.728	0.156	0.122
Bh to BM	68.711	74.018	67.942	73.987	-1.120	-0.042
Bh to BS	13.104	63.212	13.872	64.073	5.856	1.362
Bh to Ja	85.207	71.084	86.489	72.864	1.505	2.504
Ja to SS	19.352	22.352	17.173	20.371	-11.260	-8.863
Ja to SM	33.808	30.294	32.015	28.554	-5.305	-5.744
Ja to BM	44.161	38.759	43.033	35.141	-2.555	-9.335
Ja to BS	27.209	56.128	25.872	51.395	-4.916	-8.433
Ja to BH	59.998	52.976	57.837	46.764	-3.602	-11.726
Overall(Average)	46.327	50.214	45.609	48.462	-1.551	-3.488

**Scenario with Alternative 4 for forecasted 10 years**

Movement	Existing average queue length	Existing vehicular delay	Alternative 4 average queue length	Alternative 4 vehicular delay	% Change in average queue length	% Change in vehicular delay
BS to SS	20.552	49.457	32.183	60.358	56.592	22.041
BS to SM	28.745	50.254	35.922	54.887	24.967	9.219
BS to Ja	18.255	11.458	19.325	13.852	5.860	20.894
BM to SS	89.661	73.101	17.832	6.172	-80.112	-91.557
BM to SM	73.099	69.595	75.047	70.557	2.665	1.382
BM to Ja	29.361	53.626	33.165	58.561	12.957	9.203
SM to BM	48.991	42.258	68.115	58.264	39.036	37.877
SM to BS	62.274	36.698	48.225	32.551	-22.559	-11.300
SM to Bh	39.013	43.884	44.047	55.632	12.903	26.771
SS to BM	31.997	48.698	38.718	57.241	21.007	17.543
SS to BS	32.200	29.966	37.882	34.978	17.646	16.726
SS to Bh	21.147	15.554	29.634	19.458	40.133	25.100
Bh to SS	79.580	97.868	78.118	97.254	-1.836	-0.627
Bh to SM	72.120	70.642	71.192	68.447	-1.286	-3.107
Bh to BM	68.711	74.018	68.504	72.968	-0.301	-1.419
Bh to BS	13.104	63.212	13.154	66.552	0.379	5.284
Bh to Ja	85.207	71.084	84.869	69.005	-0.396	-2.925
Ja to SS	19.352	22.352	19.347	22.284	-0.026	-0.304
Ja to SM	33.808	30.294	34.389	31.147	1.717	2.816
Ja to BM	44.161	38.759	13.168	9.492	-70.182	-75.510
Ja to BS	27.209	56.128	13.142	10.114	-51.700	-81.980
Ja to BH	59.998	52.976	16.983	5.943	-71.694	-88.782
Overall(Average)	45.388	50.086	40.589	44.351	-10.574	-11.450

**Scenario with Alternative 5 for forecasted 10 years**

SN	MOVEMENT	Alternative 5 average queue length	Alternative 5 vehicular delay	LOS
1	SS to Ja	28.096	42.185	E
2	SS to Bh	24.720	18.505	C
3	BM to SM	1.888	0.000	A
4	SM to BM	1.888	0.000	A
5	BS to Ja	15.030	15.685	B
6	BS to Bh	19.197	26.832	D
7	Ja to SS	27.235	29.685	D
8	Ja to BS	37.906	38.547	E
9	Ja to Bh	45.466	46.914	E
10	Bh to SS	44.526	60.793	F
11	Bh to BS	30.882	34.024	D
12	Bh to Ja	43.350	33.586	D
13	Overall (Average)	26.682	28.896	D
	Existing	43.986	50.031	
	% change	39.340	42.243	

## **APPENDIX E: Photographs**



Tape Measurement for Existing Geometry