TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

THAPATHALI CAMPUS

A MAJOR PROJECT FINAL REPORT

ON

"EVALUATING THE EFFECTIVENES OF VISVAP-PROGRAMMED SEMI-ACTUATED SIGNAL CONTROL OVER EXISTING FIXED-TIME CONTROL: A CASE STUDY OF BABARMAHAL INTERSECTION, KATHMANDU VALLEY "

Submitted By:

Aayam Jung Karki	(THA078BCE004)
Ayush Poudel	(THA078BCE025)
Bidur Ghimire	(THA078BCE028)
Bishal Chapagain	(THA078BCE033)
Ek Bahadur Thapa	(THA078BCE044)
Suraksha Gyawali	(THA078BCE132)

Submitted To:

Department of Civil Engineering

Thapathali Campus

Kathmandu, Nepal

Under the Supervision of

Dr. Rojee Pradhananga

May, 2026

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ABSTRACT

Urban traffic congestion at signalized intersections in Kathmandu is exacerbated by the use of conventional fixed-time signal control, which fails to respond to fluctuating traffic demand. This study investigates the effectiveness of a VISVAP-based semi-actuated signal control system at the Babarmahal intersection. Field traffic data, including turning movements and geometric characteristics, were collected and analyzed using Highway Capacity Manual procedures to evaluate existing operational conditions. A detailed microsimulation model was developed in PTV VISSIM and calibrated to replicate real traffic behavior. The existing Fixed-Time Signal Control (FTSC) was modeled and validated based on observed volume and queue conditions. The FTSC was optimized using VISSIM built in optimization. Furthermore, it was manually optimized taking the signal phasing plans obtained from VISSIM as a base to achieve the best results. Subsequently, a semi-actuated control logic was used for off-peak hour which was designed in VISVAP using detector-based inputs, and non-linear traffic flow rates to optimize signaling plans. Multiple simulation scenarios were conducted under peak and off-peak traffic conditions to compare system performance. Key performance indicators including average delay, queue length, travel time, and level of service were evaluated. Results indicated that the manually optimized FTSC outperformed the other scenarios for peak hour and semi-actuated system significantly reduces unnecessary green time allocation and improves intersection efficiency for off-peak. A substantial decrease in average delay and queue length was observed, along with smoother traffic progression. The adaptive nature of the system allows better utilization of available green time under variable demand conditions. The findings demonstrate that semi-actuated signal control offers a practical and effective solution for improving urban intersection performance in developing cities. This study supports the implementation of demand-responsive traffic signal systems for sustainable traffic management in Kathmandu.

Keywords: Traffic Signal Control, Semi-Actuated Control, VISVAP, PTV VISSIM, Traffic Simulation, Intersection Performance, Kathmandu.

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1 INTRODUCTION

1.1 Background

Urban Traffic Congestion at signalized Intersection remains a Critical challenge in modern transportation system. Traffic congestion is the degradation of traffic flow condition on road and become slower speed which increase the travel time and increased Vehicle queues. It occurs when the demand of road space exceeds its capacity. Intersection Congestion is the main problem in urban area occurs when vehicle demand exceeds the capacity of a signalized or unsignalized crossing, leading to delays, queuing, and reduced traffic flow efficiency. Unlike general intersection congestion is often caused by conflicting vehicle movements, inefficient signal timing.

Congestion arises when there are more vehicles on the road than the infrastructure can handle. Significant delays in urban areas frequently originate at intersections, where conflicting traffic streams converge. There is extensive experience with chronic gridlock and congestion in the Kathmandu Valley [**?**].

One of the popular concepts in traffic signalization is signalization is Fixed time traffic signal. A Fixed- time traffic signal is a traditional signal control system that operates on predetermined, unchanging timing plans. These signal cycle through preset green, yellow, and red phase at regular interval, regardless of real traffic demand.

Fixed time Traffic signal is wastes of times on empty approaches, which increases the delays in peak hours. When traffic demand fluctuated, the efficacy of Optimum Fixed-Time Management declined, resulting in significant increases in average vehicle delay, fuel consumption, and exhaust emissions. To solve the wastes of times on empty approaches, we introduce the actuated traffic signal. An actuated traffic signal is a signal control system that adjusts its timing in real-time based on vehicle or pedestrian demand, detected through sensor (e.g. inductive loops, camera, and radar).

A semi-Actuated Traffic signal is a type of Traffic Control system that combines elements of both fixed-time and fully actuated signals. It is mostly designed for the intersection where the major road carries a significantly higher traffic volume most of the time, while intersecting road i.e. minor road have experience lower, variable traffic flow. Semi-actuated signals operate with vehicle detection only on the minor approaches. The major road usually receives a consistent green phase by default. Vehicle arriving on the minor road are detected by sensors (like inductive loops or cameras).

Microsimulation tools like PTV VISSIM with VISVAP are widely used to modal and optimize actuated signal control. VISSIM is best software to simulation capabilities enable precise evaluation of traffic dynamics, while VISVAP facilitates the programming

of adaptive signal logic. VISSIM simulation program, the time intervals when the fluctuations in traffic demands occur and the quantities (proportions) of the fluctuations at these time intervals can be determined by the users. Thus, changes in intersection performance resulting from short- or long-term fluctuations caused by concerts, sports events, traffic accidents, or adverse weather can be analyzed using VISSIM [**?**] .

1.2 Research Gaps and Problem Statement

Traffic congestion at major intersections throughout the Kathmandu Valley has reached critical levels, significantly degrading urban mobility, the economy, and public well-being. The current situation at the Babarmahal intersection is at a critical phase. The current fixed-time traffic signal system operates inefficiently, failing to adapt to the highly asymmetric traffic flows observed at this junction. The main issue of this intersection is the mismatched allocation of green signal time relative to actual Vehicle demand. The two major legs carry a high traffic volume, i.e., Baneshowr - Babarmahal leg and Maitighar-Babarmahal, whereas the two minor legs, i.e., toward Department of Road and toward Arts Gallery, carry a low traffic Volume. The inefficient Traffic light signal, i.e., long green time interval to the minor legs during periods when these minor legs experienced little or no Vehicular flow. Valuable green time is wasted on this time, which leads to heavily congested major roads and increases delay time.

The absence of the demand-responsive signal control is the main problem of this intersection. While a semi-actuated traffic signal system, which dynamically adjusts minor leg green time based on real-time vehicle detection , i.e., changes the traffic light toward the minor leg and gives the green on the major leg while there are no vehicles on the minor leg.

1.3 Objectives

This study aims to:

1. Assess the performance of a four-legged signalized intersection under existing fixed-time control using PTV VISSIM.
2. Optimize signal timings via actuated control in VISVAP, focusing on parameters like detector placement and green time allocation.
3. Compare the results with fixed-time control to quantify improvements in delay and queue length.

1.3.1 Study Area

The study focuses on the critical Babarmahal Road intersection (27.692506N,85.323863E) located in the administrative and cultural heart of

Kathmandu, Nepal. It is a four-legged signalized intersection. The intersection features four distinct legs:

a. Major East leg: Carry a high-Volume Traffic along the Baneshwor-Babarmahal axis.
b. Major West leg: Carry a high-volume traffic along the Maitighar- Babarmahal axis.
c. Minor North leg: Leading directly towards the Department of Road (DOR).
d. Minor south leg: leading towards the Arts Gallery.

Figure 1-1 Aerial view of Intersection from Google Earth Pro

Figure 1-2 Intersection during visit

The traffic volume along the Maitighar (central) approach and the Baneshwor approach is significantly higher, classifying them as major roads within the intersection. In contrast, the Arts Gallery approach and the Department of Roads approach experience relatively

lower and more fluctuating traffic volumes throughout the day, making them minor roads. Given this variation in traffic demand, implementing a semi-actuated traffic signal control system at this intersection is expected to be beneficial. Such a system can help reduce queue lengths, minimize vehicle delays, improve the Level of Service (LOS), and offer other operational advantages.

Geometric Specifications of Babarmahal Intersection

Table 1-1 Geometrical Parameters

Parameters	**Specifications**
Number of Legs	4(Four-legged intersection)
Approaches	Maitighar, Baneshwor, Arts Gallery, Department of Road (DOR)
Number of lanes Per Approach	Maitighar Approach: 8 lanes Baneshwor Approach: 8 lanes ArtsGallery Approach: 2 lanes DOR Approach: 2 lanes
Lane Width	**Maitighar Approach:** Service Lane: 3.5m(Total 4 lanes) Main Lane: 3m(Total 4 lanes) **Baneshowr Approach:** Service Lane: 3.5m(Total 4 lanes) Main Lane: 3m(Total 4 lanes) **ArtsGallery Approach:** Main Lane: about 2.5m(Total 2 lanes) **DOR Approach:** Main Lane: 2.5m(Total 2 lanes)
Pedestrian Crosswalks	Present on two legs (Maitighar approach and Arts Gallery approach)
Crosswalk Length	About 3.1m
Existing Signal Poles	Present at all four corners (Fixed-Time Signal Control)

NOTE: The above measurements are preliminary estimates obtained using Google Earth Pro and will be verified through field surveys.

Table 1-2 Geometric and type of lane

Orientations	**No. of Lane**	**Movement**	**Wide of Lane**	**Lane Type**
DOR	Lane 1	through/left/right	3.0 m	
	Lane 2	through/left/right	3.0 m	
Art-Gallery	Lane 3	through/left/right	2.5 m	
	Lane 4	through/left/right	4.0 m	
Babar Mahal	Lane 5	through/left	3.5 m	Service
	Lane 6	through/left	3.5 m	Service
	Lane 7	through/left	3.5 m	Service
	Lane 8	through/left	3.5 m	Service
	Lane 9	through	3.5 m	Main
	Lane 10	through	3.5 m	Main
Maitighar	Lane 11	right	3.5 m	Main
	Lane 12	through	3.5 m	Main
	Lane 13	through/left	3.5 m	Service
	Lane 14	through/left	3.5 m	Service
	Lane 15	through/left	3.5 m	Service
	Lane 16	through/left	3.5 m	Service
	Lane 17	through	3.5 m	Main
	Lane 18	through/right	3.5 m	Main
	Lane 19	through/left/right	3.5 m	Main
	Lane 20	through/left/right	3.5 m	Main

2 LITERATURE REVIEW

Intersections are key junctions in the road networks where multiple roads meet or cross. Their design and traffic control methods play a vital role in ensuring smooth traffic flow, safety, and overall efficiency. Traffic management at intersections has been a complex issue in transportation systems for a long time. Several real-time signal control strategies have been implemented, but have not been able to effectively solve this problem completely [**?**].

Broadly, intersections are categorized into signalized and unsignalized types based on the control mechanism used to manage traffic movement.

2.1 Signalized Intersection

A signalized intersection uses traffic signals to control the movement of vehicles and pedestrians. These signals show green, yellow, and red lights to indicate when to proceed, slow down, or stop. The signals operate on a timed cycle, assigning specific green light durations to different directions to maintain smooth and orderly traffic flow. [**?**]. Traffic signals help organize the flow of vehicles and people at intersections, making sure everyone gets their turn to move safely. By giving clear directions on when to stop and go, they help prevent traffic jams and reduce the chances of accidents. This makes the roads safer and more efficient for both drivers and pedestrians. "The traffic signal timing plan is the key that assigns the required time based on the travel demand at the intersection and keeps the cycle length to a minimum green time". The signal controller works as the time setting device for the specific intersection [**?**]. Traffic flow movements are controlled by traffic signals without any conflict points in the signalized intersections. The movements are indicated by green, yellow, and red signals for the vehicle and pedestrian. The road users in the traffic include passenger cars, heavy goods vehicles, large goods vehicles, cycles, pedestrians, public transportation, and motorbikes [**?**]. Traffic s ignals are electrically operated control devices to avoid conflicts between vehicles and pedestrians [**?**]. The three main concepts that describe the traffic signal are the cycle, cycle length, and phase. The cycle is the complete sequence of all the phases. Cycle length is the duration of one complete cycle. The phase is the time interval during which a specific group of vehicle traffic movements is permitted or restricted at the signalized intersection. The signal control cycle has different phases, with each phase representing a combination of permitted movements for multiple lanes receiving the right of way simultaneously [**?**]. The basic control is applied through FTSC, and ATSC strategies include the control of FATSC (Full Actuated Traffic Signal Control), SATSC (Semi Actuated Traffic Signal Control), and Adaptive Traffic Signal Control (ADTSC). These signal systems adjust according to traffic needs using data from detectors [**?**]

2.2 Pretimed signal control

Pretimed control, also known as fixed time signal control, is a signal control system in which the cycle length, phase plan, and phase times are preset to repeat continuously. In this system, a preset time is given to each movement every cycle, regardless of changes in traffic conditions. Pretimed signal control operates on a fixed schedule, where each movement (e.g., vehicular or pedestrian phases) is allocated a predetermined amount of time within a signal cycle regardless of real-time traffic demand [**?**]. Based on historic data at the intersection, the signal timing values were calculated, and these values are programmed into the pre-timed controllers. The pre-timed signal control has many advantages. For example, since both the start and end of green are predictable, it can be used for efficient coordination with adjacent pre-timed signals. Also, as this system does not require detectors, its operations are immune to problems that arise due to the failure of detectors. But on the other hand, fixed signal time control becomes inefficient at isolated intersections where traffic arrivals are very low. Pre-timed control is ideally suited to closely spaced intersections, mostly found in downtown areas. Also, this system is a great option for those intersections where a maximum of three phases is required [**?**]. In the absence of traffic fluctuations in traffic demands, optimum fixed timed management (OFTM) is widely used in isolated intersection approaches to manage traffic flow. Fluctuations in traffic demand decrease the efficiency of OFTM, which causes longer queue lengths, delay, fuel consumption, and exhaust emissions [**?**]. Changing the timing of traffic signals is a cheap and simple way to improve traffic flow and reduce congestion. [**?**]. But traditional fixed-time traffic signals operate on preset schedules and often fail to respond effectively to changing traffic volumes, especially during peak hours [**?**].

2.3 Actuated signal control

Whenever there are short-term or long-term fluctuations in traffic demand at some intersection approaches, the effectiveness and efficiency of the Optimum Fixed Time Management (OFTM) system might decrease or can be adversely affected [**?**]. Traffic management systems based on any created algorithm are referred to as vehicle-actuated signal management systems. A vehicle-actuated management system determines the green and red signal timings according to the current dynamics of vehicle arrivals and queuing information obtained by detectors placed on the lanes in the intersection approaches [**?**]. One of the applications of Intelligent Transportation Systems (ITS) is vehicle-actuated (traffic- actuated) management systems. The effectiveness of these systems depends heavily on the control logic. The selection of the most appropriate control parameters for the designed control logic determines the effectiveness and functions of the actuated systems [**?**]. Vehicle-actuated controllers are also a type of

adaptive system, but the term “adaptive” usually refers to an area traffic control system (ATSC) where signal timings at various junctions are changed together based on that real time traffic conditions [**?**]. An ATCS is a complex system that involves extensive surveillance, such as pavement loop detectors, and infrastructure to connect with central and local controllers. However, these systems are highly efficient, as they include algorithms that adjust a signal’s split, offset, phase length, and phase sequences to control and minimize delays, ultimately reducing the number of stops [**?**]. The analysis results show that the developed vehicle-actuated management system can effectively adapt to fluctuations in traffic demand at signalized intersection approaches.

The system significantly reduces average vehicle delays, fuel consumption, and exhaust emissions. Implementation of a vehicle-actuated management system can greatly improve the performance of an intersection in the presence of fluctuating or varying traffic demand [**?**]. The actuated signal controller has detectors on all the approach lanes. When a detector detects the vehicle, the information is transferred to the controller, and the controller will give the service needed for the road users. The current signal tage will reach its minimum green time if they do not have more vehicles, and then it will change to the next stage to give the right of way to the vehicles. Detectors are placed on the lanes to communicate with the controller, and they should be properly numbered. The detector numbering depends on the phase numbering or the type of signal controller used. Fully actuated signal systems adjust the traffic lights based on real-time data collected from all lanes at an intersection, making these systems the most flexible. Semi-actuated systems only collect data from some lanes, so they only gather partial demand information and make decisions based on that data. Fully actuated control works best at isolated intersections where there are fluctuations in traffic demand throughout the day [**?**]. The maximum green time should be set for the actuated signals to determine the green signal splits for the intersection. If the maximum green time is set too high, then the high-demand lanes would start to affect the operations on the other approach lanes. The minimum green time is the amount of green time required for the vehicle to clear the signalized intersections; it should be enough for the vehicle to pass the intersection, otherwise it will affect the efficiency of the intersection (Sinowatcher, n.d.).

In a semi-actuated control system, the design logic control dynamically adjusts signal timings by determining the green light duration for the secondary road based on the arriving traffic flow. When the detector detects no vehicles or the absence of traffic, the control logic eliminates the green interval and moves to the next phase, which greatly reduces cycle time and delay. This dynamic adjustment of the switching signal operates instantly using an ’if-then’ conditional logic to optimize traffic signal performance [**?**]. Vehicle-actuated signal systems were developed to improve upon fixed-time systems by detecting vehicles approaching an intersection and adjusting green time accordingly.

Although more efficient than fixed-time systems, vehicle-actuated signals are still limited in their ability to coordinate across multiple intersections (Brown & Patel, 2019).

The cost for both the initial set-up and the maintenance is the major disadvantage of fully actuated control. The high cost is due to the amount of detection required. Also, there are chances for a higher percentage of vehicles to stop since the green time is not held for upstream traffic. Another disadvantage is that, if the traffic patterns are regular, the extra benefit obtained from the addition of local actuation is minimal or can be zero [**?**]. Using a fuzzy logic-based vehicle actuated management system reduced delays by 10investigation for vehicle-actuated signal control [**?**]. The green and red signal timings at each cycle were determined using global optimization and complementarity for vehicle-actuated management systems (Ribeiro and Simoes et al). At the end of the analysis, it was concluded that a fully-actuated management system could provide better and more encouraging results than the fixed- time and semi-actuated management systems.

2.4 Adaptive signal control

Adaptive Traffic Control Systems (ATCSs) change signal timings in real time based on how much traffic is on the road and how the system is working. These systems use smart rules to change things like how long lights stay green, when they start, and the order of signals to reduce delays and stops. They need a lot of monitoring, often using sensors under the road, and special equipment to connect with control centers [**?**]. Adaptive traffic control systems are developed to solve the limitations of pre-timed control by instantly adapting to field conditions, such as changing traffic signal timings based on the traffic present and fluctuations in demand or movement [**?**]. Various adaptive traffic control systems like SCOOT, SCATS, and OPAC optimize signal timings based on real-time and predicted traffic demand to improve flow through coordinated green waves. However, the installation and maintenance costs of these systems are very high, and they also require complex infrastructure. As a result, they are not widely implemented and are built in only a few cities around the world [**?**].

3 THEORETICAL BACKGROUND

3.1 Terminologies and Basic Definitions

The following terms are used throughout this chapter and are defined here for clarity.

- **Intersection:** An intersection refers to the area where two or more roads meet or cross. It serves as a space through which vehicles navigate to change direction and reach their intended destinations. Its primary role is to direct traffic appropriately across different routes.
- **Approach:** An approach consists of a group of lanes at an intersection that accommodates all turning and through movements originating from a single direction — including left turns, right turns, and straight-through traffic.
- **Passenger Car Unit (PCU):** PCU is a standardized measure applied in traffic modeling to allow different types of vehicles within a traffic stream to be evaluated on a common basis. It converts diverse vehicle types into equivalent passenger car units for consistent analysis.
- **Highway Capacity Manual (HCM):** The HCM is a reference publication issued by the Transportation Research Board of the National Academies of Science in the United States. It offers concepts, guidelines, and step-by-step procedures for determining the capacity and quality of service of various road facilities.
- **Cycle:** A cycle refers to one full sequence of signal indications at a traffic signal.
- **Cycle Length (C):** The total time taken for a traffic signal to complete a full cycle, typically measured in seconds.
- **Phase:** A phase is a defined portion of a cycle that is allocated to one or more combinations of traffic movements, all of which receive the right-of-way simultaneously during one or more signal intervals.
- **Interval:** An interval is a segment of time during which all signal indications at an intersection remain unchanged.
- **Change Interval (Y):** This refers to the yellow and/or all-red signal intervals that appear at the end of a phase. Their purpose is to allow the intersection to clear before conflicting movements are released. This interval is also referred to as the "Amber Period."
- **Green Time (G):** Green time indicates the duration — measured in seconds — during which the green signal is displayed f or a particular phase, allowing designated movements to proceed.
- **Lost Time:** Lost time refers to periods when the intersection is not being productively used by any traffic movement. This includes the change and clearance intervals when

the intersection is being cleared, as well as start-up delays at the beginning of each phase, when vehicles at the front of a queue take time to begin moving.

- **Effective Green Time (g):** Effective green time is the jusable duration during which organized groups of vehicles can move through the intersection without interruption. It is typically calculated by adding the green time and the change/clearance intervals, then subtracting the lost time for that movement. This value is expressed in seconds.
- **Green Ratio (g/C):** The green ratio is the proportion of effective green time relative to the total cycle length.
- **Effective Red (r):** Effective red is the time period, in seconds, during which a particular movement or group of movements is prohibited from proceeding. It is derived by subtracting the effective green time from the total cycle length.

3.2 Traffic Signals and Signal Control

Traffic signals are electromechanical devices that regulate the right-of-way at intersections by assigning alternating green, yellow, and red indications to competing traffic streams. Their primary purpose is to reduce the frequency and severity of conflicts, improve intersection throughput, and enhance safety for all road users. Signal control strategies can be broadly categorized into fixed-time control, vehicle-actuated control, and adaptive control, each differing in its responsiveness to real-time traffic conditions.

3.2.1 Fixed-Time Signal Control

Fixed-time signal control, also referred to as pre-timed control, operates on a predetermined cycle length, phase sequence, and green split that remain constant regardless of fluctuating traffic volumes. Signal timing plans are developed from historical traffic data and applied uniformly across specified time periods. While fixed-time control is straightforward to implement and maintain, it lacks the flexibility to respond to real-time variations in traffic demand. During off-peak periods or unexpected congestion, this rigidity can result in unnecessary delay, sub-optimal cycle lengths, and reduced intersection efficiency. Fixed-time plans may be developed using optimization tools such as TRANSYT or SYNCHRO, or through manual HCM-based methods, and are typically deployed at intersections with predictable, relatively stable traffic patterns.

3.2.2 Vehicle-Actuated Signal Control

Vehicle-actuated signal control dynamically adjusts signal timing in response to real-time vehicle demand detected by in-ground loop detectors, video sensors, or other detection technologies. Unlike fixed-time control, actuated systems terminate a phase early when demand subsides and extend green time when vehicles continue to arrive, thereby reducing unnecessary delay and improving intersection efficiency. Actuated control

is particularly effective at intersections with variable or unpredictable traffic volumes. The principal modes of vehicle-actuated control are semi-actuated and fully actuated operation, distinguished by the extent to which detection is applied across intersection approaches.

3.2.3 1.2.3 Semi-Actuated Signal Control

Semi-actuated signal control applies vehicle detection exclusively on minor or secondary approaches, while the major street phases operate on fixed, pre-programmed timing parameters. Under this configuration, the major street retains a guaranteed minimum green time and continues to receive the right-of-way until a vehicle actuation is registered on a side-street detector. Upon detection, the controller initiates a phase change to serve the minor street demand, subject to the fulfillment of the major street minimum green interval. Once the minor street demand is served or the maximum green limit is reached, control reverts to the major street. This scheme effectively reduces unnecessary interruptions to high-volume major road traffic while still providing responsive service to lower-volume side streets. Semi-actuated control is widely employed at intersections where traffic volumes on major and minor approaches are significantly imbalanced, as it reduces average delay and improves overall intersection performance compared to fixed-time operation.

Key operational parameters of semi-actuated control include:

- **Minimum Green:** Ensures adequate departure time for queued vehicles at the start of each phase.
- **Maximum Green:** Prevents excessive detention of cross-street traffic by limiting the green duration on the major approach.
- **Passage Time (Extension):** Extends the active phase upon each vehicle actuation, allowing the signal to hold green as long as demand continues up to the maximum green limit.
- **Yellow Change and All-Red Clearance Intervals:** Provide intersection clearance between conflicting phases.

3.2.4 Fully Actuated Signal Control

Fully actuated signal control deploys vehicle detection on all approaches of the intersection, enabling every phase to respond independently to real-time traffic demand. In this mode, both the major and minor street phases can be extended, skipped, or terminated based on detector inputs, resulting in a variable cycle length that continuously adapts to prevailing traffic conditions. Fully actuated controllers evaluate demand on each approach and sequence phases accordingly, granting green time only where and

when vehicles are present. This maximizes efficiency under variable demand but requires a more comprehensive detection infrastructure and a more sophisticated controller.

Fully actuated control is most appropriate at isolated intersections with highly variable multi-directional traffic volumes, where no single approach consistently dominates demand. When properly calibrated, fully actuated systems can substantially reduce average vehicle delay, minimize unnecessary red time, and improve the level of service across all approaches. However, their complexity and higher installation costs make them less suitable for closely spaced, coordinated signal systems where fixed cycle lengths are necessary to maintain progression along a corridor.

Table 3-1 Comparison of Semi-Actuated and Fully Actuated Signal Control

Feature	**Semi-Actuated Control**	**Fully Actuated Control**
Detection Coverage	Minor approaches only	All approaches
Cycle Length	Variable (minor) / Fixed (major)	Fully variable
Best Application	Major/minor volume imbalance	High variability, isolated signals
Infrastructure Cost	Moderate	Higher
Signal Coordination	Compatible	Difficult in coordinated networks

3.3 VISVAP: Vehicle-Actuated Signal Timing Optimization Software

VISVAP (Vehicle-actuated Signal timing optimization for Variable traffic conditions using Actuated Programs) is a specialized software tool developed to program and optimize vehicle-actuated traffic signal controllers, particularly semi-actuated and fully actuated systems. It was developed as part of efforts to bridge the gap between theoretical actuated signal timing principles and practical field implementation, providing traffic engineers with a structured framework for designing, testing, and deploying actuated signal timing plans.

3.3.1 Background and Development

VISVAP was developed to address the limitations of conventional fixed-time optimization programs, which are unable to model the dynamic, demand-responsive behavior of actuated controllers. Unlike fixed-time tools such as TRANSYT or SYNCHRO, VISVAP explicitly accounts for detector placement, actuation logic, passage time settings, minimum and maximum green constraints, and phase termination criteria. The software enables engineers to simulate actuated controller behavior under a range of traffic demand scenarios and optimize timing parameters accordingly.

The program was developed within the framework of research on actuated signal control and is specifically designed to work in conjunction with microscopic traffic simulation platforms, most notably PTV VISSIM. VISVAP generates controller parameter files that can be directly imported into VISSIM for simulation-based evaluation, enabling a realistic and repeatable assessment of signal performance before field deployment.

3.3.2 Operational Principles of VISVAP

VISVAP operates by defining a set of actuated control logic rules for each phase and detector configuration at an intersection. The software allows the user to specify:

- **Detector Type and Location:** Including stop-bar detectors and advanced detectors, with configurable sensitivity and detection zone lengths appropriate to the intersection geometry.
- **Phase Sequence and Ring-Barrier Structure:** Following the standard NEMA (National Electrical Manufacturers Association) dual-ring controller structure used in most modern actuated signal controllers.
- **Minimum Green Settings:** Ensuring adequate initial service for each phase before any termination can occur.
- **Maximum Green Settings:** Capping the green duration to prevent excessive delay to conflicting movements.
- **Passage Time (Vehicle Extension):** Defining the interval by which the green phase is extended upon each vehicle actuation at the detector.
- **Gap and Time-Before-Reduce Settings:** Parameters governing when the controller begins reducing passage time after a period of no actuation, and the rate of reduction toward the minimum gap threshold.
- **Yellow and All-Red Intervals:** Configurable clearance intervals between phases to ensure safe intersection clearance.

Once the timing parameters are defined, VISVAP generates a VAP (Vehicle Actuated Programming) file or equivalent controller script that encodes the actuated logic. This file is then loaded into the VISSIM simulation environment, where the VAP module interprets the controller instructions and governs signal operations dynamically in response to simulated vehicle detections.

3.3.3 VISVAP in the Context of Semi-Actuated Control

For semi-actuated control applications, VISVAP is configured such that detection is assigned exclusively to minor-street approaches while the major-street phase operates based on fixed minimum and maximum green parameters. The VISVAP-programmed

controller monitors detector inputs on the side-street approaches and initiates a phase call when a vehicle is detected, subject to the major-street minimum green constraint. The controller extends the major-street green phase up to the maximum green limit if no side-street demand is registered, effectively minimizing unnecessary interruptions to the dominant traffic flow.

This configuration closely replicates real-world semi-actuated controller behavior and allows simulation-based performance evaluation across varying traffic demand scenarios. The ability to systematically test different minimum green, maximum green, and passage time combinations within VISVAP enables engineers to identify the timing parameter set that minimizes average vehicle delay and optimizes the level of service for the prevailing intersection conditions.

3.3.4 Integration with PTV VISSIM

VISVAP is designed to interface directly with the VISSIM microscopic traffic simulation platform through the Vehicle Actuated Programming (VAP) external controller module. When deployed within VISSIM, VISVAP-generated controller files govern signal phase transitions in real time based on simulated vehicle detections at defined detector locations. This integration enables the simulation of actuated signal behavior at a level of fidelity that closely replicates field conditions, including stochastic vehicle arrivals, queue formation and dissipation, and the dynamic interaction between detector inputs and controller logic.

The VISSIM-VISVAP combination provides a powerful and widely recognized platform for before-and-after analysis of signal control strategies, allowing researchers and practitioners to quantitatively compare the performance of semi-actuated VISVAP-programmed control against existing fixed-time plans in terms of average vehicle delay, queue length, throughput, and level of service.

3.3.5 Advantages of VISVAP-Programmed Semi-Actuated Control

Compared to conventional fixed-time signal control, VISVAP-programmed semi-actuated operation offers several operational advantages:

- **Demand Responsiveness:** The signal serves minor-street demand only when vehicles are present, eliminating unnecessary interruptions to major-street flow during low side-street demand periods.
- **Reduced Average Delay:** By avoiding unnecessary phase changes and adapting green duration to real-time demand, average vehicle delay across all approaches is typically reduced relative to fixed-time plans.

- **Improved Level of Service:** Reduced delay translates to improved LOS grades, particularly for major-street through movements.
- **Flexibility in Parameter Optimization:** VISVAP facilitates systematic optimization of timing parameters through simulation-based testing, enabling the identification of the most efficient control settings for specific traffic conditions.
- **Lower Infrastructure Requirement than Fully Actuated:** Detection is required only on minor approaches, making semi-actuated control a cost-effective intermediate option between fixed-time and fully actuated systems.

3.4 Traffic Flow

Traffic flow patterns describe how vehicles move and distribute across road networks. These patterns are shaped by a range of factors, including road design, traffic signal operation, driver behavior, and external conditions such as weather or accidents. Broadly, traffic flow can be grouped into several types: free flow, where vehicles travel without restriction; synchronized flow, where vehicles move at comparable speeds in closer proximity; and congested flow, which is marked by slow movement and frequent stops due to excessive traffic density or road blockages. A thorough understanding of these patterns is fundamental to traffic engineering, as it helps improve road efficiency, reduce delays, and ease congestion. Modern solutions such as Intelligent Transportation Systems (ITS) and adaptive traffic management systems leverage real-time data to dynamically adjust signals and lane usage for optimized flow. Traffic flow analysis also plays a critical role in urban planning, road safety assessments, and the development of effective transportation policies.

3.4.1 Types of Traffic Flow Pattern

Traffic flow can be classified into several distinct types based on how vehicles move and interact on the road:

- **Free Flow :**In this state, vehicles travel at their preferred speeds with minimal disruption, keeping safe distances between one another. Traffic density is low, resulting in smooth and uninterrupted travel.
- **Synchronized Flow :**Vehicles move at roughly similar speeds but with reduced spacing between them, often as a result of traffic signal influence or road conditions. Lane changes are less frequent, and overall movement is more orderly.
- **Congested Flow :** Elevated vehicle density causes a reduction in speed, frequent stops, and longer travel times. This condition is most common during peak commuting hours, in the aftermath of accidents, or when road sections are partially blocked.

- **Unstable Flow :** Traffic in this state alternates between free-flow and congested conditions, with rapid speed fluctuations and frequent braking. This often results in a stop-and-go pattern of movement.
- **Stop-and-Go Flow :** Vehicles repeatedly accelerate and decelerate due to congestion, bottlenecks, or lane merges. This type of flow is inefficient and results in higher fuel consumption.
- **Forced Flow :** Under extremely congested conditions, road closures, or accidents, vehicles are compelled to slow down significantly or stop entirely, often resulting in widespread delays and gridlock.

3.4.2 Traffic Conflicts

Traffic conflicts at unsignalized intersections arise when vehicles or other road users, such as pedestrians or cyclists from different approaches, attempt to occupy the same space at the same time. These conflicts are typically resolved through established right-of-way rules and a hierarchy of movement priorities. In the context of traffic flow characteristics, four key maneuvers are involved: diverging, merging, crossing, and weaving. While diverging and merging movements from the left side generally do not cause significant conflicts, similar movements from the right side tend to interfere with traffic traveling straight ahead.

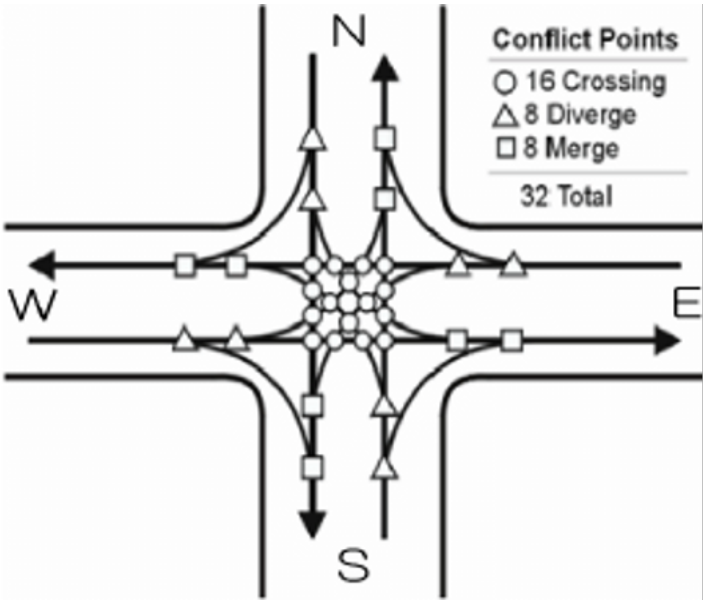


Figure 3-1 Traffic Conflict

3.5 Level of Service (LOS)

Level of Service (LOS) is a qualitative measure used to evaluate the performance and quality of traffic flow on a given road segment or at an intersection. It classifies

roadway conditions based on parameters such as vehicle speed, traffic density, and the ease of maneuvering, providing a structured way to assess how well traffic is moving. Both the Highway Capacity Manual (HCM) and the AASHTO Geometric Design of Highways and Streets use a grading system ranging from A to F to define LOS, where A indicates the best possible driving conditions, and F represents severe and unmanageable congestion.

LOS-A: Describes free-flowing traffic conditions in which vehicles travel at or above posted speed limits with very little interference. Drivers enjoy a high degree of comfort and freedom of movement, with an average vehicle spacing of approximately 167 meters (550 feet), equivalent to about 27 car lengths. Traffic disturbances are rare and easily resolved. These conditions are typically found in urban areas during late-night hours or consistently in rural environments.

LOS-B: Traffic still flows freely, though the ability to maneuver within lanes is somewhat reduced compared to LOS A. Vehicles maintain speeds consistent with LOS A conditions, with an average spacing of around 100 meters (330 feet) or approximately 16 car lengths. Drivers generally experience a comfortable and manageable driving environment.

LOS-C: Traffic remains stable and close to free-flow conditions, but lane changes demand greater attentiveness from drivers. Vehicles are spaced approximately 67 meters (220 feet) or 11 car lengths apart. The majority of drivers find these conditions acceptable, and roadways operate below their maximum capacity while still functioning efficiently. Minor incidents may have a limited impact on overall flow, although localized delays can occur. LOS C is often considered a target condition for urban highways and most rural roads.

LOS-D: Traffic flow begins to show signs of instability, with modest reductions in speed as vehicle volume increases. Maneuverability is more constrained, leading to decreased driver comfort. Average vehicle spacing falls to around 50 meters (160 feet), or about 8 car lengths. Even minor incidents can trigger noticeable delays. LOS D is typical along busy commercial corridors on weekdays or on major urban arterials during peak periods. For many urban streets, LOS D during rush hours is considered an acceptable target, as upgrading to LOS C would often require expensive infrastructure improvements.

LOS-E: Represents traffic operating at or near full roadway capacity with unstable flow. Speeds become inconsistent, fluctuating frequently due to the limited availability of gaps for maneuvering. Even though vehicles may be spaced about six car lengths apart, speeds can still approach or exceed 80 km/h (50 mi/h) in some cases. Any disruption, such as a merging vehicle or a sudden lane change, can produce a shockwave effect

that propagates upstream and causes significant delays. Driver comfort is noticeably diminished at this level.

LOS-F: Indicates a complete breakdown of traffic flow, characterized by vehicles moving in dense clusters with minimal gaps and frequent complete stops. Travel times become highly unpredictable as demand surpasses the roadway's capacity. A road that suffers from chronic congestion is classified under this category, as LOS is assessed based on typical conditions rather than isolated incidents. For example, a highway may generally operate at LOS D during the morning peak, but on certain days, conditions may fluctuate between LOS C and LOS E or even temporarily reach LOS F with traffic coming to a complete standstill.

3.6 Capacity

According to the Highway Capacity Manual (HCM 7th Edition, 2022), capacity is defined as the highest sustained rate of traffic flow that a transportation facility can handle under a given set of conditions. This value is shaped by a combination of factors, including roadway geometry, the mix of vehicle types, traffic control measures, driver behavior, and environmental conditions. The HCM provides detailed methodologies for evaluating a wide range of facilities, including freeways, urban roads, roundabouts, two-lane highways, and multimodal networks. Its most recent edition introduces enhanced approaches for multimodal analysis, congestion assessment, and the integration of big data. Under typical conditions, freeway capacity ranges between 2,200 and 2,400 passenger cars per hour per lane (pcphpl), while urban intersections generally operate at around 1,800 pcphpl. However, according to the Nepal Urban Road Standard (NURS 2076), the capacity for a four-lane two-way road is specified as 4,000 pcu/hr. The HCM also accounts for the influence of pedestrians, cyclists, and emerging micromobility trends on overall capacity. These advancements support more effective traffic management, intersection optimization, and transportation planning for improved road network performance.

According to HCM :

$$c_i = s_i \times \frac{g_i}{c}$$

where:

- c_i = capacity of lane group i (veh/h),
- s_i = saturation flow rate for lane group i (veh/h),
- g_i / C = effective green ratio for lane group i.

Capacity at signalized intersections is based on the concept of saturation flow and saturation flow rate. The flow ratio for a given lane group is defined as the ratio of the actual or projected demand flow rate for the lane group (vi) and the saturation flow rate (si). The flow ratio is given the symbol (v/s) i for lane group i. The capacity of a given lane group may be stated as shown in above equation.

3.7 Vehicle to Capacity Ratio

3.8 Headway

In traffic engineering, headway refers to the time gap or spatial distance between two consecutive vehicles traveling in the same lane and direction. It is a fundamental parameter for maintaining smooth traffic flow and ensuring road safety. There are two main categories of headway:

- **Time Headway :** The time elapsed between two successive vehicles as they pass a fixed reference point, typically measured in seconds.
- **Distance Headway :** The physical gap between two consecutive vehicles, generally expressed in meters or feet.

Shorter headways tend to contribute to congestion and increase the likelihood of rear-end collisions, while longer headways promote safer and more efficient movement. Traffic engineers study headway data to refine signal timing, reduce bottlenecks, and improve overall road safety.

3.8.1 Time Headway

Time headway, often referred to simply as headway, is a microscopic traffic characteristic closely linked to traffic volume. It is defined as the time difference between two successive vehicles passing a fixed reference point. In practice, it is measured as the time interval between the passage of the rear bumper of one vehicle and the rear bumper of the next vehicle past a given location. If all individual headways (h) across a time period t are summed:

$$\sum_{i=1}^{nt} \times (h_i) = t$$

But the flow is defined as the number of vehicles n measured in time interval t, that is,

$$q = nt/t$$

$$= nt/\sum_{i=1}^{nt} \times (h_i)$$
$$= 1/h_a v$$

where, h_{av} is the average headway. Thus, the average headway is the inverse of flow. Time headway is often referred to as simply the headway.

3.8.2 Distance Headway

Distance headway is a related spatial parameter defined as the distance between corresponding points of two consecutive vehicles at a specific instant in time. In practice, it is often measured from a photograph as the distance between the rear bumper of the leading vehicle and the rear bumper of the following vehicle. If all individual spacing values across a road segment of length x are summed:

$$k = nx/x$$
$$= nx/\sum_{i=1}^{nx} \times (s_i)$$
$$= 1/S_{av}$$

Where, S_{av} is the average distance headway.

The average distance headway is the inverse of density and is sometimes called spacing.

3.9 Saturation Flow

Saturation flow rate is the foundational parameter from which intersection capacity is derived. It is based on the minimum time headway that a lane group can sustain as vehicles cross the stop line. The saturation flow rate is calculated independently for each lane group at an intersection. When measured directly from field observations under prevailing conditions, it can be used without further adjustment. However, if a default base saturation flow rate is used instead, it must be corrected for various influencing factors, including intersection geometry, traffic composition, environmental conditions, and the proportion of heavy vehicles in the traffic stream.

3.10 Passenger Car Unit

The Passenger Car Unit (PCU) is a standardized metric used in traffic engineering to convert heterogeneous traffic streams comprising vehicles of varying sizes, performance characteristics, and operational behaviors, such as trucks, buses, motorcycles, and

bicycles, into equivalent units of passenger cars. This conversion enables uniform analysis of traffic flow, capacity, and congestion levels. PCU values reflect the relative impact of each vehicle type on overall traffic dynamics. For instance, a large truck may be assigned a PCU value between 3 and 4, given its slower acceleration, larger footprint on the road, and greater disruptive effect on surrounding traffic. A motorcycle, by contrast, may be assigned a PCU of 0.2 to 0.5, reflecting its high maneuverability and minimal space requirements. These values are not fixed; they vary depending on road geometry, the composition of traffic, gradient, and regional driving patterns.

PCU is an essential tool for designing transportation infrastructure (such as determining appropriate lane widths and signal timings), evaluating road capacity using standards like the HCM, and running traffic simulations in software such as VISSIM. By converting diverse vehicle types into a single comparable unit, PCU enables objective analysis and well-informed decision-making in transportation planning. However, for PCU values to be reliable, they must be locally calibrated to account for site-specific conditions and driving behaviors.

3.11 Peak Hour Factor (PHF)

The Peak Hour Factor (PHF) is a measure that captures the variation in traffic demand between the peak hour and the broader daily traffic pattern. It quantifies how much traffic intensifies during the busiest part of the day, typically the morning or evening rush, relative to the average hourly flow throughout the day.

For a 15-minute analysis period, PHF is defined as:

$$PHF = V/(4 * V_{m15})$$

where:

- V = hourly volume,
- V_{m15} = maximum 15-minute volume within the hour, vehs
- PHF = Peak hour factor

3.12 Unsignalized Intersection

Unsignalized intersections operate without traffic signals and instead depend on regulatory signs such as STOP or YIELD signs to manage traffic movement. At these intersections, vehicles approaching from minor roads must judge available gaps in the major road traffic before safely entering or crossing. Right-of-way is governed by a predefined hierarchy of movements, in which higher-priority movements take precedence.

A typical priority order is as follows:

- **Highest priority:** Through traffic on the major street.
- **Second priority:** Right-turning vehicles from the major street.
- **Lower priority:**Left-turning vehicles from the major street, or through traffic on the minor street.
- **Lowest priority:** Right or left turns from the minor street.

When movements conflict, for example, a right-turning vehicle from the major street versus through traffic on the same major street, the movement with the higher priority proceeds first. Lower-priority movements must wait until all conflicting higher-priority traffic has cleared the intersection. This process is inherently stochastic (random) in nature, making it mathematically complex to model due to the variability in driver behavior and the unpredictability of traffic dynamics.

3.13 Control Delay

The delay experienced by a driver at an intersection is influenced by multiple factors, including traffic control measures, road geometry, traffic volume, and the occurrence of incidents. Total delay is defined as the additional time a traveler spends compared to what would be expected under ideal travel conditions with no accidents, no traffic controls, no congestion, and no geometric restrictions. It represents the difference between the actual travel time and the theoretical baseline travel time.

The average control delay per vehicle is estimated for each lane group and aggregated for each approach and for the intersection as a whole. LOS is directly related to the control delay value.

The criteria are listed in the **??**

Table 3-2 LOS Criteria for signalized Intersection

Level of Service	Average Control Delays(s/veh)
A	0-10
B	>10-20
C	>20-35
D	>35-55
E	>55-80
F	>80

Of the total delay, only the component attributable to traffic control measures, specifically stop signs, is quantified in this context. This approach is consistent with the methodology used for signalized intersections discussed earlier in the manual. Control delay is

composed of several sub-components: the initial deceleration delay as the vehicle slows down, the time spent in the queue as vehicles ahead move forward incrementally, the time during which the vehicle is completely stopped, and the acceleration delay as the vehicle resumes normal speed. For practical field measurement purposes, control delay is defined as the total time a vehicle takes from the moment it joins the back of the queue to the moment it crosses the stop line and starts moving.

3.13.1 Uniform Delay

$$d_1 = \frac{(0.5c \times (1 - g/c)^2)}{(1 - [\min(1,\mathrm{x})g/c])}$$

where:

- d_1 = uniform control delay assuming uniform arrivals (s/veh)
- C = cycle length (s); cycle length used in pretimed signal control, or average cycle length for actuated control
- g = effective green time for lane group (s); green time used in pretimed signal control, or average lane group effective green time for actuated control (see Appendix B for signal timing estimation of actuated control parameters)
- X = v/c ratio or degree of saturation for lane group.

This equation gives an estimate of delay assuming uniform arrivals, stable flow, and no initial queue. It is based on the first term of Webster's delay formulation and is widely accepted as an accurate depiction of delay for the idealized case of uniform arrivals. Note that values of X beyond 1.0 are not used in the computation of d_1.

3.13.2 Incremental Delay

$$d_2 = 900T \times [(X - 1) + \sqrt{((X - 1)^2 + \frac{8kIX}{cT})}]$$

where:

- d_2 = incremental delay to account for the effect of random and oversaturation queues, adjusted for duration of analysis period and type of signal control (s/veh); this delay component assumes that there is no initial queue for the lane group at the start of the analysis period
- T = duration of analysis period (h)
- k = incremental delay factor that is dependent on controller settings
- I = upstream filtering/metering adjustment factor

- c = lane group capacity (veh/h)
- X = lane group v/c ratio or degree of saturation

3.13.3 Initial Queue Delay

When a residual queue from a previous time period causes an initial queue to occur at the start of the analysis period (T), additional delay is experienced by vehicles arriving in the period since the initial queue must first clear the intersection. This procedure is also extended to analyze delay over multiple time periods, each having a duration T, in which an unmet demand may be carried from one-time period to the next. If this is not the case, a value of zero is used for d_3.

3.13.4 Aggregated Delay Estimates

The procedure for delay estimation yields the control delay per vehicle for each lane group. It is often desirable to aggregate these values to provide delay for an intersection approach and for the intersection as a whole. This aggregation is done by computing weighted averages, where the lane group delays are weighted by the adjusted flows in the lane groups.

Thus, the delay for an approach is computed using Equation:

$$d_A = \frac{\sum d_i \times v_i}{\sum v_i}$$

where:

- d_A = delay for Approach A (s/veh),
- d_i = delay for lane group i (on Approach A) (s/veh),
- v_i = adjusted flow for lane group i (veh/h)

Control delays on the approaches can be further aggregated using the equation below to provide the average control delay for the intersection:

$$d_I = \frac{\sum d_A \times v_A}{\sum v_A})$$

where:

- d_I = delay per vehicle for intersection (s/veh),
- d_A = delay for Approach A (s/veh),
- v_A = adjusted flow for Approach A (veh/h).

3.14 Signal Timing

Several key factors govern how traffic signals are timed at intersections. According to the FHWA Traffic Signal Timing Manual, these factors include:

Location: Traffic characteristics such as speed, composition, and volume differ significantly from one location to another, making the specific location a critical input in signal timing decisions.

Transportation Network Characteristics: While a standalone intersection can be timed in isolation, signalized intersections located within a road network must be coordinated with one another to maintain consistent traffic progression and minimize cumulative delays. The spacing between adjacent signals is a particularly important variable in this coordination.

Intersection Geometry: Physical characteristics such as the number of lanes, lane widths, and the overall shape of the intersection directly affect its capacity. Signal timing must reflect these geometric features to ensure safe and conflict-free movement for both vehicles and pedestrians while keeping delays to a minimum.

User Characteristics: Intersections serve a diverse range of road users, including pedestrians, cyclists, and motor vehicles, each moving at different speeds and requiring different clearance times. Signal timing must account for this diversity. Equally important is the balance between traffic demand (arrival rates) and roadway capacity (throughput) to prevent excessive queuing and congestion.

3.15 Phase Design

Phase design in traffic engineering involves establishing the order and timing of traffic signal phases at an intersection to enhance traffic efficiency, reduce delays, and ensure safety for all users. A phase represents a segment of a signal cycle that permits certain vehicle or pedestrian movements while preventing conflicting flows. The goal of phase design is to divide conflicting movements at an intersection into distinct phases, ensuring that movements within each phase do not interfere with one another. However, completely separating all movements would require a large number of phases, which may not always be practical. Therefore, the objective is to design phases that minimize conflicts or reduce their severity while maintaining efficient traffic flow.

3.15.1 Two-Phase Design

A two-phase design in traffic engineering is a signal system that divides an intersection into two distinct phases. In this setup, traffic from one approach (e.g., north-south) moves through the intersection while the other approach (e.g., east-west) is stopped. The

next phase then allows the perpendicular direction to proceed. This design prioritizes through traffic in one direction at a time and is most effective for intersections with high through-traffic volumes and minimal turning movements. Alternatively, when turning movements are considerable, a four-phase signal system is generally implemented.

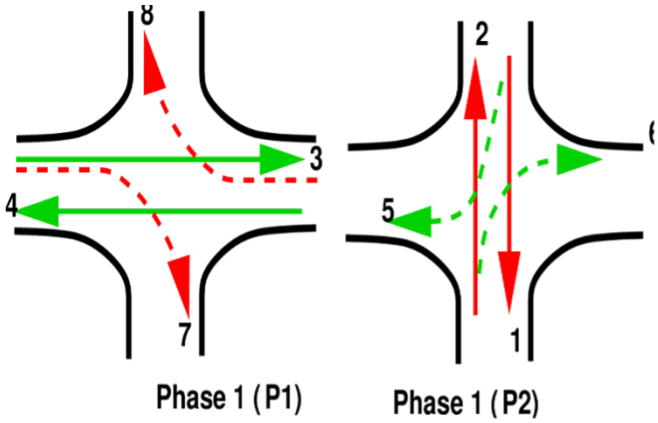


Figure 3-2 Two-Phase Design

3.15.2 Four-Phase Design

A four-phase design in traffic engineering is a signal iming system that organizes intersection movements into four distinct phases to efficiently manage conflicting traffic flows. This approach is particularly beneficial for intersections with high traffic volumes and significant turning movements, ensuring improved traffic flow and safety. In the first phase, vehicles on the major road (e.g., north-south) move straight, while turning movements may be restricted or permitted. The second phase provides a dedicated signal for left-turning vehicles on the major road, reducing conflicts with opposing traffic. The third phase allows through movements on the minor road (e.g., east-west), with turning movements managed separately if needed. Finally, the fourth phase gives left-turning vehicles on the minor road their own signal to ensure safe passage without interference from opposing traffic.

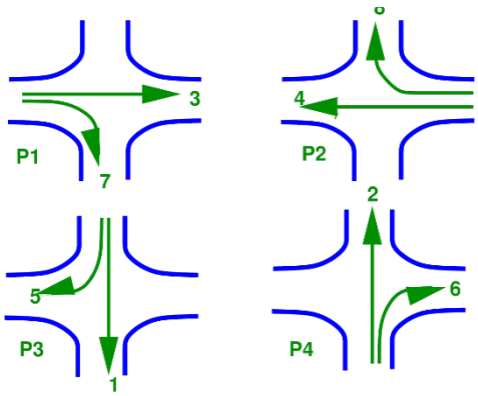


Figure 3-3 Four-Phase Design

3.16 Queuing Theory

As outlined in the Highway Capacity Manual (HCM), queuing theory examines how vehicle queues form and dissipate at unsignalized intersections, where traffic movements are governed by priority rules and gap acceptance behavior. At these locations, vehicles on minor roads must wait for adequate gaps in the major-road traffic stream before they can proceed, a process that can lead to delays and the formation of queues. The HCM uses probabilistic models — including the Poisson distribution for modeling vehicle arrivals and M/M/1 or M/G/1 queuing models — to estimate queue lengths, delays, and intersection capacity. The key variables affecting queue behavior include the volume of major-road traffic, the critical gap that minor-road drivers are willing to accept, follow-up headway times, and individual driver behavior. By evaluating control delay using this framework, engineers can determine the Level of Service (LOS) and identify opportunities to improve intersection efficiency and safety without necessarily installing traffic signals.

3.17 Nepal Urban Road Standard (NURS,2076)

The **Nepal Urban Road Standard (NURS) 2076** provides guidelines for the planning, design, construction, and maintenance of urban roads in Nepal. It categorizes roads based on function, capacity, and right-of-way, ensuring efficient urban mobility and safety. The standard emphasizes sustainable road development, pedestrian-friendly infrastructure, and integration with public transport. It sets specifications for carriageways, sidewalks, drainage, and intersections, promoting uniformity in urban road networks. Additionally, it incorporates environmental and accessibility considerations to enhance urban livability.

3.18 Traffic Simulation

Traffic simulation — also referred to as the simulation of transportation systems — involves the construction of mathematical models representing various transportation infrastructure elements, such as freeway interchanges, arterial roads, roundabouts, and urban road networks. These models are developed using specialized computer software to assist in the planning, design, and operational optimization of transportation systems.

Simulation is an indispensable tool in transportation analysis because it enables the study of highly complex systems that would be too intricate to evaluate using conventional analytical or numerical methods. It also supports experimental investigations, allows for the exploration of cause-and-effect relationships that traditional methods might miss, and produces visually intuitive representations of both existing and projected traffic scenarios. These visualizations help engineers and planners anticipate potential problems and develop well-informed solutions before physical implementation.

To evaluate and compare different traffic management approaches, a variety of network signal analysis, timing, and simulation tools are available. Highway Capacity Software (HCS) techniques are among the most commonly used methods for assessing roadway performance and optimizing traffic flow.

Several well-established simulation tools and software applications are used in the field to analyze and improve traffic conditions:

1. **PTV VISSIM :** A widely used microscopic traffic simulation platform capable of detailed modeling of mixed traffic streams, signal control systems, and multimodal transport networks.
2. **AnyLogic :** A versatile simulation tool that supports multimodal transportation analysis with flexible modeling capabilities.
3. **SYNCHRO :** Specializes in traffic signal optimization and capacity analysis for urban intersections.
4. **SIDRA :** Used to evaluate the operational performance of intersections, roundabouts, and signalized corridors.
5. **HCM-Arterials :** A methodology-based tool grounded in the Highway Capacity Manual for analyzing the performance of arterial roadways.6. SIGNAL 97 - Designed specifically for traffic signal analysis, optimization, and timing adjustments.
6. **SimTraffic :** A simulation program that models and visualizes vehicle movements and interactions across road networks.

Through the use of these simulation tools, transportation engineers are able to evaluate a wide range of traffic scenarios, optimize roadway capacity, improve signal operations, and contribute to safer and more efficient road networks overall.

4 METHODOLOGY

4.1 Primary data collection.

The data used in this study were obtained from the District Police Office, Bhadrakali, Kathmandu, which provided CCTV video footage of the Babarmahal Intersection. The footage covered a continuous 24-hour period over three consecutive weekdays, from July 20th, 2025, to July 22nd, 2025, capturing the full spectrum of daily traffic conditions, including morning peak, off-peak, evening peak, and nighttime hours.

The use of CCTV-based video data ensured non-intrusive and accurate traffic observation without disrupting the natural flow of traffic at the intersection. The video footage was subsequently processed to extract classified traffic volume counts, turning movement counts, and other relevant traffic parameters required for the development and calibration of the microsimulation model in PTV VISSIM, as described in the subsequent sections.

The geometric data, including lane widths and GPS coordinates for each lane, were obtained through **field measurement and a GPS survey** conducted on June 5th, 2025. Signal timing parameters, including cycle length, phase sequences, and green times, were recorded from the existing traffic signal controller at the site.All collected data were subsequently used to develop and calibrate the microsimulation model in **PTV VISSIM**, as described in the subsequent sections.

The video footage was processed and analyzed to determine the peak and off-peak traffic conditions at the intersection. Traffic volume observation extracted from the footage revealed that **the maximum traffic flow was observed between 9:30 AM and 10:30 AM**, which was therefore selected as the **peak hour** for this study. Similarly, the period between **1:00 PM and 2:00 PM** was identified as representing comparatively lower traffic demand and was selected as the **off-peak hour**. Classified traffic volume counts and turning movement counts were extracted from the CCTV footage for both these one-hour periods and used as input data for the microsimulation model in PTV VISSIM.For the purpose of traffic volume count, vehicles were classified into eight categories, namely Heavy Truck, Mini Truck, Big Bus, Micro Bus, Utility Van, Pickup, Safa Tempo, and Bike, in accordance with the vehicle classification system adopted by the **Department of Roads, Nepal Road Standard 2070**.

4.2 Existing Conditions analysis using the HCM manual.

The performance of the Babarmahal Intersection under the existing fixed-time signal control was analytically assessed following the signalized intersection analysis procedure outlined in the Highway Capacity Manual (HCM). This manual method was applied to the peak-hour traffic data collected on the first day of the survey (9:30–10:30 AM)

to determine approach-level and intersection-wide values of control delay and Level of Service (LOS). The HCM analysis serves as an independent analytical baseline for Scenario 1, allowing a validation comparison with the microsimulation results obtained from PTV VISSIM.

The existing signal operates on a cycle length of 157 seconds, comprising four phases. The green time allocations for each phase are summarized in **??**

Table 4-1 Existing Fixed-Time Signal Phase Plan — Babarmahal Intersection

Phase	**Movement Description**	**Green Time (s)**
A	Right turns: Baneshwor → DOR and Maitighar → Art Gallery	25
B	Through movement: Maitighar ↔ Baneshwor (main corridor)	80
C	Art Gallery approach movements	25
D	DOR approach movements	27
Cycle Length		169 s

4.2.1 Step 1: Peak Hour Factor (PHF)

The Peak Hour Factor (PHF) quantifies how uniformly traffic is distributed within the peak hour. It is defined as the ratio of the total hourly volume to four times the peak 15-minute volume, and is given by:

$$\text{PHF} = \frac{V_{hour}}{4 \times V_{15,peak}}$$

where:

- V_{hour} = the total PCU count during the peak hour
- $V_{15,peak}$ = the highest 15-minute PCU count within that hour

. PHF values closer to 1.0 indicate a more uniform distribution of traffic, while lower values indicate a sharply peaked flow pattern.

For the Maitighar approach, the 15-minute PCU totals across all turning movements (towards Baneshwor service lane, Baneshwor main lane, DOR, and Art Gallery) were summed for each interval as follows: 9:30–9:45 = 403.00; 9:45–10:00 = 386.25; 10:00–10:15 = 451.50; and 10:15–10:30 = 491.00. The total hourly volume is 1731.75

PCU/hr, with the peak 15-minute interval occurring at 10:15–10:30. Substituting into the formula:

$$\begin{aligned} PHF &= 1731.75/(4 \times 491.00) \\ &= 1731.75/1964.00 \\ &= 0.882 \end{aligned}$$

The PHF values for all four approaches were similarly computed and are presented in **??**

Table 4-2 Peak Hour Factor (PHF) by Approach

Approach	**9:30-9:45**	**9:45-10:00**	**10:00-10:15**	**10:15-10:30**	**Total (PCU/hr)**	**Peak V_{15}**	**PHF**
Maitighar	403.00	386.25	451.50	491.00	1731.75	491.00	0.882
Baneshwor	621.50	533.75	490.25	538.75	2184.25	621.50	0.879
Art Gallery	92.25	85.00	85.75	89.50	352.50	92.25	0.955
DOR	5.50	12.25	15.00	20.50	53.25	20.50	0.649

4.2.2 Step 2: Peak 15-Minute Flow Rate

The hourly field volume V (PCU/hr) is converted to a peak 15-minute equivalent flow rate v using the PHF. This conversion accounts for the fact that traffic demand within the peak hour is not uniform, and the highest intensity period governs capacity and delay. The flow rate is given by:

$$v = V/PHF$$

For the Maitighar approach:

$$\begin{aligned} v &= 1731.75/0.882 \\ &= 1963.44 PCU/hr \end{aligned}$$

Dividing by a PHF less than 1.0 yields a flow rate higher than the raw hourly count, representing the worst-case demand intensity that the intersection must accommodate. The flow rates, along with the corresponding signal phase and green time, for all approaches are presented in **??**.

4.2.3 Step 3: Saturation Flow Rate

The saturation flow rate (s) represents the maximum number of PCUs that can be discharged from an approach per hour, assuming a continuous green signal. Under ideal

Table 4-3 Peak Flow Rates by Approach

Approach	**V (PCU/hr)**	**PHF**	**v (PCU/hr)**	**Phase**	**Green (s)**	**Cycle (s)**	**g/C**
Maitighar	1731.75	0.882	1963.44	B	80	157	0.5096
Baneshwor	2184.25	0.879	2484.93	B	80	157	0.5096
Art Gallery	352.50	0.955	369.11	C	25	157	0.1592
DOR	53.25	0.649	82.05	D	27	157	0.1720

conditions, a single lane has a base saturation flow rate (s_o) of 1900 PCU/hr/ln. This base value is adjusted for prevailing field conditions using the following expression:

$$s = s_o \times f_w \times f_{HV} \times f_g \times f_a \times f_{LU} \times N$$

where:

- s_o = base saturation flow rate
- f_w = lane width adjustment factor
- f_{HV} = heavy vehicle adjustment factor
- f_g = grade adjustment factor
- f_a = area type adjustment factor
- f_{LU} = lane utilisation factor
- N = number of lanes

4.2.4 Heavy Vehicle Factor (f_{HV})

Among the adjustment factors, the heavy vehicle factor is the most significant for the Maitighar and Baneshwor approaches due to the considerable number of large buses observed, particularly in the service lanes. The factor is computed as:

$$f_{HV} = 1/[1 + P_{HV} \times (E_T - 1)]$$

where:

- P_{HV} = is the proportion of heavy vehicles in the traffic stream
- E_T = passenger car equivalent for heavy vehicles, taken as 2.0

For the Maitighar service lane, 131 out of 689 counted vehicles were big buses (P_{HV} = 0.19), yielding a weighted average f_{HV} = 0.9241 across both lanes combined. The adjustment factor values applied to each approach are summarised in **??**.

Table 4-4 Saturation Flow Rate Adjustment Factors and Results

Approach	N	S_o	f_w	f_{HV}	f_g	f_a	f_{LU}	s (PCU/hr)
Maitighar	2	1900	1.00	0.9241	1.00	0.90	0.95	3002.31
Baneshwor	2	1900	1.00	0.9509	1.00	0.90	0.95	3089.44
Art Gallery	1	1900	1.00	1.0000	1.00	0.90	1.00	1710.00
DOR	1	1900	1.00	1.0000	1.00	0.90	1.00	1710.00

4.2.5 Step 4: Capacity and Degree of Saturation

The effective capacity (c) of each approach lane group is the product of the saturation flow rate and the green ratio (g/C), representing the number of PCUs that can be served per hour given the available green time:

$$c = s \times (g/C)$$

The degree of saturation, or volume-to-capacity ratio (X), is then computed as the ratio of the peak flow rate to the capacity:

$$X = v/c$$

An X value below 1.0 indicates that the approach is operating within capacity. An X value exceeding 1.0 signals oversaturation, meaning vehicles cannot all be discharged within a single cycle, and residual queues accumulate progressively. For the Maitighar approach:

$$\begin{aligned} c &= 3002.31 \times (80/157) \\ &= 1529.84 \text{ PCU/hr} \\ X &= 1963.44/1529.84 \\ &= 1.2834 \end{aligned}$$

The capacity and degree of saturation for all approaches are presented in **??**.

Table 4-5 Capacity and Degree of Saturation by Approach

Approach	s (PCU/hr)	c (PCU/hr)	v (PCU/hr)	v/c Ratio (X)
Maitighar	3002.31	1529.84	1963.44	1.2834
Baneshwor	3089.44	1574.24	2484.93	1.5785
Art Gallery	1710.00	272.29	369.11	1.3556
DOR	1710.00	294.08	82.05	0.2790

4.2.6 Step 5: Control Delay

Control delay per vehicle is the primary performance measure for signalized intersections under the HCM methodology. It comprises three components:

$$d = d_1 + d_2 + d_3$$

4.2.7 Uniform Delay (d_1)

Uniform delay assumes vehicles arrive at a perfectly steady rate throughout the cycle. It is given by:

$$d_1 = [0.5 \times C \times (1 - g/C)^2]/[1 - \min(1, X) \times (g/C)]$$

The term min(1, X) prevents the denominator from becoming negative or zero under oversaturated conditions. For the Maitighar approach:

$$\begin{aligned} d_1 &= [0.5 \times 157 \times (1 - 0.5096)^2]/[1 - \min(1, 1.2834) \times 0.5096] \\ &= 18.88/0.4904 \\ &= 38.50 \text{ sec/veh} \end{aligned}$$

4.2.8 Incremental Delay (d_2)

Incremental delay accounts for the additional waiting caused by random vehicle arrivals and, more critically, by residual overflow queues when demand exceeds capacity. It is expressed as:

$$d_2 = 900T \times [(X - 1) + \sqrt{((X - 1)^2 + (8 \times kIX/cT))}]$$

where:

- T = analysis period duration (0.25 hr for a 15-minute period)
- k = incremental delay factor (0.5 for fixed-time signals)
- I = upstream filtering factor (1.0 for isolated intersections)

For the Maitighar approach:

$$\begin{aligned} d_2 &= 900 \times 0.25 \times [(1.2834 - 1) + \sqrt{((1.2834 - 1)^2 + \frac{(8 \times 0.5 \times 1.0 \times 1.2834)}{(1529.84 \times 0.25))}}] \\ &= 225 \times [0.2834 + \sqrt{(0.0803 + 0.01342)}] \end{aligned}$$

$= 225 \times [0.2834 + 0.3062]$

$= 225 \times 0.5896$

$= 132.66\ sec/veh$

4.2.9 Initial Queue Delay (d_3)

The initial queue delay d_3 accounts for any pre-existing residual queue at the start of the analysis period. Since the analysis begins at the start of the peak hour with no assumed carry-over queue from a prior period, d_3= 0 for all approaches.

4.2.10 Total Control Delay — Maitighar Approach

$$
\begin{aligned}
d &= d_1 + d_2 + d_3 \\
&= 38.50 + 132.66 + 0 \\
&= 171.16\ sec/veh
\end{aligned}
$$

At 171.16 sec/veh, the Maitighar approach operates at Level of Service F, indicating a breakdown condition where demand substantially exceeds the signal's serving capacity, causing progressive queue accumulation across cycles. The complete delay results for all approaches are given in Table X+5.

Table 4-6 Control Delay and Level of Service by Approach

Approach	d_1 sec/veh	d_2 sec/veh	d_3 sec/veh	Total Delay (sec/veh)	LOS
Maitighar	38.50	132.66	0	171.16	F
Baneshwor	38.50	263.41	0	301.91	F
Art Gallery	66.00	182.14	0	248.14	F
DOR	56.53	2.35	0	58.89	E
Intersection Overall	(weighted average)			241.39	F

4.2.11 Step 6: Intersection-Wide Delay and Level of Service

The overall intersection delay is computed as the flow-weighted average of all approach delays, giving proportionally greater weight to approaches carrying higher traffic volumes:

$$d_{intersection} = \frac{\sum(v_i \times d_i)}{\sum v_i}$$

Substituting the values from **??**

$$d_{intersection} = \frac{1963.44 \times 171.16 + 2484.93 \times 301.91 + 369.11 \times 248.14 + 82.05 \times 58.89}{[1963.44 + 2484.93 + 369.11 + 82.05]}$$

$$\begin{aligned} d_{intersection} &= \frac{335,876 + 750,218 + 91,606 + 4,832}{4,899.53} \\ &= 1,182,532/4,899.53 \\ &= 241.39\ sec/veh \end{aligned}$$

4.2.12 Key Observations

The HCM analysis of the existing fixed-time signal control at Babarmahal Intersection reveals a severely deficient operating condition during the morning peak hour. Three out of four approaches — Maitighar (X = 1.2834), Baneshwor (X = 1.5785), and Art Gallery (X = 1.3556) — operate at degrees of saturation well above 1.0, confirming heavily oversaturated conditions where vehicular demand cannot be cleared within a single signal cycle. This results in progressive queue accumulation and excessively high incremental delays, particularly at the Baneshwor approach (d_2 = 263.41 sec/veh) which carries the highest traffic demand.

The Art Gallery approach, despite carrying a relatively modest volume, records a disproportionately high delay of 248.14 sec/veh primarily due to its short allocated green time of 25 seconds — corresponding to a green ratio of only 0.1592. This highlights a significant mismatch between the existing green time distribution and the actual traffic demand across phases.

The DOR approach is the only one operating below capacity (X = 0.279), reflecting its comparatively low traffic demand. Its delay of 58.89 sec/veh at LOS E is attributable primarily to the long red time it experiences within the 157-second cycle rather than to demand-induced overflow.

The intersection-wide control delay of 241.39 sec/veh at LOS F represents a critical breakdown condition, providing a strong quantitative justification for the signal timing optimisation explored in Scenarios 2 and 3 of this study. These HCM-derived values serve as the analytical baseline against which the VISSIM simulation outputs for Scenario 1 are validated.

4.2.13 Comparison of HCM and VISSIM Results for Existing Scenario

The performance of Babarmahal Intersection under the existing fixed-time signal control (Scenario 1) was evaluated using two independent methods: the Highway Capacity Manual (HCM) analytical procedure and PTV VISSIM microsimulation. While both methods assessed the same intersection under identical traffic demand and signal timing conditions, they differ fundamentally in their underlying approach — HCM employs deterministic analytical formulas, whereas VISSIM models individual vehicle behaviour stochastically through microsimulation.

It is also important to note that the two methods report delay using different parameters. HCM reports control delay, which is an analytically computed measure encompassing all signal-induced delay components, including deceleration, stopped time, acceleration, and overflow delay. VISSIM reports queue delay extracted from node results, which captures queuing-related delay from simulated vehicle trajectories. Although both measures serve as indicators of signal performance and are conceptually related, they are not strictly equivalent parameters and therefore cannot be directly compared numerically. Accordingly, this comparison is limited to the Level of Service (LOS) grades derived from each method, as both HCM and VISSIM assign LOS based on the same HCM delay thresholds, making LOS the most appropriate basis for cross-method comparison.

It is further noted that VISSIM reports performance at the individual turning movement level, whereas HCM yields results at the approach level. To facilitate comparison, the movement-level VISSIM delay values were aggregated by approach through a simple arithmetic average to derive an approach-level LOS, as described below.

4.2.14 Aggregation of VISSIM Movement-Level Results

PTV VISSIM reports queue delay for each individual turning movement within the intersection. To derive approach-level LOS values comparable to those from HCM, the movement delays were averaged for each approach and the resulting value was classified against HCM LOS thresholds. The procedure is illustrated using the Maitighar approach as a sample calculation.

Table 4-7 VISSIM Movement-Level Queue Delays — Maitighar Approach (Scenario 1)

Movement	**Queue Delay (sec/veh)**
Maitighar Service → Anamnagar	28.43
Maitighar Service → Babarmahal Service	45.05
Maitighar Main → Art Gallery	139.64
Maitighar Main → Babarmahal Main	51.40

The approach-level average queue delay is computed as:

$$\begin{aligned} AverageDelay &= (28.43 + 45.05 + 139.64 + 51.40)/4 \\ &= 264.52/4 \\ &= 66.13\ sec/veh \end{aligned}$$

Based on **??** HCM LOS thresholds, a delay of 66.13 sec/veh falls within the range of 55–80 sec/veh, corresponding to Level of Service E. The same procedure was applied to the remaining three approaches. The aggregated approach-level VISSIM results are presented in **??**.

Table 4-8 Aggregated VISSIM Approach-Level Queue Delay and LOS — Scenario 1

Approach	**Movements Averaged**	**Avg. Queue Delay (sec/veh)**	**LOS**
Maitighar	4 movements	66.13	E
Babarmahal	4 movements	66.28	E
Art Gallery	5 movements	45.71	D
Anamnagar	3 movements	57.93	E
Overall Intersection	**(VISSIM node result)**	**59.60**	**E**

4.2.15 HCM vs VISSIM — Comparison of Level of Service

?? presents a side-by-side comparison of the Level of Service assigned by HCM and VISSIM for each approach and the overall intersection under the existing signal control scenario. As discussed above, LOS is used as the basis for comparison since it is derived from the same HCM thresholds in both methods, making it the most appropriate common metric.

Table 4-9 Comparison of HCM and VISSIM Level of Service — Existing Scenario (Scenario 1) Approach HCM Control Delay (sec/veh) HCM LOS VISSIM LOS

Approach	**HCM Control Delay (sec/veh)**	**HCM LOS**	**VISSIM LOS**
Maitighar	171.16	F	E
Babarmahal	301.91	F	E
Art Gallery	248.14	F	D
Anamnagar	58.89	E	E
Overall Intersection	**241.39**	**F**	**E**

4.2.16 Discussion

The LOS-based comparison presented in **??** reveals both areas of agreement and divergence between the HCM and VISSIM methods. The following observations are drawn from the comparison:

Methodological Differences in Delay Parameters: As noted earlier, HCM control delay and VISSIM queue delay are related but not equivalent parameters. HCM derives control delay analytically using deterministic formulas that assume idealized lane discipline, uniform vehicle behavior, and standardized saturation flow adjustment factors. VISSIM, on the other hand, measures queue delay empirically from simulated vehicle trajectories, incorporating field-calibrated driver behavior parameters that more realistically reflect the mixed traffic conditions and poor lane discipline characteristic of Kathmandu urban intersections. These methodological differences are the primary reason for the LOS divergence observed across most approaches.

Anamnagar Approach — Agreement: Both HCM and VISSIM assign LOS E to the Anamnagar approach, representing the strongest point of agreement between the two methods. This convergence is expected given that the Anamnagar approach operates well below capacity, where overflow queuing is minimal, and the deterministic HCM formula more closely approximates real conditions simulated by VISSIM.

Qualitative Agreement on Overall Congestion: Despite the LOS differences at individual approaches, both methods consistently identify Babarmahal Intersection as operating under severely congested conditions during the morning peak hour. HCM classifies three approaches at LOS F and one at LOS E, while VISSIM classifies the overall intersection at LOS E. The directional agreement — that the intersection is significantly over-stressed under the existing fixed-time signal plan — validates the general conclusion drawn from both methods and reinforces the need for signal timing optimization.

Basis for Methodology Decision: Given the fundamental differences between HCM control delay and VISSIM queue delay, and the inherent limitations of applying HCM's idealized assumptions to the complex mixed traffic environment of Kathmandu, VISSIM node results are adopted as the primary and consistent source of performance data across all three scenarios in this study. The HCM analysis serves as a supplementary analytical reference that corroborates the qualitative finding of poor intersection performance under the existing signal control.

4.3 Model Development using VISSIM

4.3.1 Network Coding

Here we draw links, connectors and intersection geometry based on field data. Link represents a single or multiple road ways and connectors are used for joining the two links.

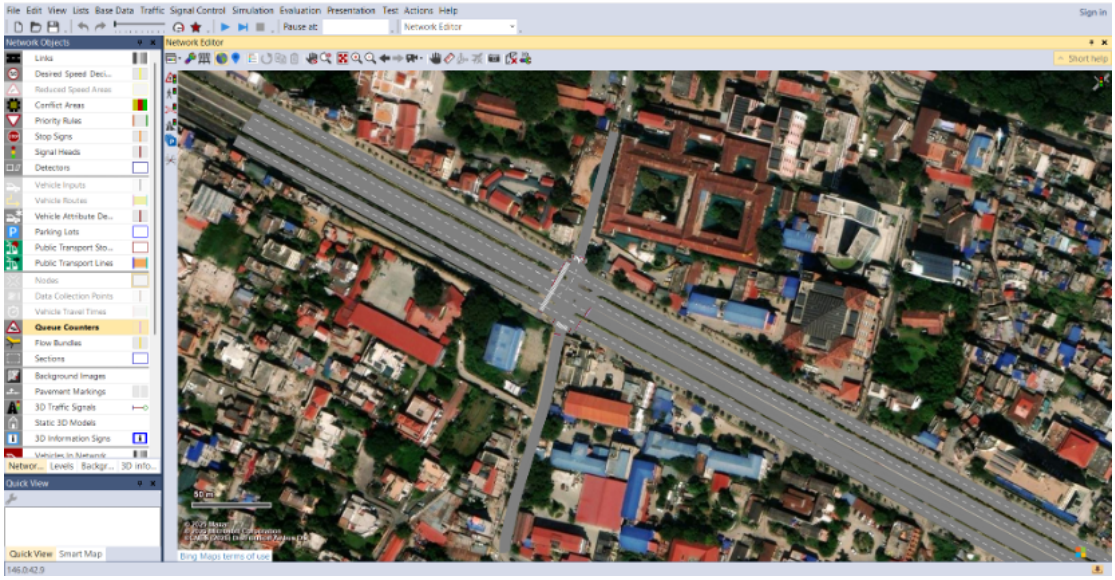


Figure 4-1 Study Area in VISSIM

4.3.2 Vehicle Input and Composition

We performed the manual traffic volume count along with vehicle composition for various approaches for different vehicles classes. By taking speed data of various classes of vehicles, we have done the speed distribution of different vehicle classes. The speed data was extracted from the CCTV footage by dividing the certain distance with time required for that vehicle class to travel that distance. Multiple observations were made and the manual speed data was taken and compared with the one taken from CCTV footage.

Firstly, traffic volume count was entered for various approaches. It was further divided into **4-time** intervals with **15 minutes intervals** each, but while entering in VISSIM we multiply it by 4 since it asks us for **Number of vehicles per hour and not per time interval.**

2D/3D models of various vehicle classes was taken from Sketch-UP and entered into the VISSIM with standard dimensions of the vehicle as Nepal Road Standard(2070).

Then we perform the vehicle composition, where we divide the traffic input into different vehicle classes.

Vehicle Inputs / Vehicle volumes by time interval

Vehicle volumes by

Number: 7	No	Name	Link	Volume(0-900)	Volume(900-1800)	Volume(1800-2700)	Volume(2700-MAX)
1	1		5: Maitighar Service to Intersection	512.0	440.0	636.0	760.0
2	2		18: Maitighar Main to Intersection	1484.0	1536.0	1684.0	1624.0
3	4		16: Babarmahal Service to Intersection	1292.0	1152.0	1384.0	1328.0
4	5		1: Art Gallery to Intersection	964.0	824.0	768.0	736.0
5	7		7: Anamnagar to Intersection	90.0	86.0	78.0	98.0
6	8		25: Babarmahal Main to Maitighar Main	1456.0	1508.0	1484.0	1600.0
7	9		22: Babarmahal Main to Anamnagar	88.0	68.0	56.0	64.0

Figure 4-2 Vehicle Inputs/Vehicle volume by time interval

2D/3D Model Distributions / Elements

Elements

Number: 11	No	Name
1	1	Heavy Truck
2	2	Mini Truck
3	3	Big Bus
4	4	Micro Bus
5	5	Car
6	6	Bike
7	7	Utility Vehicle
8	8	Pickup
9	9	Tempo
10	10	Pedestrian-M
11	11	Pedestrian-F

Number: 1	Share	Model2D3D
1	0.100	302: Heavy Truck

Figure 4-3 2D/3D Model Distributions/Elements

$$Vehicle\ Composition(Bike) = \frac{Traffic\ count\ of\ Bike}{Total\ traffic\ count} \text{(for specific purpose)}$$

Similarly, the vehicle composition was done for each vehicle present in that approach.

4.3.3 Routing Decisions (Turning Movements)

For each vehicle classes it was defined the proportion of vehicles turning left, going through, and turning right at each leg from Static Vehicle Routing Decision/ Static Vehicle Routes.

4.3.4 Driving Behavior Parameters

Setting Wiedemann car-following model parameters and lane change behavior suited to mixed traffic conditions.

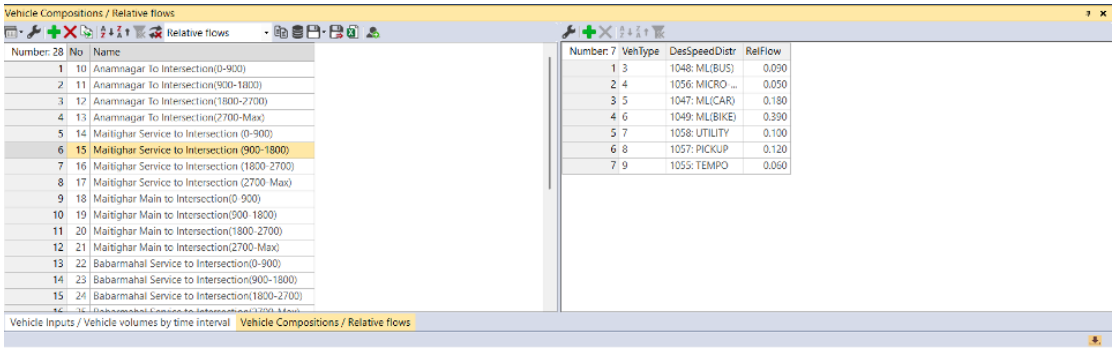


Figure 4-4 Vehicle Composition/ Relative Flow

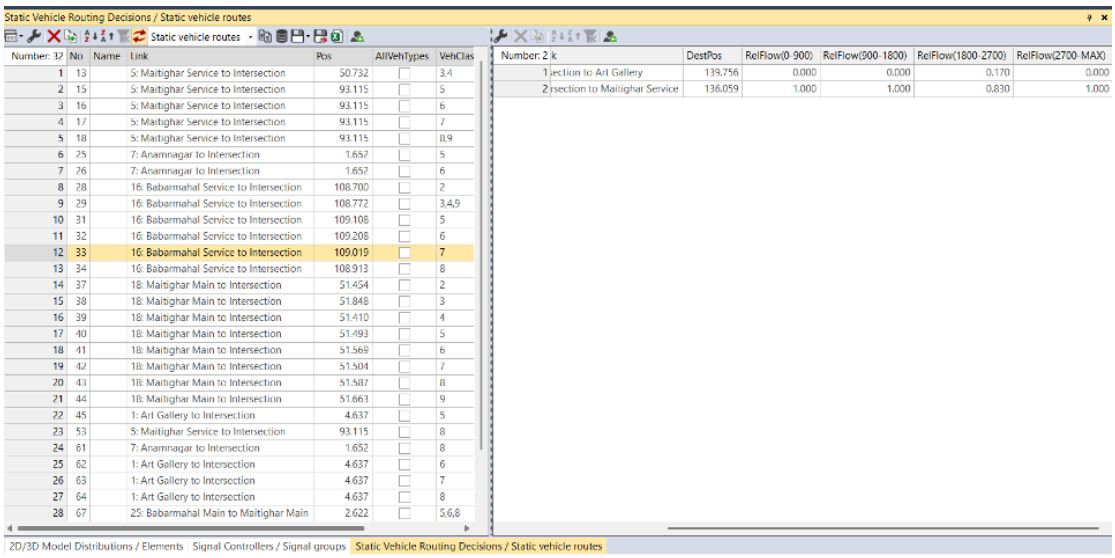


Figure 4-5 Static Vehicles Routing Decisions/ Static vehicles Routes

4.3.5 Signal Controller Setup

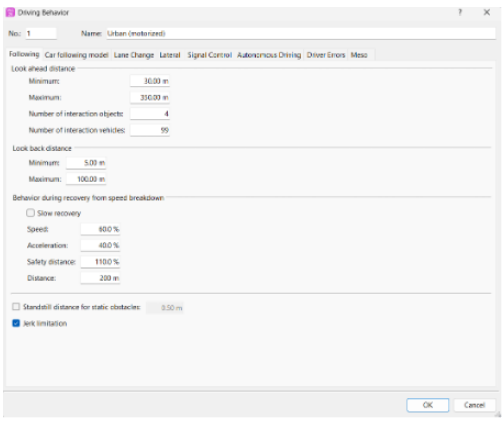
Defining fixed-time signal phases, cycle length, green/amber/red times, and phase sequences.

4.3.6 Conflict Areas and Priority Rules

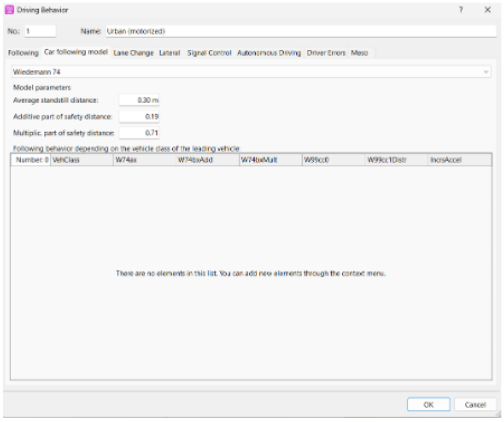
Defining vehicle interaction zones within the intersection. The conflict areas were modelled using passive priority to replicate the non-lane-disciplined and gap-acceptance based driving behavior observed in study area. As the intersection operates under signal control, explicit priority assignment was not needed. The setting of passive conflict zones allowed smoother vehicle interactions and improved simulation stability that closely resembled the real driver behavior in congested urban intersections.

4.3.7 Pedestrian Input

Adding pedestrian crossings and volume if considered in the study.



(a)



(b)

Figure 4-6 Driving Behavior

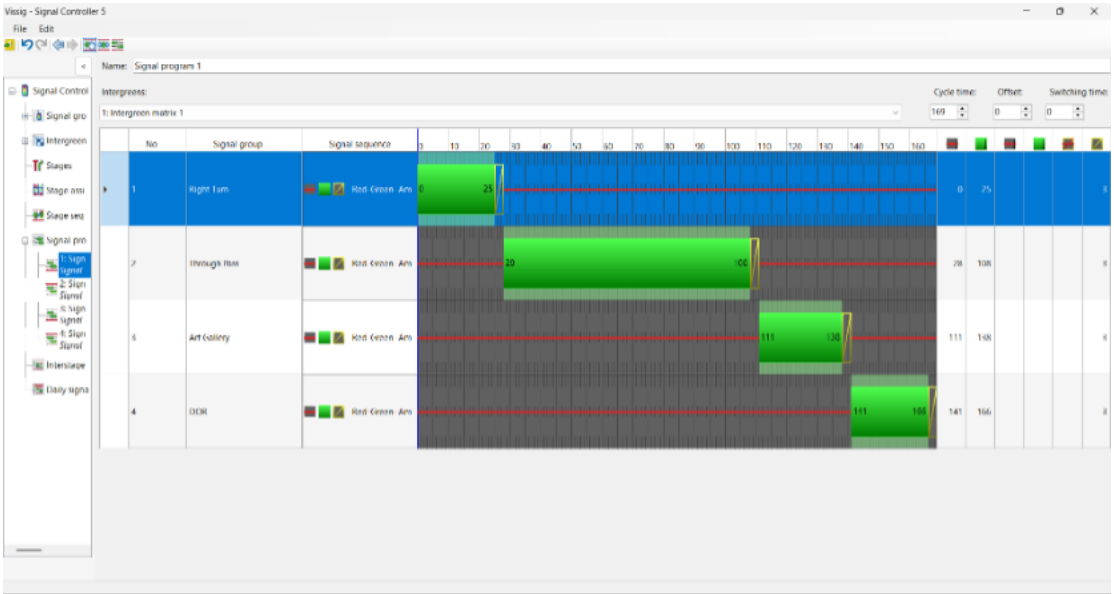
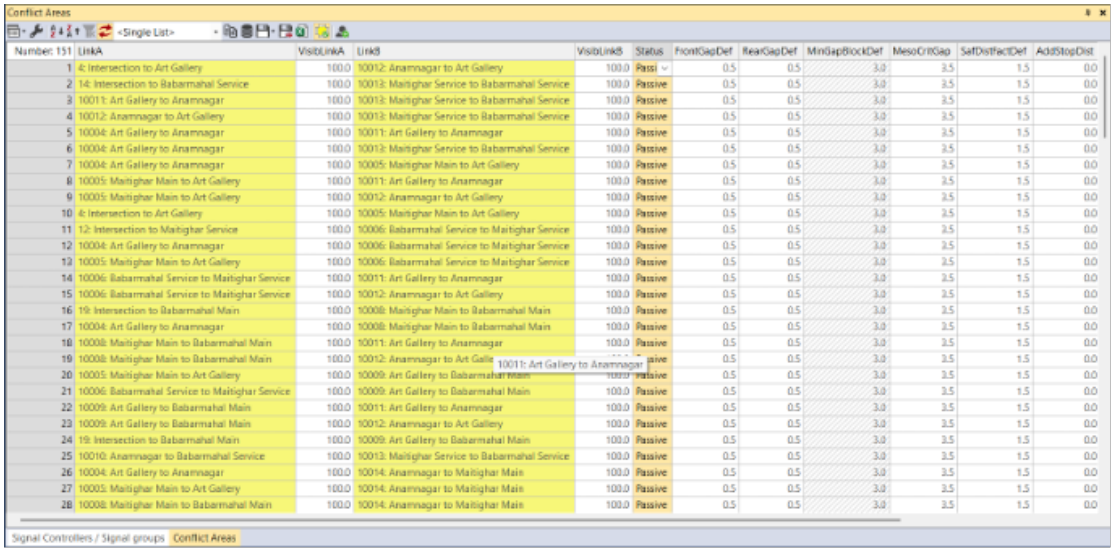


Figure 4-7 Vissig - Signal Controller 5

4.4 Calibration and Validation

The developed VISSIM model was calibrated and validated using the traffic data extracted from the CCTV footage obtained from the District Police Office, Bhadrakali. For the purpose of calibration, traffic volume data collected during **two consecutive days (July 20th and July 21st)** were utilized. The model parameters, including Wiedemann car-following model coefficients and desired speed distributions, were iteratively adjusted until the simulated traffic volumes and queue lengths sufficiently replicated the observed field conditions.

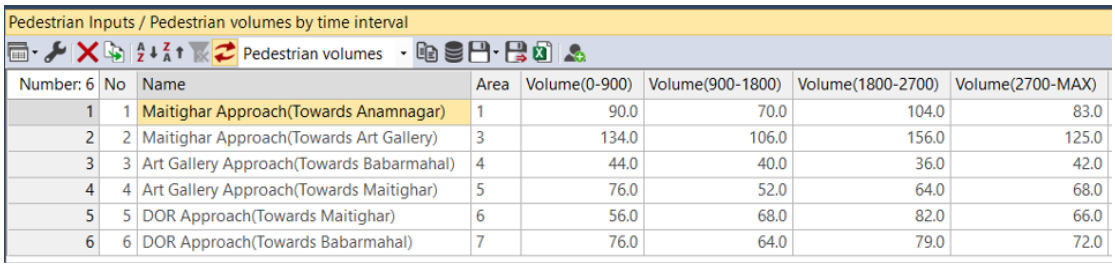
The calibrated model was subsequently validated using the traffic data from the **third day (July 22nd)**, which was kept independent of the calibration process to ensure an unbiased assessment of model performance.



Conflict Areas

Number: 151	LinkA	VisibLinkA	LinkB	VisibLinkB	Status	FrontGapDef	RearGapDef	MinGapBlockDef	MesoCritGap	SafDistFactDef	AddStopDist
1	4: Intersection to Art Gallery	100.0	10012: Anamnagar to Art Gallery	100.0	Passi	0.5	0.5	3.0	3.5	1.5	0.0
2	14: Intersection to Babarmahal Service	100.0	10013: Maitighar Service to Babarmahal Service	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
3	10011: Art Gallery to Anamnagar	100.0	10013: Maitighar Service to Babarmahal Service	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
4	10012: Anamnagar to Art Gallery	100.0	10013: Maitighar Service to Babarmahal Service	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
5	10004: Art Gallery to Anamnagar	100.0	10011: Art Gallery to Anamnagar	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
6	10004: Art Gallery to Anamnagar	100.0	10013: Maitighar Service to Babarmahal Service	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
7	10004: Art Gallery to Anamnagar	100.0	10005: Maitighar Main to Art Gallery	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
8	10005: Maitighar Main to Art Gallery	100.0	10011: Art Gallery to Anamnagar	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
9	10005: Maitighar Main to Art Gallery	100.0	10012: Anamnagar to Art Gallery	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
10	4: Intersection to Art Gallery	100.0	10005: Maitighar Main to Art Gallery	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
11	12: Intersection to Maitighar Service	100.0	10006: Babarmahal Service to Maitighar Service	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
12	10004: Art Gallery to Anamnagar	100.0	10006: Babarmahal Service to Maitighar Service	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
13	10005: Maitighar Main to Art Gallery	100.0	10006: Babarmahal Service to Maitighar Service	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
14	10006: Babarmahal Service to Maitighar Service	100.0	10011: Art Gallery to Anamnagar	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
15	10006: Babarmahal Service to Maitighar Service	100.0	10012: Anamnagar to Art Gallery	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
16	19: Intersection to Babarmahal Main	100.0	10008: Maitighar Main to Babarmahal Main	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
17	10004: Art Gallery to Anamnagar	100.0	10008: Maitighar Main to Babarmahal Main	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
18	10008: Maitighar Main to Babarmahal Main	100.0	10011: Art Gallery to Anamnagar	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
19	10008: Maitighar Main to Babarmahal Main	100.0	10012: Anamnagar to Art Galle	[illegible]	[illegible]	0.5	0.5	3.0	3.5	1.5	0.0
20	10005: Maitighar Main to Art Gallery	100.0	10009: Art Gallery to Babarmahal Main	[illegible]	[illegible]	0.5	0.5	3.0	3.5	1.5	0.0
21	10006: Babarmahal Service to Maitighar Service	100.0	10009: Art Gallery to Babarmahal Main	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
22	10009: Art Gallery to Babarmahal Main	100.0	10011: Art Gallery to Anamnagar	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
23	10009: Art Gallery to Babarmahal Main	100.0	10012: Anamnagar to Art Gallery	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
24	19: Intersection to Babarmahal Main	100.0	10009: Art Gallery to Babarmahal Main	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
25	10010: Anamnagar to Babarmahal Service	100.0	10013: Maitighar Service to Babarmahal Service	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
26	10004: Art Gallery to Anamnagar	100.0	10014: Anamnagar to Maitighar Main	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
27	10005: Maitighar Main to Art Gallery	100.0	10014: Anamnagar to Maitighar Main	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0
28	10008: Maitighar Main to Babarmahal Main	100.0	10014: Anamnagar to Maitighar Main	100.0	Passive	0.5	0.5	3.0	3.5	1.5	0.0

Figure 4-8 Conflict Area



Pedestrian Inputs / Pedestrian volumes by time interval

Number: 6	No	Name	Area	Volume(0-900)	Volume(900-1800)	Volume(1800-2700)	Volume(2700-MAX)
1	1	Maitighar Approach(Towards Anamnagar)	1	90.0	70.0	104.0	83.0
2	2	Maitighar Approach(Towards Art Gallery)	3	134.0	106.0	156.0	125.0
3	3	Art Gallery Approach(Towards Babarmahal)	4	44.0	40.0	36.0	42.0
4	4	Art Gallery Approach(Towards Maitighar)	5	76.0	52.0	64.0	68.0
5	5	DOR Approach(Towards Maitighar)	6	56.0	68.0	82.0	66.0
6	6	DOR Approach(Towards Babarmahal)	7	76.0	64.0	79.0	72.0

Figure 4-9 Pedestrian Inputs

Table 4-10 Calibrated VISSIM Parameters for Mixed Traffic Simulation

S.N	Parameters	Calibrated Values
1	Look ahead distance-min	35 m
2	Look-back distance-min	5.0 m
3	Average standstill distance	0.3 m
4	Additive part of safety distance	0.19
5	Multiplicative part of safety distance	0.70
6	Min. headway (front/rear)	0.50 m
7	General Behavior	Free lane selection
8	Desired Position at Free Flow	Any

4.4.1 Volume

Calculation of GEH value: The GEH statistic is calculated using the formula:

$$GEH = \sqrt{\frac{2(V_s - V_o)^2}{V_s + V_o}} \tag{4-1}$$

Where:

- V_s = Simulated volume (from VISSIM)
- V_o = Observed volume (from field data)

Acceptance Criteria:

- $GEH < 5.0 \rightarrow$ Good fit
- GEH 5.0 – 10.0 $\rightarrow$ Acceptable (investigate further)
- $GEH > 10.0 \rightarrow$ Poor fit (recalibrate)

Table 4-11 Observed Field Count Data for Different Vehicle Classes and Movements: Peak Hour Day 1

S.N.	Movement (From To)	Vehicle Classification – Software Simulation Data									
		Heavy Truck	Mini Truck	Bus	Micro Bus	Car	Bike	LUV	Pick up	Tempo	Vehs ALL
1	Art Gallery to Anamnagar	0	0	0	0	40	151	0	0	0	191
2	Art Gallery to Maitighar Service	0	0	0	0	7	200	0	0	0	207
3	Art Gallery to Babarmahal Service	0	0	0	0	47	253	1	0	0	301
4	Art Gallery to Babarmahal Main	0	0	0	0	25	118	2	0	0	145
5	Art Gallery to Maitighar Main	0	0	0	0	8	46	0	0	0	54
6	Maitighar Service to Anamnagar	0	0	0	0	9	18	5	0	0	32
7	Maitighar Service to Babarmahal Service	0	0	136	33	178	391	42	0	49	829
8	Anamnagar to Art Gallery	0	0	0	0	14	58	0	0	0	72
9	Anamnagar to Babarmahal Service	0	0	0	0	18	51	3	1	0	73
10	Anamnagar to Maitighar Main	0	0	0	0	2	2	0	0	0	4
11	Babarmahal Service to Art Gallery	0	0	0	0	90	254	0	0	7	351
12	Babarmahal Service to Maitighar Service	0	11	138	37	186	830	7	2	28	1239
13	Maitighar Main to Art Gallery	0	0	0	0	30	159	1	0	0	190
14	Maitighar Main to Babarmahal Main	0	0	0	0	336	1585	28	0	6	1955
15	Babarmahal Main to Anamnagar	0	0	6	5	191	499	0	0	0	701
16	Babarmahal Main to Maitighar Main	0	0	0	9	221	1596	0	10	0	1836

Table 4-12 Observed Field Count Data for Different Vehicle Classes and Movements: Peak Hour Day 2

S.N.	Movement (From to To)	Vehicle Classification — Observed Field Count Data									
		Heavy Truck	Mini Truck	Bus	Micro Bus	Car	Bike	LUV	Pick up	Tempo	Vehs ALL
1	Art Gallery to Anamnagar	0	0	0	0	46	168	0	0	0	214
2	Art Gallery to Maitighar Service	0	0	0	0	17	220	2	0	0	239
3	Art Gallery to Babarmahal Service	0	0	0	0	62	253	3	4	0	322
4	Art Gallery to Babarmahal Main	0	0	0	0	33	122	2	1	0	158
5	Art Gallery to Maitighar Main	0	0	0	0	12	47	0	0	0	59
6	Maitighar Service to Anamnagar	0	0	0	0	12	20	3	0	0	35
7	Maitighar Service to Babarmahal Service	0	0	138	45	168	403	34	0	50	838
8	Anamnagar to Art Gallery	0	0	0	0	10	57	1	0	0	68
9	Anamnagar to Babarmahal Service	0	0	0	0	16	53	3	0	0	72
10	Anamnagar to Maitighar Main	0	0	0	0	3	1	1	0	0	5
11	Babarmahal Service to Art Gallery	0	0	0	0	96	272	0	2	5	375
12	Babarmahal Service to Maitighar Service	0	2	147	51	205	883	3	2	13	1306
13	Maitighar Main to Art Gallery	0	0	0	0	29	149	2	0	0	180
14	Maitighar Main to Babarmahal Main	0	1	4	9	401	1579	54	5	7	2060
15	Babarmahal Main to Anamnagar	1	0	7	3	197	559	0	3	0	770
16	Babarmahal Main to Maitighar Main	2	2	5	11	266	1604	10	8	0	1908

Table 4-13 Observed Field Count Data for Different Vehicle Classes and Movements: Peak Hour Day 3

S.N.	Movement (From to To)	Vehicle Classification — Software Simulation Data									
		Heavy Truck	Mini Truck	Bus	Micro Bus	Car	Bike	LUV	Pick up	Tempo	Vehs ALL
1	Art Gallery to Anamnagar	–	–	–	–	2.887	1.380	–	–	–	2.143
2	Art Gallery to Maitighar Service	–	–	–	–	2.887	1.380	–	–	–	2.143
3	Art Gallery to Babarmahal Service	–	–	–	–	2.032	0.000	1.414	2.828	–	1.190
4	Art Gallery to Babarmahal Main	–	–	–	–	1.486	0.365	0.000	1.414	–	1.056
5	Art Gallery to Maitighar Main	–	–	–	–	1.265	0.147	–	–	–	0.665
6	Maitighar Service to Anamnagar	–	–	–	–	0.926	0.459	1.000	–	–	0.518
7	Maitighar Service to Babarmahal Service	–	–	0.171	1.921	0.760	0.602	1.298	–	0.142	0.312
8	Anamnagar to Art Gallery	–	–	–	–	1.155	0.132	–	–	–	0.478
9	Anamnagar to Babarmahal Service	–	–	–	–	0.485	0.277	–	–	–	0.117
10	Anamnagar to Maitighar Main	–	–	–	–	0.632	0.817	–	–	–	0.471
11	Babarmahal Service to Art Gallery	–	–	–	–	0.622	1.110	–	2.000	0.817	1.260
12	Babarmahal Service to Maitighar Service	–	3.530	0.754	2.111	1.359	1.811	1.789	0.000	3.313	1.878
13	Maitighar Main to Art Gallery	–	–	–	–	0.184	0.806	0.817	–	–	0.735
14	Maitighar Main to Babarmahal Main	–	1.414	2.828	4.243	3.386	0.151	4.061	3.162	0.392	2.344
15	Babarmahal Main to Anamnagar	–	–	0.392	1.000	0.431	2.609	–	2.450	–	2.544
16	Babarmahal Main to Maitighar Main	–	2.000	3.162	0.632	2.884	0.200	4.472	0.667	–	1.664

REGRESSION ANALYSIS: R-squared value after calibration was found to be 0.954902, which indicated that 95.49% of the variance of the field data is explained by the variance of the VISSIM output. The regression equation for this calibration:

Expected Traffic Volume(VISSIM)= 0.954902* Actual VISSIM Volume

The obtained expected traffic volume was then compared with the traffic volume obtained after a simulation was performed on VISSIM.

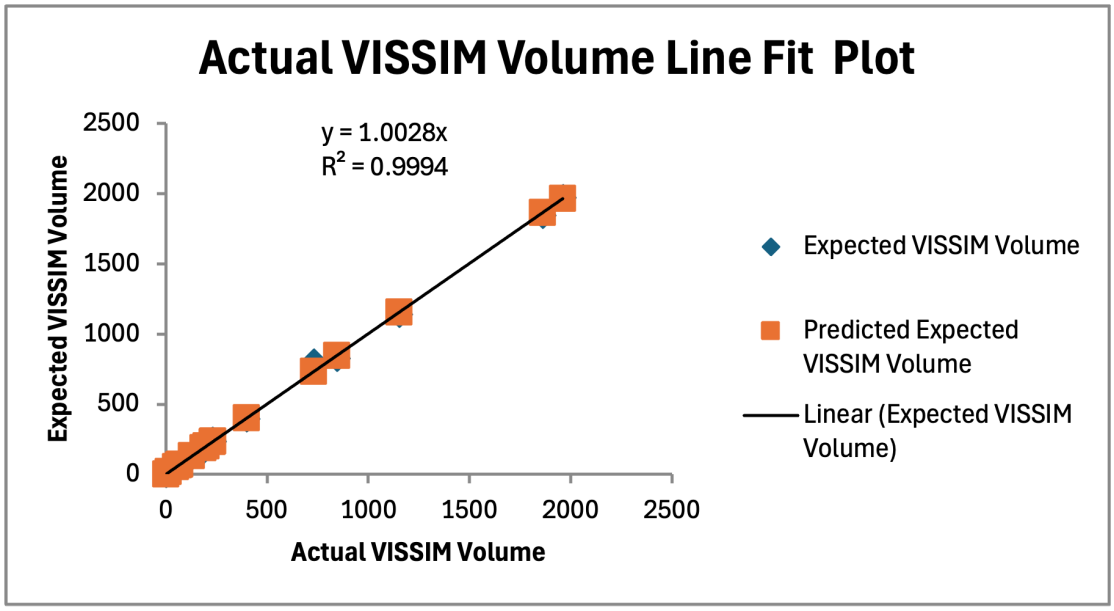


Figure 4-10 Actual VISSIM Volume Line Fit Plot

The value of R^2 being close to 1 indicates that 2 days data validates the 3rd-day data. Hence, the calibration and validation were successfully performed.

Off Peak Hour

Table 4-14 Observed Field Count Data for Different Vehicle Classes and Movements: Off-Peak Hour Day 1

S.N.	Movement (From to To)	Vehicle Classification — Software Simulation Data									
		Heavy Truck	Mini Truck	Bus	Micro Bus	Car	Bike	LUV	Pick up	Tempo	Vehs ALL
1	Art Gallery to Anamnagar	0	0	0	0	38	76	5	0	0	119
2	Art Gallery to Maitighar Service	0	3	0	0	27	108	2	2	0	142
3	Art Gallery to Babarmahal Service	0	3	0	0	68	194	0	0	0	265
4	Art Gallery to Babarmahal Main	0	0	0	0	38	118	4	2	0	162
5	Art Gallery to Maitighar Main	0	0	0	0	38	51	2	2	0	93
6	Maitighar Service to Anamnagar	0	0	0	0	8	12	4	0	0	24
7	Maitighar Service to Babarmahal Service	0	0	124	40	147	239	26	41	57	674
8	Anamnagar to Art Gallery	0	0	0	0	16	38	1	2	0	57
9	Anamnagar to Babarmahal Service	0	0	0	0	22	31	2	0	0	55
10	Anamnagar to Maitighar Main	0	0	0	0	9	28	0	0	0	37
11	Babarmahal Service to Art Gallery	0	0	0	0	49	138	4	0	0	191
12	Babarmahal Service to Maitighar Service	0	0	114	30	183	639	23	21	20	1030
13	Maitighar Main to Art Gallery	0	0	0	0	33	135	9	7	0	184
14	Maitighar Main to Babarmahal Main	0	1	0	6	198	1312	61	72	0	1649
15	Babarmahal Main to Anamnagar	0	0	6	0	14	42	0	0	0	62
16	Babarmahal Main to Maitighar Main	0	9	0	6	228	1248	9	11	0	1511

Table 4-15 Observed Field Count Data for Different Vehicle Classes and Movements: Off-Peak Hour Day 2

S.N.	**Movement (From to To)**	**Vehicle Classification — Software Simulation Data**									
		Heavy Truck	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Vehs ALL**
S.N.	Movement (From to To)	Heavy Truck	Mini Truck	Bus	Micro-Bus	Car	Bike	L.V	Pickup	Tempo	Vehs (ALL)
1	Art Gallery to Anamnagar	0	1	0	0	35	90	4	2	0	132
2	Art Gallery to Maitighar Service	0	2	0	0	42	110	3	2	0	159
3	Art Gallery to Babarmahal Service	0	3	0	0	77	196	2	2	0	280
4	Art Gallery to Babarmahal Main	0	2	0	0	52	120	2	3	0	179
5	Art Gallery to Maitighar Main	0	2	0	0	37	56	3	1	0	99
6	Maitighar Service to Anamnagar	0	0	0	0	9	15	4	0	0	28
7	Maitighar Service to Babarmahal Service	0	0	116	41	91	309	34	29	41	661
8	Anamnagar to Art Gallery	0	0	0	0	12	39	1	1	0	53
9	Anamnagar to Babarmahal Service	0	0	0	0	17	33	1	1	0	52
10	Anamnagar to Maitighar Main	0	0	0	0	9	28	0	0	0	37
11	Babarmahal Service to Art Gallery	0	0	0	0	62	133	4	1	0	200
12	Babarmahal Service to Maitighar Service	0	1	108	38	177	661	23	16	31	1055
13	Maitighar Main to Art Gallery	0	0	0	0	25	132	4	7	0	168
14	Maitighar Main to Babarmahal Main	0	1	0	11	231	1375	53	72	0	1743
15	Babarmahal Main to Anamnagar	0	0	5	0	21	39	1	1	0	67
16	Babarmahal Main to Maitighar Main	0	5	0	2	233	1318	19	11	0	1588

Table 4-16 Observed Field Count Data for Different Vehicle Classes and Movements: Off-Peak Hour Day 3

S.N.	Movement (From to To)	Vehicle Classification — Software Simulation Data									
		Heavy Truck	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Vehs ALL**
1	Art Gallery to Anamnagar	–	–	–	–	0.497	1.537	0.471	2.000	–	1.160
2	Art Gallery to Maitighar Service	–	–	–	–	2.554	0.192	–	–	–	1.386
3	Art Gallery to Babarmahal Service	–	–	–	–	1.057	0.143	2.000	2.000	–	0.909
4	Art Gallery to Babarmahal Main	–	–	–	–	2.087	0.183	1.155	0.632	–	1.302
5	Art Gallery to Maitighar Main	–	–	–	–	0.163	0.684	–	–	–	0.612
6	Maitighar Service to Anamnagar	–	–	–	–	0.343	0.816	0.000	–	–	0.784
7	Maitighar Service to Babarmahal Service	–	–	0.730	0.157	5.134	4.229	1.461	–	2.286	0.503
8	Anamnagar to Art Gallery	–	–	–	–	1.069	0.161	–	–	–	0.539
9	Anamnagar to Babarmahal Service	–	–	–	–	1.132	0.354	–	–	–	0.410
10	Anamnagar to Maitighar Main	–	–	–	–	0.000	0.000	–	–	–	0.000
11	Babarmahal Service to Art Gallery	–	–	–	–	1.745	0.430	–	1.414	–	0.644
12	Babarmahal Service to Maitighar Service	–	1.414	0.569	1.372	0.447	0.863	0.000	1.162	2.178	0.774
13	Maitighar Main to Art Gallery	–	–	–	–	1.486	0.260	1.961	–	–	1.206
14	Maitighar Main to Babarmahal Main	–	1.414	–	1.715	2.253	1.719	1.060	0.000	–	2.283
15	Babarmahal Main to Anamnagar	–	–	0.426	–	1.673	0.471	–	1.414	–	0.623
16	Babarmahal Main to Maitighar Main	–	1.512	–	2.000	0.329	1.954	2.673	0.000	–	1.956

REGRESSION ANALYSIS: R-squared value after calibration was found to be 0.953183, which indicated that 95.31% of the variance of the field data is explained by the variance of the VISSIM output. The regression equation for this calibration:

Expected Traffic Volume(VISSIM)= 0.95383* Actual VISSIM Volume

The obtained expected traffic volume was then compared with the traffic volume obtained after a simulation was performed on VISSIM.

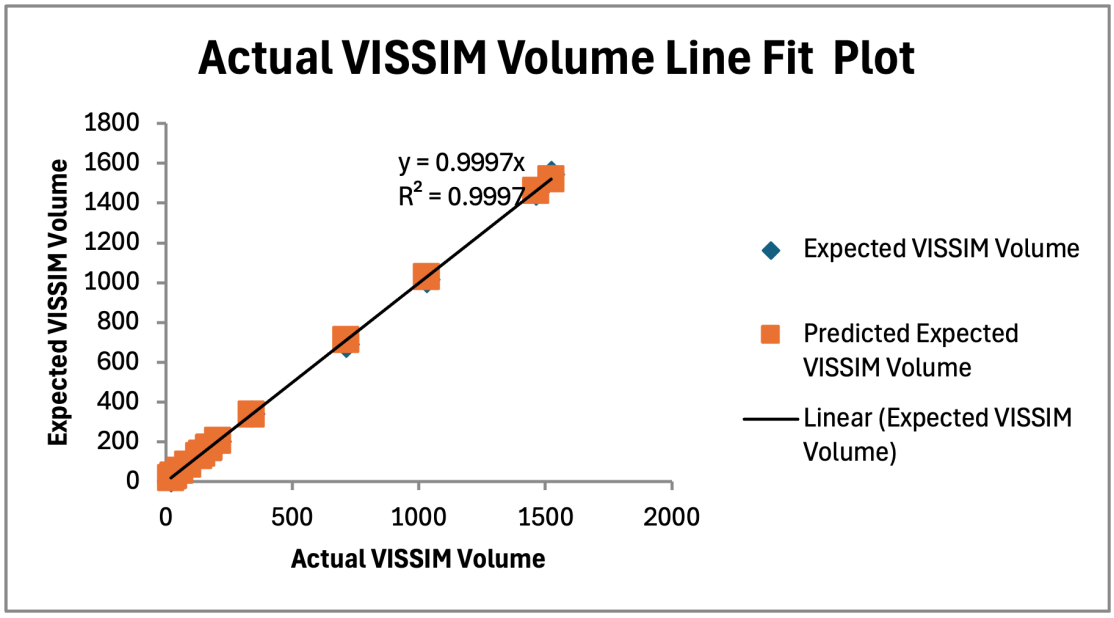


Figure 4-11 Actual VISSIM Volume Line Fit Plot

The value of R^2 being close to 1 indicates that 2 days data validates the 3rd-day data. Hence, the calibration and validation were successfully performed.

4.4.2 Queue Length

Queue length validation was performed by comparing the simulated queue lengths extracted from the calibrated VISSIM model against the observed queue lengths measured from the field. Observed queue lengths were obtained by manually tracking the maximum queue formed on each approach during successive signal cycles throughout the peak hour period of 9:30 AM to 10:30 AM. The corresponding simulated queue lengths were extracted from the VISSIM queue counter evaluation outputs placed on each approach link. The percentage difference between the observed and simulated values was computed for each approach, and the model was considered validated where the difference remained within the acceptable threshold of $plusminus20\%$, consistent with standard microsimulation practice. The results confirmed that the calibrated model adequately reproduced field queue conditions, establishing its suitability for scenario-based analysis.

Peak Hour

Table 4-17 Peak Hour

Link	Queue Observed (m)	Queue From VISSIM (m)	Error (%)
Art Gallery to Intersection	32	38.42	20.0625
Babarmahal Service to Intersection	23	19.88	-13.56522
Anamnagar to Intersection	4.5	5.4	20
Maitighar Service to Intersection	22	18.74	-14.81818
Maitighar Main to Intersection	25	27.19	8.76
Babarmahal Main to Anamnagar	186	155.46	-16.41935
Babarmahal Main to Maitighar Main	38	42.28	11.263158

Off Peak Hour

Table 4-18 Off-Peak Hour

Link	Queue Observed (m)	Queue From VISSIM (m)	Error (%)
Art Gallery to Intersection	43	52.82	22.8372093
Babarmahal Service to Intersection	16.8	19.56	16.42857143
Anamnagar to Intersection	5	4.44	-11.2
Maitighar Service to Intersection	14.8	17.11	15.60810811
Maitighar Main to Intersection	25	24.66	-1.36
Babarmahal Main to Anamnagar	25	24.66	-1.36
Babarmahal Main to Maitighar Main	3	3.63	21

4.5 Performance Comparison and Scenario Development.

This section presents a comparative evaluation of the three fixed-time signal control scenarios developed and simulated in PTV VISSIM for the Babarmahal Intersection. The three scenarios are:

- Scenario 1 — Existing Fixed-Time Signal Control (baseline)
- Scenario 2 — VISSIM Built-in Optimized Fixed-Time Control
- Scenario 3 — Manually Optimized Fixed-Time Control

Performance is evaluated across four measures: queue delay (sec/veh), Level of Service (LOS), queue length (m), and vehicle travel time (sec). All results were extracted from VISSIM node evaluation outputs following a simulation duration of 3600 seconds.

Since VISSIM reports results at the individual turning movement level, movement-level values were aggregated by approach through a simple arithmetic average to enable consistent approach-level comparison across all scenarios. The signal timing parameters applied in each scenario are summarised in Table X. Of the three scenarios, Scenario 3 — Manually Optimized Fixed-Time Control — required the most involved development process. Using the VISSIM built-in optimized timing of Scenario 2 (A = 48 s, B = 51 s, C = 51 s, D = 7 s) as the starting reference, green time was iteratively adjusted in increments of 2 to 5 seconds by redistributing time from over-served phases to under-served ones while keeping the total cycle length constant. After each adjustment, the simulation was re-run, and the resulting queue delay, queue length, and vehicle travel time were evaluated to determine whether the change yielded an improvement. This hit-and-trial process was repeated across multiple iterations until no further reduction in overall intersection queue delay could be achieved without worsening another approach, arriving at the final timing plan of A = 28 s, B = 62 s, C = 33 s, and D = 10 s on a 133-second cycle.

4.5.1 Queue Delay

Queue delay represents the average additional time a vehicle spends waiting due to signal control, including deceleration, stopped time, and acceleration phases. Table X+1 presents the approach-level average queue delay for all three scenarios.

Table 4-19 Approach-Level Average Queue Delay by Scenario (sec/veh)

Approach	**Scenario 1 (sec/veh)**	**Scenario 2 (sec/veh)**	**Scenario 3 (sec/veh)**
Art Gallery	45.71	50.82	54.28
Maitighar	66.13	65.86	47.71
Anamnagar	57.93	58.59	46.11
Babarmahal	66.28	73.28	46.00
Overall Intersection	**59.60**	**64.16**	**43.73**

The results indicate that Scenario 3 yields the lowest queue delay across all approaches and at the overall intersection level, with an intersection-wide average of 43.73 sec/veh compared to 59.60 sec/veh for Scenario 1 and 64.16 sec/veh for Scenario 2. Notably, Scenario 2 (VISSIM built-in optimized) produces a higher overall delay than the existing Scenario 1, suggesting that the automated optimization may have redistributed green time in a manner that benefits certain movements at the expense of others. Scenario 3, through manual refinement of the VISSIM-optimized timing, achieves a more balanced distribution of green time, resulting in reduced delays across all four approaches.

4.5.2 Level of Service (LOS)

Level of Service (LOS) is a qualitative measure of intersection performance derived from queue delay values using HCM thresholds. Table X+2 presents the approach-level LOS for all three scenarios based on the aggregated queue delay values.

Table 4-20 Approach-Level Level of Service by Scenario

Approach	Scenario 1 LOS	Scenario 2 LOS	Scenario 3 LOS
Art Gallery	D	D	D
Maitighar	E	E	D
Anamnagar	E	E	D
Babarmahal	E	E	D
Overall Intersection	**E**	**E**	**D**

Scenario 3 records the shortest queue lengths at the Maitighar (20.08 m), Anamnagar (5.15 m), and Babarmahal (34.36 m) approaches, as well as the lowest overall average queue length of 24.95 m. This represents a reduction of approximately 28% compared to Scenario 1 (34.87 m) and 35% compared to Scenario 2 (38.38 m) at the intersection level. The exception is the Art Gallery approach, where Scenario 3 records a marginally higher queue length (26.24 m) compared to Scenario 1 (20.63 m), which may be attributed to the slightly increased green time allocated to competing phases under the manual optimization. Scenario 2 consistently produces longer queues than Scenario 1 across three out of four approaches, further reinforcing that the VISSIM built-in optimization does not yield an overall improvement over existing conditions for this intersection.

4.5.3 Queue Length

Queue length reflects the spatial extent of vehicle queuing at each approach during the simulation period. Average queue lengths by approach for all three scenarios are presented in **??**

Table 4-21 Approach-Level Average Queue Length by Scenario (m)

Approach	Scenario 1 (m)	Scenario 2 (m)	Scenario 3 (m)
Art Gallery	20.63	23.56	26.24
Maitighar	29.42	29.71	20.08
Anamnagar	7.22	7.50	5.15
Babarmahal	52.47	59.39	34.36
Overall Intersection	**34.87**	**38.38**	**24.95**

4.5.4 Vehicle Travel Time

Vehicle travel time represents the average time taken by vehicles to traverse the intersection from entry to exit, encompassing both waiting time and travel through

the signal-controlled area. Approach-level average travel times are presented in Table X+4.

Table 4-22 Approach-Level Average Vehicle Travel Time by Scenario (sec)

Approach	**Scenario 1 (sec)**	**Scenario 2 (sec)**	**Scenario 3 (sec)**
Art Gallery	58.89	44.23	66.86
Maitighar	85.05	83.24	66.72
Anamnagar	77.33	70.19	67.92
Babarmahal	73.47	81.23	59.26
Overall Intersection	**72.15**	**67.56**	**65.10**

Scenario 3 achieves the lowest overall intersection travel time of 65.10 seconds, compared to 72.15 seconds for Scenario 1 and 67.56 seconds for Scenario 2. At the approach level, Scenario 3 records the shortest travel times for the Maitighar (66.72 sec), Anamnagar (67.92 sec), and Babarmahal (59.26 sec) approaches. The Art Gallery approach is an exception, where Scenario 2 yields the lowest travel time (44.23 sec) and Scenario 3 the highest (66.86 sec). This is consistent with the queue length observation for Art Gallery, suggesting that the manual optimization reallocated green time away from this approach in favour of the higher-volume Maitighar and Babarmahal approaches, resulting in a trade-off at Art Gallery.

4.5.5 Overall Performance Summary

Table X+5 presents a consolidated summary of all four performance measures at the overall intersection level across the three scenarios.

The consolidated results consistently identify Scenario 3 — manually optimized fixed-time control — as the best-performing scenario across the majority of performance measures and approaches. It achieves the lowest overall queue delay (43.73 sec/veh), the best overall LOS (D), and the shortest overall queue length (24.95 m) and vehicle travel time (65.10 sec) at the intersection level. These improvements are attributed to the iterative manual refinement of signal timing that builds on the VISSIM-optimized values of Scenario 2, allowing the analyst to fine-tune green time distribution in a way that better reflects the actual demand patterns observed at the Babarmahal Intersection.

Scenario 2, despite employing an automated optimization algorithm, does not outperform the existing Scenario 1 in terms of overall queue delay and queue length. This highlights a key limitation of automated optimization tools — they optimize for a specific objective function that may not fully capture the complexity of mixed traffic behaviors at urban intersections in the Kathmandu context. The manual optimization in Scenario 3 addresses this limitation by incorporating engineering judgement informed by the simulation outputs, resulting in a more effective and balanced signal timing plan.

4.6 Comparison and Recommendations.

Based on the performance evaluation presented in the preceding sections, this section draws a consolidated comparison across the three fixed-time signal control scenarios and provides a recommendation for the most effective signal timing strategy for the Babarmahal Intersection.

4.6.1 Consolidated Performance Comparison

?? summarizes the overall intersection-level performance of all three scenarios across the four evaluation parameters.

Table 4-23 Consolidated Overall Intersection Performance — All Scenarios

Performance Measure	**Scenario1 (Existing)**	**Scenario2 (VISSIM Optimized)**	**Scenario3 (Manual Optimized)**
Queue Delay (sec/veh)	59.60	64.16	43.73
Level of Service	E	E	D
Queue Length (m)	34.87	38.38	24.95
Vehicle Travel Time (sec)	72.15	67.56	65.10

4.6.2 Comparison

Across all four performance measures at the overall intersection level, Scenario 3 consistently records the best values — the lowest queue delay (43.73 sec/veh), the highest LOS grade (D), the shortest queue length (24.95 m), and the lowest vehicle travel time (65.10 sec). Scenarios 1 and 2 both operate at LOS E overall, with Scenario 2 performing worse than the existing Scenario 1 in terms of queue delay and queue length despite incorporating automated signal optimization. This outcome underscores that the VISSIM built-in optimization, while useful as a reference, does not inherently guarantee an improvement over existing conditions when applied to the complex mixed-traffic environment of the Babarmahal Intersection.

The only notable exception across all approach-level results is the Art Gallery approach, where Scenario 3 records a higher queue length and travel time compared to Scenarios 1 and 2. This is a deliberate trade-off resulting from the real location of green time towards the higher-demand Maitighar and Babarmahal approaches in the manual optimization, and does not diminish the overall superiority of Scenario 3 at the intersection level.

4.6.3 Recommendations

Based on the comparative analysis, the following recommendations are made for signal timing at the Babarmahal Intersection:

1. **Adoption of Manually Optimized Fixed-Time Signal Timing (Scenario 3):** Scenario 3 is recommended as the most effective fixed-time signal timing strategy for the Babarmahal Intersection during peak hours. With a phase plan of A = 28 s, B = 62 s, C = 33 s, and D = 10 s on a 133-second cycle, it achieves the best overall intersection performance across all four evaluation parameters and represents a practical, implementable improvement over the existing signal plan.
2. **Caution Against Direct Adoption of Automated Optimization Outputs:** Scenario 2 demonstrates that the outputs of automated signal optimization tools should not be adopted directly without engineering review. In this case, the VISSIM built-in optimization produced a timing plan that increased overall queue delay and queue length relative to the existing condition. The manual optimization in Scenario 3, which used Scenario 2 as a starting reference and refined it through iterative adjustment, yielded substantially better results. It is therefore recommended that automated optimization outputs always be treated as a reference rather than a final solution.
3. **Further Investigation Using Semi-Actuated Control:** While Scenario 3 offers a meaningful improvement over existing fixed-time control, fixed-time signal plans are inherently limited in their ability to respond to real-time fluctuations in traffic demand. The application of the VISVAP-programmed semi-actuated signal control, which is evaluated separately for off-peak conditions in this study, warrants further investigation as a strategy for improving intersection performance across varying demand periods.

4.7 Semi Actuated Control

Semi-actuated control is a practical traffic management strategy designed specifically for intersections where a heavily traveled major street crosses a minor street with much lighter traffic. In these situations, the main goal is to keep traffic flowing smoothly on the major street while still allowing minor street traffic to proceed when needed. To achieve this, the major street is given priority and holds the green light by default. The right-of-way is only transferred to the minor street when a vehicle needs to cross or merge onto the major street and cannot find a safe gap in traffic. Because the major street automatically receives the green light, there is no need to install detectors (sensors) on it. Instead, detection equipment is placed only on the minor street approaches to monitor incoming traffic. This approach is both cost-effective and efficient, as it focuses monitoring resources where they are actually needed.

Semi-actuated control works best under specific traffic conditions. It is ideal when there is a clear difference in traffic volume between the two intersecting roads. If an intersection has two roads of similar importance and traffic levels, a fully-actuated system would be better. However, when there is a significant difference in traffic volume,

semi-actuated control prevents the unnecessary delays that fixed-time systems often create on busy major streets.

Semi-actuated control is efficient because it keeps the green light on the major street most of the time. This means fewer stops for drivers on the busy road. The system is also simple to use. Drivers on the minor street just stop at the line and wait. When the sensor detects them, the controller transfers the green light to let them cross. This way, minor street traffic is never completely stuck, and the major road still gets priority. The system also costs less to install and maintain because it only needs sensors on the minor street, not on the major street (Ni, 2020).

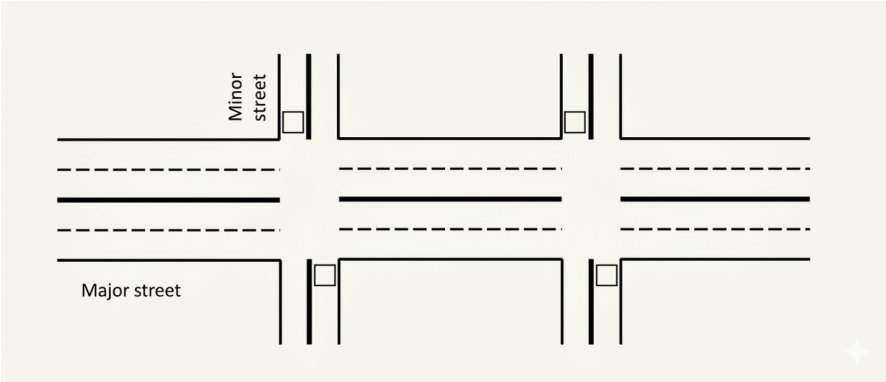


Figure 4-12 Application scenario of Semi-Actuated

4.8 Working Mechanism of Semi-Actuated Control

When the side street receives a green light, it is guaranteed a minimum amount of time to remain green. If no vehicles are waiting or present after this minimum time, the light simply stays green for that duration and then changes back to the main road. This natural and safe transition is called a "Gap Out." However, if vehicles are still present after the minimum time, the sensor detects them. For every new vehicle that passes over the sensor, the system adds a small amount of extra time, called "Passage Time," to allow it through. This process continues until the arrival of vehicles stops, and none arrive within that passage time window. At that point, the light safely "Gaps Out" to return control to the main road. If a large queue of vehicles accumulates on the side street, they could potentially extend the green light indefinitely, causing traffic congestion on the busy main road. To prevent this, the system enforces an absolute time limit called "Maximum Green." Once this limit is reached, the system abruptly terminates the side street signal and forces the light to change. This forced termination is called a "Max Out. "If a ‘Max Out’ occurs and leaves a vehicle trapped beyond the sensor, the system creates an ‘artificial call’ to remember that vehicle. This ensures the signal returns to the side street as soon as possible, allowing the stranded vehicle to proceed safely and effectively (Ni, 2020)

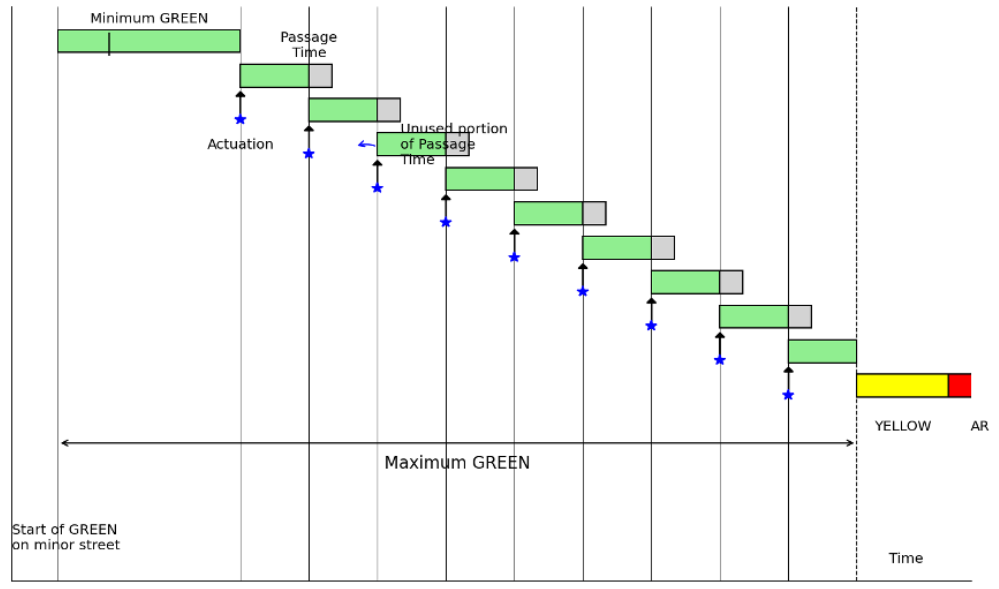


Figure 4-13 Working Principle of Semi-Actuated signal control

4.9 Basic Timing Parameters in Actuated Control

In Semi-Actuated Traffic Signal Control (SATSC), signal timings are dynamically adjusted based on vehicle detection. However, several fundamental timing parameters must first be calculated to ensure proper operation of the signal system. These include the minimum green time, extension time (unit extension), passage time, maximum green time, and cycle length. These parameters ensure that queues are cleared efficiently while maintaining flexibility for varying traffic demand (Duraku & Boshnjaku, 2024).

4.9.1 Minimum Green Time (G_{min})

The minimum green time represents the shortest duration for which a signal phase remains green once activated. This parameter ensures that vehicles queued at the stop line have enough time to begin moving and pass through the intersection. It also accounts for the start-up lost time caused by driver reaction and vehicle acceleration (Duraku & Boshnjaku, 2024).

The minimum green time is mathematically related to the detector placement and queue length. It is calculated using Equation (**??**):

$$G_{min} = T_L + [h * \text{Integer}(d/x)] \tag{4-2}$$

where:

- Gmin = Minimum green time (seconds)

- TL = Start-up time loss (typically 2.0 – 4.0 seconds)
- h = Saturation headway (seconds/vehicle)
- d = Distance between detector and stop line (m)
- x = Average spacing between stored vehicles (typically 6–7 m)

The integer function represents the number of vehicles stored between the detector and the stop line, which determines the minimum time required for queue clearance.

4.9.2 Extension Time or Unit Extension (U)

The extension unit (U) represents the additional time added to the green interval when a vehicle is detected during the green phase. This allows the signal to remain green as long as vehicles continue arriving within a specified time gap. According to the Traffic Detector Manual, the recommended extension time is (Duraku & Boshnjaku, 2024):

- 3.0 seconds for approach speeds ≤ 45 km/h
- 3.5 seconds for higher speeds

4.9.3 Passage Time (P)

Passage time is the travel time required for a vehicle to move from the detector location to the stop line. It is calculated using Equation (**??**):

$$P = \frac{d}{1.47 \times S_{15}} \tag{4-3}$$

where:

- P = Passage time (seconds)
- d = Distance between detector and stop line (ft)
- S_{15} = 15th percentile approach speed of vehicles (mph)

To ensure proper operation, the condition U ≥ P must be satisfied, ensuring the green phase remains active long enough for the approaching vehicle to reach the stop line.

4.9.4 Maximum Green Time (G_{max})

The maximum green time defines the upper limit for a green phase, preventing excessive delay for conflicting movements. The effective green time (g_i) for each phase is distributed proportionally based on traffic demand using Equation (**??**):

$$g_i = (C_i - L) \times \frac{V_{C_i}}{V_C} \tag{4-4}$$

Where:

- g_i = Effective green time for phase i (s)
- C_i = Cycle length (s)
- L = Total lost time in the cycle (s)
- V_{C_i} = Traffic volume in the critical lane for phase i (pcu/h)
- VC = Sum of volumes in all critical lanes (pcu/h)

4.9.5 Critical Cycle Length (C_c)

The critical cycle length is the total time for all phases to complete one sequence when the side street reaches Gmax. It is calculated using Equation (**??**)

$$C_c = \sum (G_i + Y_i) \tag{4-5}$$

where:

- C_c = Critical cycle length (seconds)
- G_i = Maximum green time for phase i
- Y_i = Yellow plus all-red interval for phase

4.9.6 Calculation of Parameters:

To demonstrate the application of signal timing parameters for the Babarmahal intersection, detailed VisVAP calculations are performed for the off-peak condition. The calculations follow the HCM methodology and incorporate sustainability principles for enhancing signal controller flexibility.

The total cycle length was set at 169 seconds, matching the current timing at the intersection and confirmed through field measurements. Following the HCM (2022) guidelines, the start-up lost time was taken as 2 seconds. The saturation headway was also set at 2 seconds, referencing the work of Duraku and Boshnjaku (2024). Additionally, yellow change intervals were set to 3 seconds to ensure intersection clearance safety.

For vehicle detection, inductive loop detectors with dimensions of 1.8m x 5m were used. These were placed approximately 2m from the stop line based on calculations for the distance ahead. The approach speed for the minor road (DOR approach) was calculated at 10 km/h, and vehicle spacing was set between 6 and 7m based on field observations.

Multiple simulations and observations showed that the minimum green time assigned was enough to clear all vehicles and satisfy passage time conditions. Since the traffic

volume on the minor road was low, providing a unit extension only led to wasted green time. Therefore, no extension time was included in the final control logic.

Input Parameters:

The following parameters have been assumed based on field observations and HCM guidelines:

- Total Cycle Length (C) = 169 seconds
- Start-up Time Loss (T_L) = 2.0 seconds
- Saturation Headway (h) = 2.0 seconds/vehicle
- Distance from Detector to Stop Line (d) = 2.0 meters
- Vehicle Spacing (x) = 6 to 7 meters
- Approach Speed (S) of minor road= 10 km/h

Minimum Green Time (G_{min}) Calculation

Using Equation (**??**)

$$
\begin{aligned}
G_{min} &= T_L + [h \times \text{Integer}(d/x)] \\
G_{min} &= 2.0 + [2.0 \times \text{Integer}(2.0/6.5)] \\
G_{min} &= 2.0 + [2.0 \times 0] \\
G_{min} &= 2.0\text{seconds (minimum)}
\end{aligned}
$$

However, based on FHWA recommendations for off-peak operations, the applied minimum green time is:

$$G_{min} = 4 \text{ seconds}$$

Passage Time (P) and Unit Extension (U) Calculation

Using Equation (**??**):

$$
\begin{aligned}
P &= d/(1.47 \times S) \\
P &= 2.0/(1.47 \times 10) = 2.0/14.7 \\
P &= 0.136 \text{ seconds}
\end{aligned}
$$

Unit Extension (U) Selection

No extension time was included in the final control logic.

Maxmimum Green Time (G_{max}) Calculation

Critical Traffic volume data for all phases is converted to Passenger Car Units (pcu/h) as follows, according to the HCM protocols:

Phase	**Volume in 15 mins**	**Factor**	V_{C_i} **(pcu/h)**
Phase 1	24.5	4	98
Phase 2	250.75	4	1003
Phase 3	46	4	184
Phase 4	6.68	4	26.72

Total Critical Movement (VC):

$$\begin{aligned} V_C &= 98 + 1003 + 184 + 26.72 \\ &= 1311.72 \text{ pcu/h} \end{aligned}$$

Using Equation (**??**), the effective green time for Phase 4 is calculated:

$$\begin{aligned} g_i &= (C_i - L) \times (V_{C_i}/V_C) \\ g_i &= (169 - 4) \times (26.72/1311.72) \\ g_i &= 165 \times 0.02037 \\ g_i &= 3.36 \text{ seconds} \end{aligned}$$

Cycle-by-Cycle Adjustment

According to principles for enhancing controller flexibility to accommodate larger demands and enable cycle-by-cycle adjustments, the calculated green time is multiplied by an adjustment factor of 1.5:

$$g_i(\text{adjusted}) = 1.5 \times 3.36 = 5.04\text{seconds}$$

Hence, we adopted 5sec Maximum Green Time for minor roads.

4.10 Vehicle Actuated Programming

Vehicle Actuated Programming (VAP) is a capability within PTV Vissim that enables signal control strategies to be triggered based on the detection and actuation of vehicles, allowing the software to replicate programmable, actuated traffic signal operations. The control logic, stored in a .VAP file, is developed using the VisVAP (Visual VAP) tool, which allows users to design and represent the underlying signal control logic through a flowchart-based programming interface. Alongside this, an Interstage file (.pua) is also generated, which holds the VAP signal data. This interstage definition file specifies the signal groups, intergreen times, individual signal stages, and the interstage transitions. It is manually created and then imported into the VISSIM environment.

VisVAP enhances the use of freely definable signal control logics using the VAP language (Vehicle Actuated Programming) in offering a comfortable tool for creating and editing program logics as flow charts. The appearance and design of flow charts in VisVAP is similar to RiLSA 2010 (German de-facto law for signal controls) and has been enhanced to facilitate loops and other features. VisVAP can be used for both stage-based and signal group-oriented design.

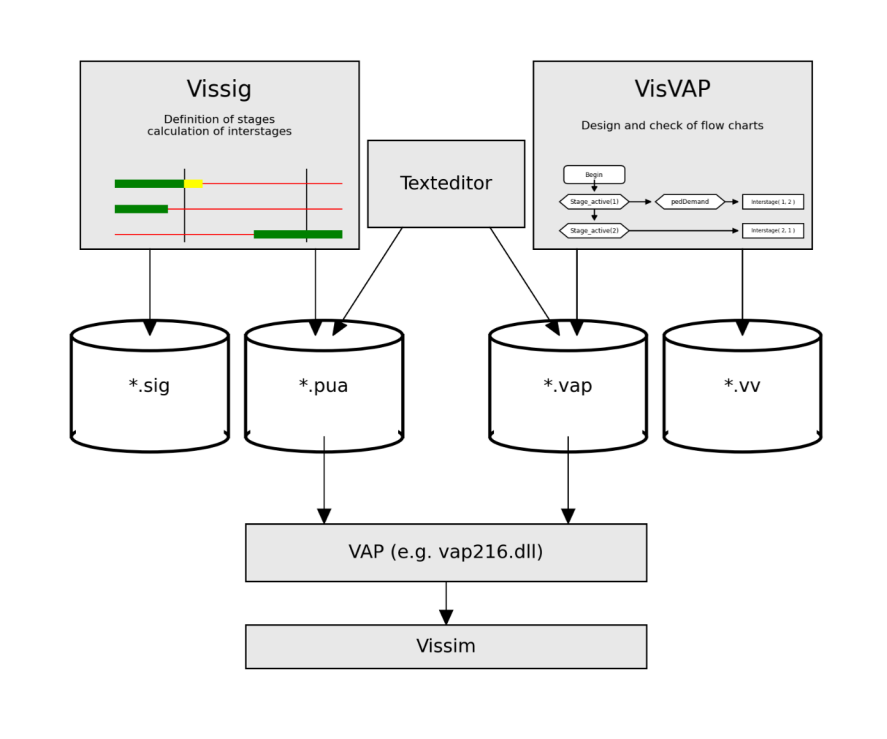


Figure 4-14 VisVAP Flowchart

Table 4-24 (PTV Planung Transport Verkehr AG, Karlsruhe, Germany)

Vap Functions	**Meaning**
Interstage(<stage1>, <stage2>)	Runs an interstage
Interstage_active(<stage1>, stage2>)	Returns 1 if any interstage is active, otherwise 0.
Start_at(<timer>, <value>)	Starts the timer <timer> with starting value <value>. The first timer increment will take place in the next simulation second.
Interstage_duration(<stage1>, <stage2>)	Returns the current second of the interstage or 0 in case the interstage is not active.
Interstage_length(<stage1>, <stage2>)	Returns length of interstage
Occup_rate(<no>)	Returns smoothened occupancy rate of detector <no> [0..1]
Occupancy(<no>)	Returns the elapsed time since detector <no> has been activated or 0 if no vehicle is present at end of time step.
P_interstage(<no>, <sec>)	Calls the interstage <no>, starting in its second <sec> (usually 0)
P_interstage_active(<no>)	Returns 1 if interstage <no> is active, otherwise 0

4.11 Model Developed According to SATSC Strategy

The Vehicle Actuated Programming (VAP) signal control has been applied to design the signal plan at this four-legged intersection. After setting up the necessary elements in the PTV Vissim interface, including lanes and connectors, vehicle volumes, traffic light configuration, and links, the block diagram logic was then implemented using the VisVAP tool. This intersection consists of four signal groups. Three of these signal groups operate as fixed signal groups, meaning their timing remains constant regardless of traffic conditions. These are:

SG1 - Right turn movement from the main lane

SG2 - Through movement of the main lane

SG3 - Art Gallery approach

SG4 - DoR approach

The fourth signal group, SG4, is assigned to the DoR approach and operates as a vehicle-actuated signal group. A detector is placed on this approach to sense the presence of incoming vehicles. When a vehicle is detected, it triggers the actuation of SG4, allowing the signal to respond dynamically to real-time traffic demand on that leg of the intersection.

This is the core application of VAP in this model, where the signal controller activates the DoR approach phase only when a vehicle is detected, thereby optimizing signal efficiency.

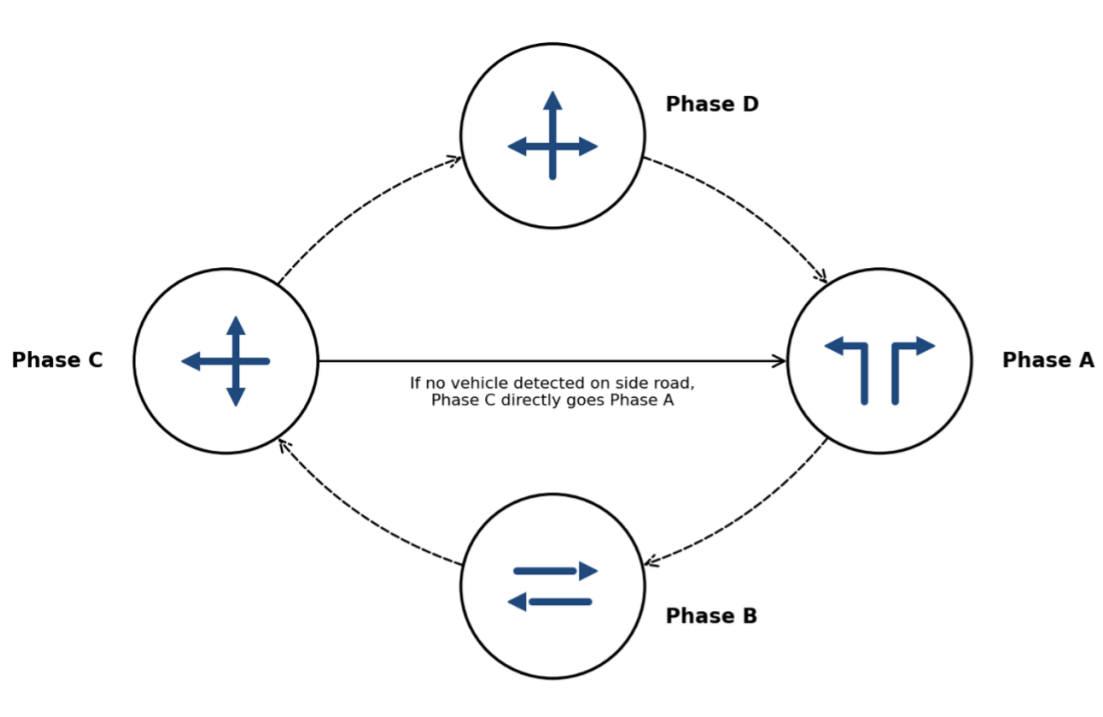


Figure 4-15 Block Diagram

The block diagram defining this control logic has been saved as a *.vap file, while the signal phases and interstage definitions have been exported as a *.pua file. Alongside the simulation model, analytical calculations have also been performed to validate the signal design at this intersection.

The logic files (*.pua and *.vap) are then imported to the Vissim model in the signal control menu. The signal controller window in Vissim is as shown in Figure **??**

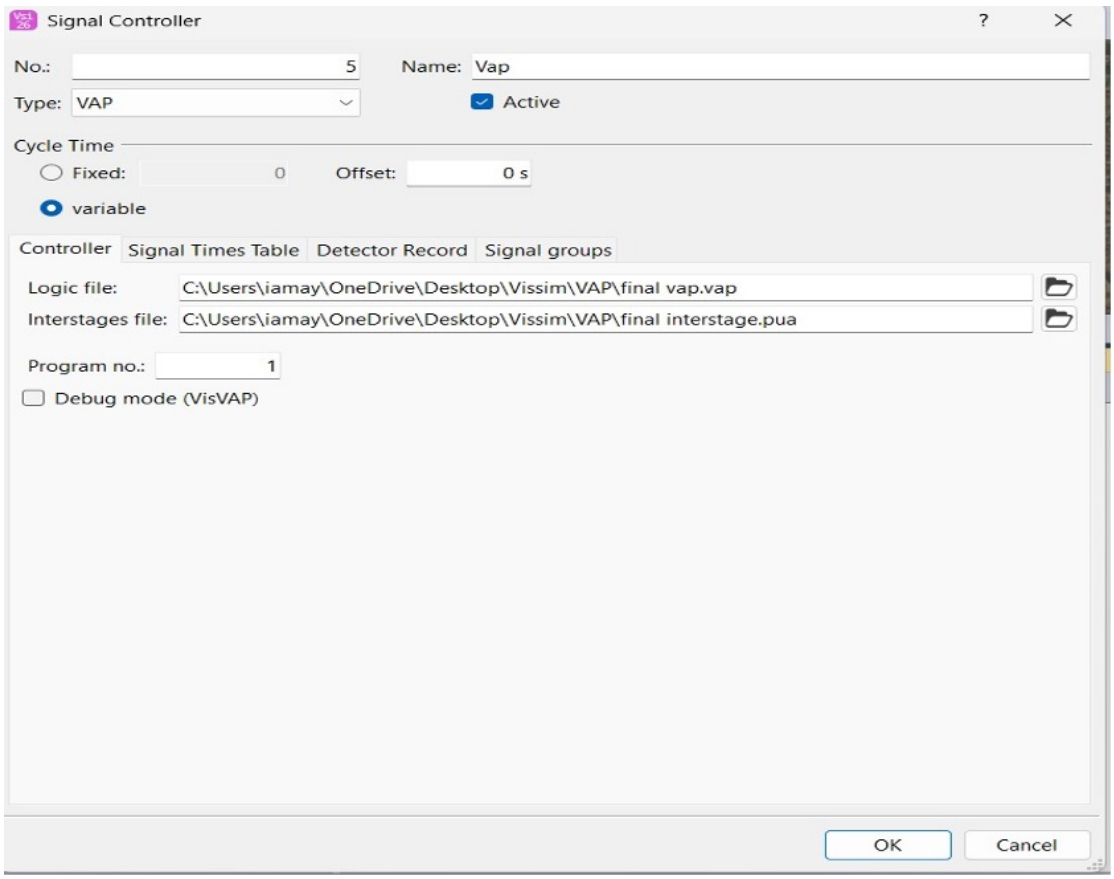


Figure 4-16 Signal controller Window

The inductive loop detector, with dimensions of **1.8 × 5 m,** has been positioned at an optimal distance of approximately d = 2 m from the stop line on the DoR approach, determined through distance-ahead calculations. The proposed vehicle speed on the DoR approach is set at **S = 40 km/h**, and the unit extension duration is set as **U = 3 seconds**, which is greater than the passage time **P = 0.57 seconds** from the detector to the stop line, in accordance with standard recommendations. The cycle duration C at the Babar Mahal Intersection varies dynamically depending on the traffic demand on the DoR approach. When no vehicles are present on the DoR approach, only the three fixed signal groups (SG1, SG2, and SG3) are activated, and the minimum cycle is set to Cmin = 64seconds. The time that would have been allocated to the DoR approach is directly transferred to the main road fixed phases, maximizing their operational efficiency.

When vehicles are detected on the DoR approach, the full signal cycle is activated, engaging all four signal groups, including the actuated SG4, with the cycle duration Cmax = 72 seconds, accommodating traffic demand from all approaches of the intersection. The signal plans of the SATSC strategy are shown in Figure **??**

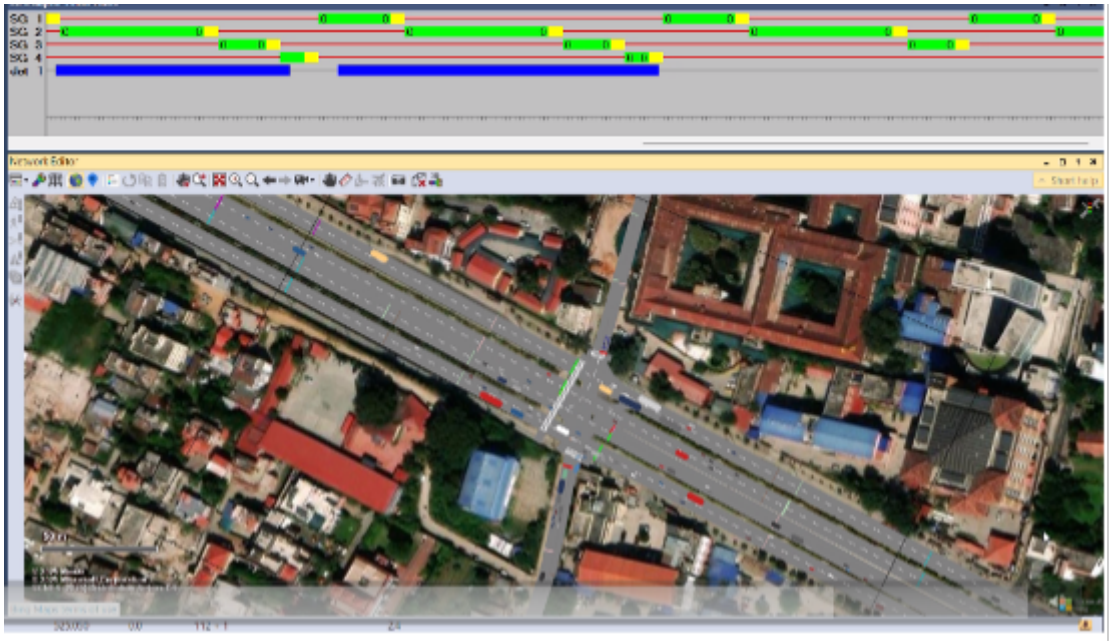


Figure 4-17 Signal plans for SATSC

4.12 Logic Design Controls

The VAP control logic for the Babar Mahal Intersection was implemented in VisVAP as a flowchart governing four signal groups, where SG1, SG2, and SG3 operate as fixed signal groups, and SG4 operates as a vehicle-actuated group on the DoR approach.

Initialization: The program starts by evaluating Init = 0. When true, TimerMain is started, and the flag is set to Init:= 1, ensuring initialization occurs only once.

Stage 1 to Stage 2: When Stage_active(1) AND TimerMain ≥ 15, the controller triggers Interstage(1,2) and resets TimerMain to zero, transitioning from the main lane through movement to the right turn phase.

Stage 2 to Stage 3: When Stage_active(2) AND TimerMain ≥ (15 + Interstage_length(1,2)), the controller triggers Interstage(2,3), transitioning to the Art Gallery approach phase.

Stage 3 to Stage 4 (Actuated): When Detection(1) AND TimerMain ≥ Interstage_length(2,3) AND Stage_active(3), indicating vehicle presence on the DoR approach, Interstage(3,4) is triggered, activating SG4. TimerSub starts, and TimerMain stops.

Stage 4 to Stage 1: When TimerSub ≥ Interstage_length(3,4) AND Stage_active(4), the controller triggers Interstage(4,1), returning to Stage 1, restarting TimerMain and stopping TimerSub.

No Detection case: When Stage_active(3) AND TimerMain ≥ Interstage_length(2,3) with no vehicle detected, Stage 4 is bypassed, and Interstage(3,1) is triggered directly, maintaining the minimum cycle of Cmin = 64 seconds with only the three fixed signal groups active.

5 RESULTS AND DISCUSSION

A set of performance indicators is employed to assess the operational quality of a signalized intersection, with queue lengths, delays, vehicle travel time, and LOS being primary measures. These indicators are interrelated as output parameters.

5.1 Queue length as a performance Indicator

Queue lengths refer to the number of vehicles waiting behind the stop line during a red signal phase, and delays represent the time vehicles spend in the queue. Common indicators include average queue length and average delays, expressed numerically or as percentages. The queue length ratio is calculated by dividing the average queue length (q_i) by its maximum value (Q_{max}), as defined in Equation:

$$Queuelengthratio = \frac{1}{n}\sum_{i=1}^{n}\frac{q_i}{Q_{max}}$$

5.1.1 Peak Hour Analysis

The figure displays the queue length comparison across three scenarios for various traffic routes and intersections.

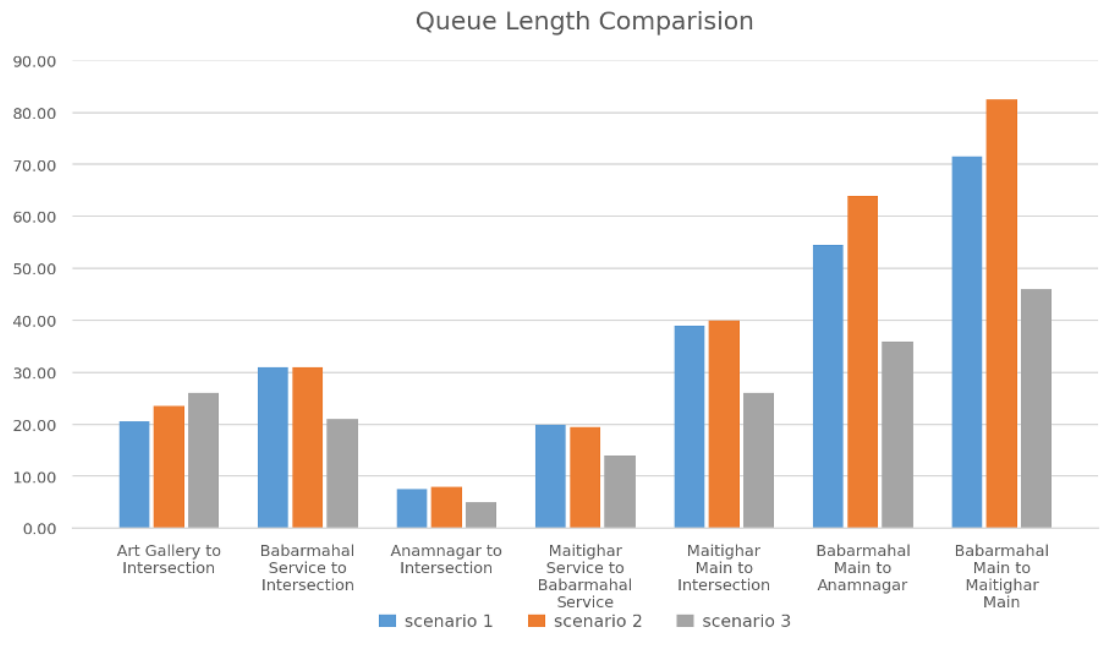


Figure 5-1 Queue length - Peak Hour

The peak hour queue length comparison reveals the same overarching trend observed during off-peak hours. Scenario 2 either maintained or worsened queuing relative to the baseline, while Scenario 3 consistently delivered the lowest queue lengths across all

movements. The Babarmahal Main to Maitighar Main movement dominates with the highest absolute values of 71.52 m, 82.87 m, and 46.00 m across Scenarios 1, 2, and 3, respectively, where Scenario 2 worsened queuing by approximately 15.9 % before Scenario 3 achieved a reduction of 35.7% from the baseline. Babarmahal Main to Anamnagar follows closely with values of 54.86 m, 64.52 m, and 35.77 m, reflecting the same pattern of Scenario 2 amplifying the West approach queuing before Scenario 3 brought it under control with a 34.8% reduction. The Maitighar Main to Intersection movement recorded values of 39.54 m, 40.26 m, and 26.43 m, with Scenario 3 reducing queue length by approximately 33.2% from the baseline. For the lighter movements, Art Gallery to Intersection, Babarmahal Service to Intersection, Anamnagar to Intersection, and Maitighar Service to Babarmahal Service queue lengths remain comparatively low across all scenarios, yet Scenario 3 still achieves the lowest values in each case, confirming that even during off-peak conditions, the manually optimized timing plan produces genuine and consistent reductions in queue accumulation across all approaches of the Babarmahal Intersection.

5.1.2 Off-Peak Hour Analysis

The table displays the queue length comparison across three scenarios for various traffic routes and intersections.

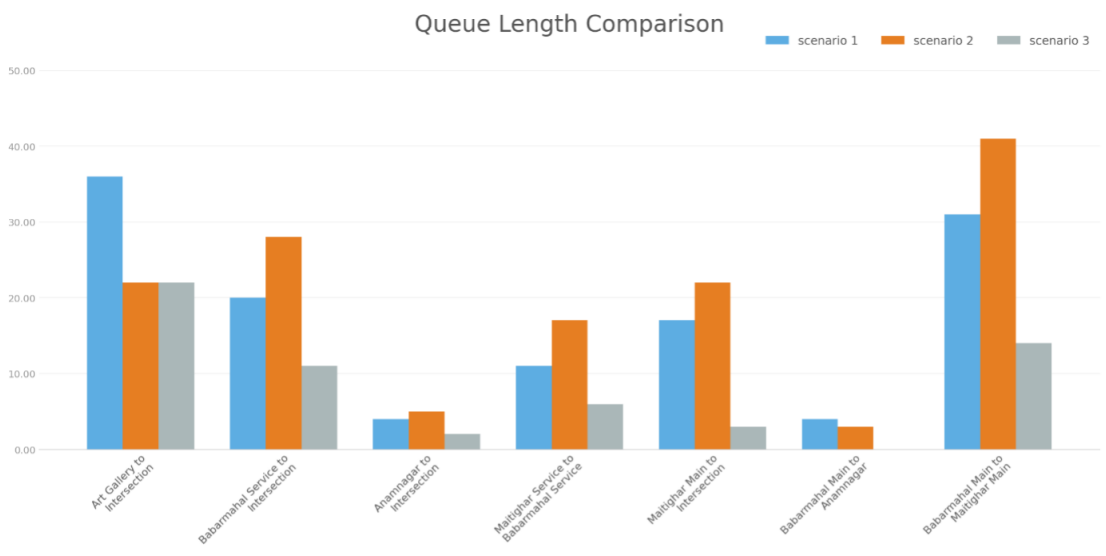


Figure 5-2 Queue Length Off-Peak Hour

The most telling indicator is the overall intersection queue length, which moves from 17.52 m (S1) -19.81 m (S2) -8.33 m (S3). This reveals that Scenario 2 actually worsened overall queue length compared to the baseline, while Scenario 3 achieved a remarkable 52.5% reduction from the baseline, the most significant system-wide improvement.

Maitighar Main to Intersection movement stands out as the most striking improvement across all scenarios. Starting at a queue length of 17.14 m in Scenario 1, it worsened to 22.11 m in Scenario 2, indicating that early interventions provided no relief for this approach. However, in Scenario 3, the queue length dropped dramatically to 2.72 m, a reduction of approximately 84% from the baseline.

5.2 Queue Delay as a Performance Indicator

Delay refers to the amount of time spent passing through an intersection, the difference between arrival time and departure time, which can be determined in various ways. The vehicle delay ratio is calculated over the duration of the cycle length.

5.2.1 Peak Hour Analysis

The figure displays the queue delay comparison across three scenarios for various traffic routes and intersections.

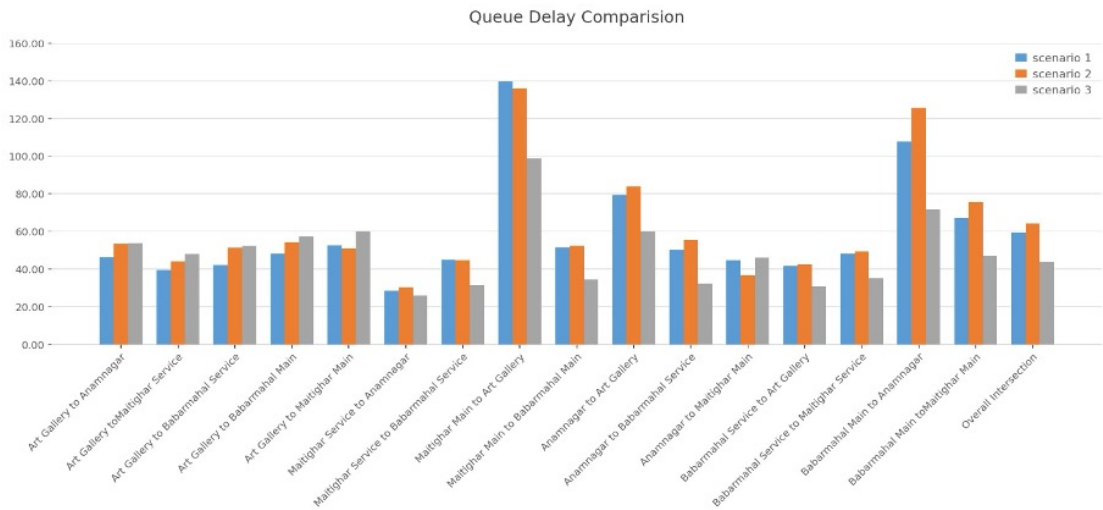


Figure 5-3 Queue Delay : Peak Hour

The queue delay comparison across the three scenarios demonstrates a consistent and decisive improvement under Scenario 3 across nearly all movements at the Babarmahal Intersection. The overall intersection queue delay follows the trend of 60.26 sec/veh (Scenario 1) to 63.45 sec/veh (Scenario 2) to 44.82 sec/veh (Scenario 3), again confirming that Scenario 2 marginally worsened delay compared to the baseline, while Scenario 3 delivered a reduction of approximately 25.6%; the most effective outcome overall. The most pronounced improvement is observed at the Maitighar Main to Art Gallery movement, which recorded the highest delays across all scenarios at 138.54, 132.18, and 97.23 sec/veh, respectively, where Scenario 3 achieved a reduction of nearly 29.8% from the baseline. Similarly, Babarmahal Main to Anamnagar exhibited notably high delays of 105.34 sec/veh under Scenario 1, worsening to 124.67 sec/veh under Scenario 2,

before Scenario 3 reduced it to 70.45 sec/veh: a reduction of approximately 33.1%. For the remaining movements including Art Gallery to Anamnagar, Art Gallery to Maitighar Service, Art Gallery to Babarmahal Service, and Maitighar Service groups, delays remained in the moderate range of 40-60 sec/veh across all scenarios, with Scenario 3 consistently recording the lowest values, reinforcing that the manually optimized timing plan achieved broad and balanced delay reductions across the entire intersection rather than benefiting select movements in isolation.

5.2.2 Off-Peak Hour Analysis

The figure displays the queue delay comparison across three scenarios for various traffic routes and intersections.

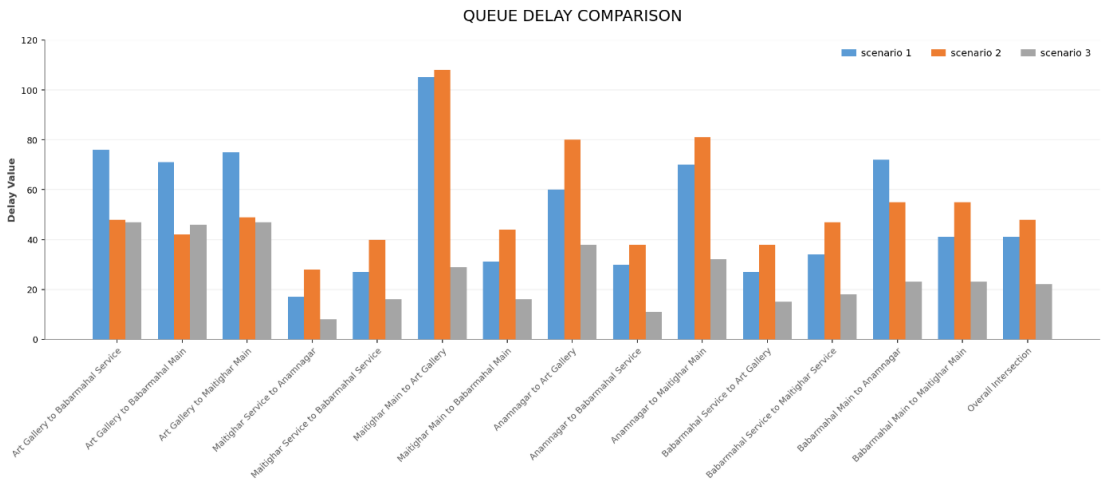


Figure 5-4 Queue Delay: Off-Peak Hour

The most telling indicator is the overall intersection queue delay, which moves from 41.49 sec (S1) -48.83 sec (S2) -22.51 sec (S3). This reveals that Scenario 2 actually worsened overall delay compared to the baseline, while Scenario 3 achieved a remarkable 45.7% reduction from the baseline, the most significant system-wide improvement.

Maitighar main to Art Gallery movement stands out as one of the most striking improvements across all scenarios. Starting at a very high queue delay of 105.69 sec in Scenario 1, it slightly worsened to 107.90 sec in Scenario 2, indicating that early interventions provided no relief for this approach. However, in Scenario 3, the delay dropped dramatically to 29.68 sec, a reduction of approximately 72% from the baseline.

5.3 Vehicle Travel Time

Vehicle travel time refers to the total time a vehicle takes to traverse a defined road segment or network link from one point to another, typically measured in seconds or minutes. It encompasses both the free-flow travel time under uncongested conditions and

any additional delay caused by traffic signals, congestion, turning movements, or other impediments. It is a fundamental measure of traffic performance, directly reflecting the efficiency and quality of traffic flow along a corridor or intersection approach.

5.3.1 Peak Hour Analysis

The figure displays the vehicle travel time comparison across three scenarios for various traffic routes and intersections.

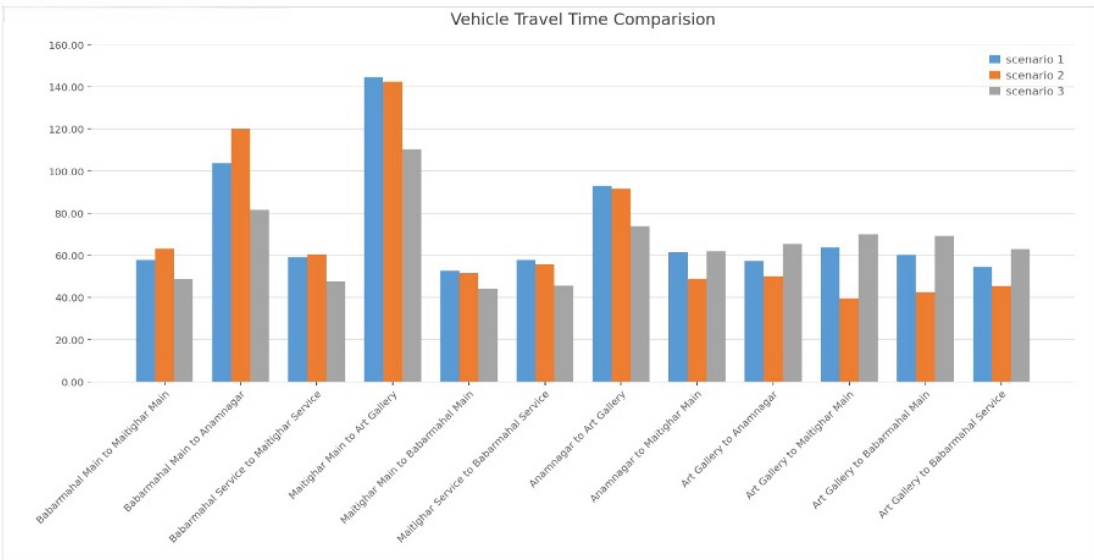


Figure 5-5 Vehicle Travel Time: Peak Hour

The vehicle travel time comparison across the three scenarios presents a subtle picture, distinguishing it from the queue delay and queue length results. The Maitighar Main to Art Gallery movement records the highest travel times across all scenarios at 143.25, 140.87, and 109.34 sec respectively, with Scenario 3 achieving the most significant reduction of approximately 23.7% from the baseline. Babarmahal Main to Anamnagar follows a similar pattern, rising from 103.45 sec in Scenario 1 to 119.67 sec in Scenario 2 before dropping to 80.12 sec under Scenario 3 — a reduction of approximately 22.5% — again highlighting that Scenario 2 worsened conditions on the heavily loaded West approach before manual optimization provided meaningful relief. Notably, for several movements, including Art Gallery to Maitighar Main, Art Gallery to Babarmahal Service, and Babarmahal Service to Art Gallery, Scenario 2 actually recorded lower travel times than both Scenario 1 and Scenario 3, suggesting that the VISSIM-optimized timing selectively favored certain lighter movements at the expense of the heavier ones. For the remaining movements, travel times across all three scenarios remain within a moderate range of 45-70 sec with marginal differences, indicating that Scenario 3 delivers the most balanced overall travel time distribution across the Babarmahal Intersection without significantly penalizing any individual movement.

5.3.2 Off-Peak Hour Analysis

The figure displays the vehicle travel time comparison across three scenarios for various traffic routes and intersections.

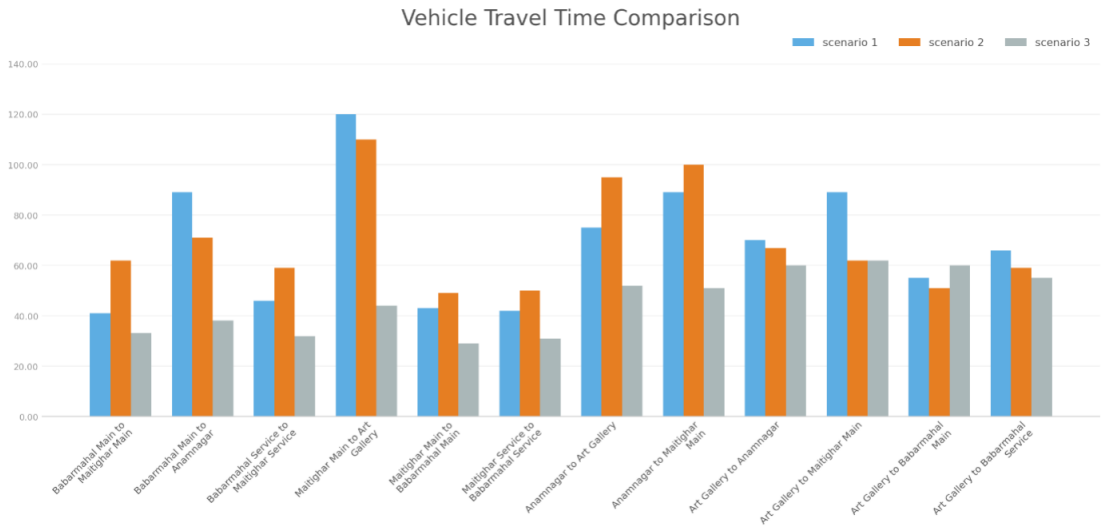


Figure 5-6 Vehicle Travel Time: Off-Peak Hour

The most telling indicator is the overall intersection vehicle travel time, which moves from 68.87 sec (S1) → 69.49 sec (S2) → 45.81 sec (S3). This reveals that Scenario 2 actually worsened overall travel time compared to the baseline, while Scenario 3 achieved a remarkable 33.5% reduction from the baseline, the most significant system-wide improvement.

Maitighar Main to Art Gallery movement stands out as the most striking improvement across all scenarios. Starting at the highest travel time of 120.34 sec in Scenario 1, it partially improved to 109.79 sec in Scenario 2, indicating that early interventions provided only marginal relief for this approach. However, in Scenario 3, the travel time dropped dramatically to 44.60 sec, a reduction of approximately 63% from the baseline.

5.4 LOS

Level of Service (LOS) is a qualitative measure used to characterize traffic flow conditions and the degree of congestion experienced by road users. Defined by the Highway Capacity Manual (HCM), LOS is graded on a scale from A to F, where LOS A represents free-flow conditions with minimal delay and LOS F denotes a complete breakdown of traffic flow with excessive delays. For signalized intersections, LOS is typically determined based on the average control delay per vehicle (in seconds), serving as a key indicator of operational performance and intersection efficiency.

5.4.1 Peak Hour Analysis

The figure displays the Level of Service (LOS) comparison across three scenarios for various traffic routes and intersections:

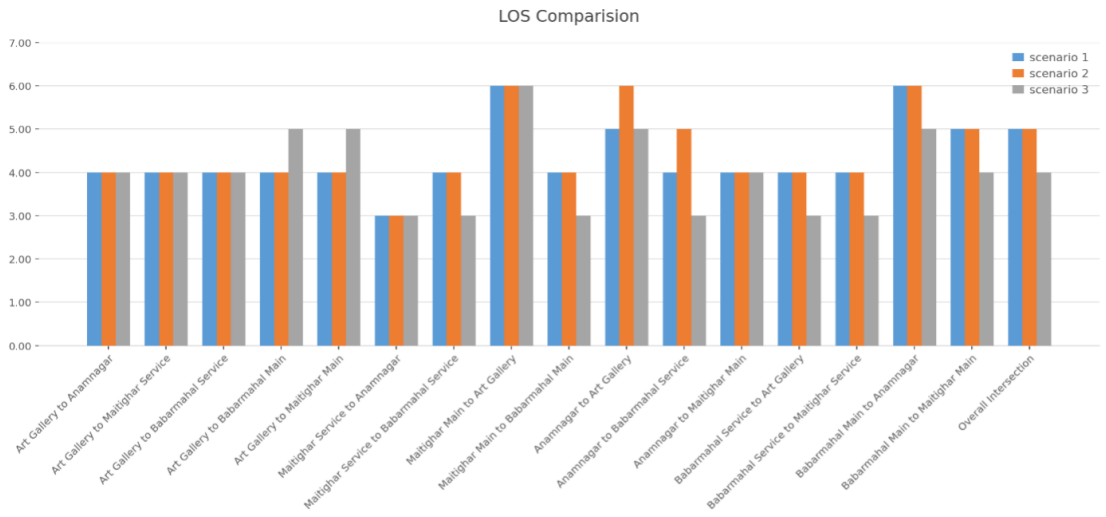


Figure 5-7 LOS: Peak Hour

The off-peak hour LOS comparison across the three scenarios demonstrates that Scenario 3 consistently achieves the lowest or equal LOS values across nearly all movements, confirming its superiority as the most effective signal timing plan. The overall intersection LOS improves from 4 (Scenario 1) → 4 (Scenario 2) → 4 (Scenario 3), indicating that while the overall grade remains unchanged during off-peak conditions, movement-level improvements are evident throughout. The most notable reductions are observed at Art Gallery to Maitighar Main and Maitighar Service to Babarmahal Service, where LOS drops from 5 under Scenarios 1 and 2 to 3 under Scenario 3, representing a two-grade improvement. The Maitighar Main to Art Gallery movement records the highest LOS of 6 across all three scenarios, indicating persistent congestion on this movement even during off-peak hours that could not be resolved through fixed-time signal optimization alone. For the majority of movements, including Art Gallery to Anamnagar, Art Gallery to Babarmahal Service, Art Gallery to Babarmahal Main, and Anamnagar-related movements, LOS remains at 4 across all scenarios, suggesting that off-peak traffic demand on these approaches is moderate and relatively insensitive to signal timing changes. Overall, Scenario 3 delivers the most consistent and balanced LOS distribution across the intersection during off-peak conditions.

5.4.2 Off-Peak Hour Analysis

The figure displays the Level of Service (LOS) comparison across three scenarios for various traffic routes and intersections.

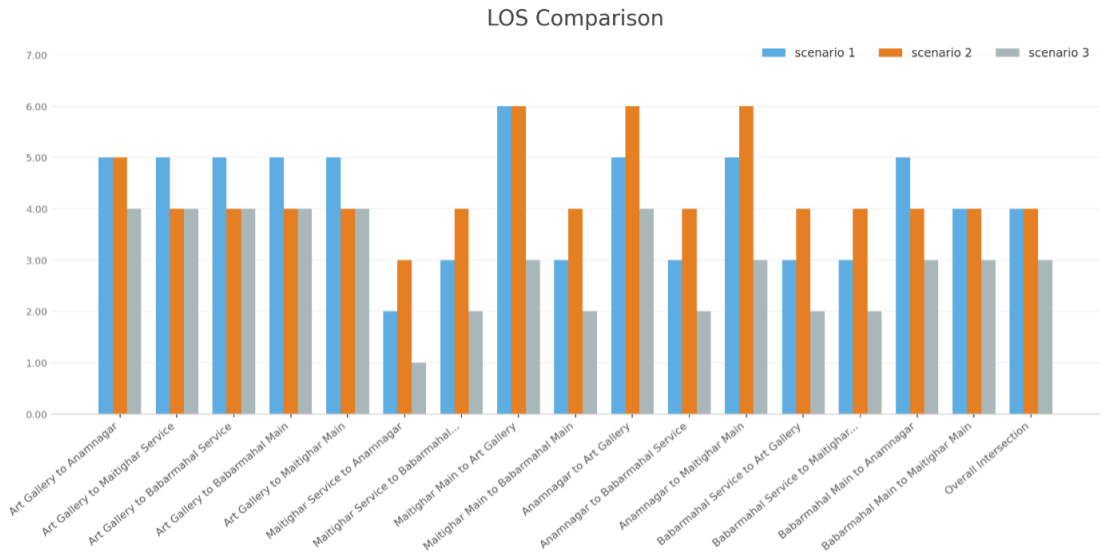


Figure 5-8 LOS: Off-Peak Hour

The most telling indicator is the overall intersection Level of Service, which moves from LOS D (S1) → LOS D (S2) → LOS C (S3). This reveals that Scenario 2 produced no improvement over the baseline, while Scenario 3 achieved a meaningful upgrade by one service level, the most significant system-wide improvement.

Maitighar Main to Art Gallery movement stands out as the most striking improvement across all scenarios. Operating at the worst possible service level of LOS F in Scenario 1, it remained at LOS_F in Scenario 2, indicating that early interventions were entirely ineffective for this approach. However, in Scenario 3, the Level of Service improved dramatically to LOS C, a jump of three service levels from the baseline, representing the most substantial LOS gain recorded across the entire intersection.

6 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The Babarmahal Intersection plays a major role in the transportation network of Kathmandu Valley. The signal controller at the intersection decides the capacity and efficiency of the intersection. The objectives of the study were achieved, which were to evaluate the effectiveness of the signal control system at the intersection and reduce congestion. The PTV VISSIM software along with VISVAP was used to create different scenarios and simulations. Key performance measures such as queue delay, queue length, and vehicle travel time were evaluated.

The overall results were analyzed for peak hour and off-peak hour conditions separately. For peak hour analysis, three scenarios were compared. Scenario 1 was the existing fixed-time signal timing, Scenario 2 was the VISSIM-optimized signal timing, and Scenario 3 was the manually optimized signal timing. The results show that Scenario 3 performs better than Scenario 1 and Scenario 2 in terms of queue delay, queue length, and vehicle travel time. The overall Level of Service of the intersection also improved from LOS E to LOS D after optimization.

For off-peak hour analysis, three scenarios were compared. Scenario 1 was the existing fixed-time signal timing, Scenario 2 was the VISSIM-optimized signal timing and Scenario 3 was the VAP-based semi-actuated signal control using minimum green times. The results clearly show that Scenario 3 performs the best among all three scenarios in terms of queue delay, queue length, and vehicle travel time. The overall Level of Service of the intersection improved from LOS D to LOS C.

The study also examined the performance of the intersection under both fixed-time signal control and semi-actuated signal control using VISVAP. The analysis implies that the implementation of a semi-actuated signal control system programmed using VISVAP could provide an effective solution for intersections with asymmetric traffic distribution between major and minor approaches, as demonstrated by the improved efficiency and reduced congestion at Babarmahal Intersection through dynamic allocation of green time based on real-time vehicle detection.

The fixed-time optimized signal control is relatively simpler to implement and does not require any detector installation. However, it cannot respond to the changing traffic demand at the intersection, especially during off-peak hours when the traffic flow on the minor approaches is very low. The semi-actuated signal control on the other hand dynamically adjusts the signal timing based on real-time vehicle detection, which makes

it a more efficient and suitable option for intersections where the traffic flow is highly asymmetric between the major and minor approaches.

6.2 Recommendation

Considerable research effort was invested in conducting 6-hour traffic flow counts over a 3-day period. To save time and enhance efficiency, the deployment of a machine learning powered software solution could be used to automate the traffic counting process.

The current analysis of the intersection was performed in isolation and did not consider the impact of neighboring intersections. To enhance the accuracy and comprehensiveness of future research, it is recommended to conduct a network-level analysis that incorporates the Maitighar Intersection, the Babarmahal Intersection, and Bijulibazar intersection.

The model calibration and validation process currently relies solely on the 95th percentile back of queue as a variable measure. To enhance the model's accuracy, saturation flow and degree of saturation could be used as additional variables for calibration and validation.

The interaction between pedestrians and vehicles was not considered in this study; however, it may be incorporated in future research to enable a more comprehensive analysis.

A ANNEX I (VOLUME COUNT)

A.1 PEAK DAY 1

Table A-1 Peak Hour Traffic Volume and PCU: Day 1

Baneshwor to Maitighar Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	1	71	425	5	4	0	506	188.75
9:45-10:00	0	0	0	2	60	396	1	1	0	460	166
10:00-10:15	0	0	2	0	41	403	0	3	0	449	150.75
10:15-10:30	0	0	0	2	65	451	0	3	0	521	185.75
Total	0	0	2	5	237	1675	6	11	0	1936	691.25

Baneshwor to Maitighar Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	1	35	17	64	242	5	0	10	374	288.5
9:45-10:00	0	0	30	9	49	251	1	0	14	354	239.25
10:00-10:15	0	0	27	8	42	204	0	2	11	294	207
10:15-10:30	0	1	30	11	53	215	0	1	8	319	234.75
Total	0	2	122	45	208	912	6	3	43	1341	969.5

Baneshwor to Art Gallery											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	29	73	0	0	1	103	48.25
9:45-10:00	0	0	0	0	22	68	0	0	0	90	39
10:00-10:15	0	0	0	0	20	52	0	1	2	75	36
10:15-10:30	0	0	0	0	18	61	0	1	0	80	34.25
Total	0	0	0	0	89	254	0	2	3	348	157.5

DOR to Art Gallery											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	1	6	0	0	0	7	2.5
9:45-10:00	0	0	0	0	3	12	0	0	0	15	6
10:00-10:15	0	0	0	0	7	16	0	0	0	23	11
10:15-10:30	0	0	0	0	5	16	0	0	0	21	9
Total	0	0	0	0	16	50	0	0	0	66	28.5

DOR to Baneshwor											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	2	4	0	0	0	6	3
9:45-10:00	0	0	0	0	3	10	0	0	0	13	5.5
10:00-10:15	0	0	0	0	1	12	0	0	0	13	4
10:15-10:30	0	0	0	0	6	17	0	0	0	23	10.25
Total	0	0	0	0	12	43	0	0	0	55	22.75

DOR To Maitighar											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	0	0	0	0	0	0	0
9:45-10:00	0	0	0	0	0	3	0	0	0	3	0.75
10:00-10:15	0	0	0	0	0	0	0	0	0	0	0
10:15-10:30	0	0	0	0	0	5	0	0	0	5	1.25
Total	0	0	0	0	0	8	0	0	0	8	2

Art Gallery to Maitighar Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	6	61	0	0	0	67	21.25
9:45-10:00	0	0	0	0	3	59	0	0	0	62	17.75
10:00-10:15	0	0	0	0	8	56	0	0	0	64	22
10:15-10:30	0	0	0	0	8	50	0	0	0	58	20.5
Total	0	0	0	0	25	226	0	0	0	251	81.5

Art Gallery to Maitighar Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	4	11	0	0	0	15	6.75
9:45-10:00	0	0	0	0	1	15	0	0	0	16	4.75
10:00-10:15	0	0	0	0	2	8	0	0	0	10	4
10:15-10:30	0	0	0	0	2	4	0	0	0	6	3
Total	0	0	0	0	9	38	0	0	0	47	18.5

Art Gallery to DOR											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	10	40	0	0	0	50	20
9:45-10:00	0	0	0	0	8	43	0	0	0	51	18.75
10:00-10:15	0	0	0	0	2	49	0	0	0	51	14.25
10:15-10:30	0	0	0	0	10	51	0	1	0	62	23.75
Total	0	0	0	0	30	183	0	1	0	214	76.75

Art Gallery to Baneshwor Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	4	29	0	1	0	34	12.25
9:45-10:00	0	0	0	0	9	33	1	0	0	43	18.25
10:00-10:15	0	0	0	0	7	24	0	0	0	31	13
10:15-10:30	0	0	0	0	7	28	0	0	0	35	14
Total	0	0	0	0	27	114	1	1	0	143	57.5

Art Gallery to Baneshwor Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	13	64	1	2	0	80	32
9:45-10:00	0	0	0	0	9	58	0	1	1	69	25.5
10:00-10:15	0	0	0	0	15	62	2	0	0	79	32.5
10:15-10:30	0	0	0	0	10	65	1	1	0	77	28.25
Total	0	0	0	0	47	249	4	4	1	305	118.25

Maitighar to Baneshwor Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	26	11	33	65	5	0	8	148	167.75
9:45-10:00	0	0	30	10	18	70	9	0	11	148	170.5
10:00-10:15	0	0	35	15	20	90	12	0	10	182	207
10:15-10:30	0	0	40	14	25	105	15	0	12	211	233.25
Total	0	0	131	50	96	330	41	0	41	689	778.5

Maitighar to Naneshwor Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	1	3	8	80	360	16	3	3	474	222.5
9:45-10:00	0	1	1	1	72	380	20	3	2	480	199
10:00-10:15	1	0	0	4	90	400	18	4	0	517	225
10:15-10:30	0	3	0	2	100	418	15	5	2	545	236
Total	1	5	4	15	342	1558	69	15	7	2016	882.5

Maitighar to DOR											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	1	3	0	0	0	4	1.75
9:45-10:00	0	0	0	0	2	4	0	0	0	6	3
10:00-10:15	0	0	0	0	3	6	0	0	0	9	4.5
10:15-10:30	0	0	0	0	4	5	1	0	0	10	6.25
Total	0	0	0	0	10	18	1	0	0	29	15.5

Maitighar to Art Gallery											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	4	28	0	0	0	32	11
9:45-10:00	0	0	0	0	3	35	2	0	0	40	13.75
10:00-10:15	0	0	0	0	4	40	1	0	0	45	15
10:15-10:30	0	0	0	0	5	38	1	0	0	44	15.5
Total	0	0	0	0	16	141	4	0	0	161	55.25

Baneshwor to DOR											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	5	0	51	120	0	0	0	176	96
9:45-10:00	0	0	0	0	60	118	0	0	0	178	89.5
10:00-10:15	0	0	0	1	64	116	0	1	0	182	96.5
10:15-10:30	0	0	0	0	56	112	0	0	0	168	84
Total	0	0	5	1	231	466	0	1	0	704	366

A.2 PEAK DAY 2

Table A-2 Peak Hour Traffic Volume and PCU: Day 2

Baneshwor to Maitighar Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	2	2	0	3	72	433	3	0	0	515	199.75
9:45-10:00	0	0	0	1	65	361	2	1	0	430	160.75
10:00-10:15	0	0	5	5	69	397	2	3	0	481	200.75
10:15-10:30	0	0	0	2	60	413	3	4	0	482	175.25
Total	2	2	5	11	266	1604	10	8	0	1908	736.5

Baneshwor to Maitighar Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	1	33	13	39	223	1	0	0	310	228.75
9:45-10:00	0	1	37	9	51	202	1	0	0	301	237.5
10:00-10:15	0	0	33	13	62	201	1	1	6	317	251.75
10:15-10:30	0	0	44	16	53	257	0	1	7	378	297.25
Total	0	2	147	51	205	883	3	2	13	1306	1015.25

Baneshwor to Art Gallery											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	28	69	0	0	1	98	46.25
9:45-10:00	0	0	0	0	25	77	0	0	0	102	44.25
10:00-10:15	0	0	0	0	25	65	0	1	4	95	46.25
10:15-10:30	0	0	0	0	18	61	0	1	0	80	34.25
Total	0	0	0	0	96	272	0	2	5	375	171

Baneshwor to DOR											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	3	0	38	141	0	0	0	182	82.25
9:45-10:00	0	0	3	1	51	143	0	0	0	198	98.25
10:00-10:15	1	0	0	1	52	139	0	1	0	194	93.25
10:15-10:30	0	0	1	1	56	136	0	2	0	196	97.5
Total	1	0	7	3	197	559	0	3	0	770	371.25

DOR to Art Gallery											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	4	9	1	0	0	14	7.25
9:45-10:00	0	0	0	0	2	9	0	0	0	11	4.25
10:00-10:15	0	0	0	0	2	16	0	0	0	18	6
10:15-10:30	0	0	0	0	2	23	0	0	0	25	7.75
Total	0	0	0	0	10	57	1	0	0	68	25.25

DOR To Baneshwor											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	5	6	0	0	0	11	6.5
9:45-10:00	0	0	0	0	4	7	2	0	0	13	7.75
10:00-10:15	0	0	0	0	1	18	0	0	0	19	5.5
10:15-10:30	0	0	0	0	6	22	1	0	0	29	12.5
Total	0	0	0	0	16	53	3	0	0	72	32.25

DOR to Maitighar											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	1	0	0	0	0	1	1
9:45-10:00	0	0	0	0	1	0	0	0	0	1	1
10:00-10:15	0	0	0	0	1	1	0	0	0	2	1.25
10:15-10:30	0	0	0	0	0	0	1	0	0	1	1
Total	0	0	0	0	3	1	1	0	0	5	4.25

Art Gallery to Maitighar Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	3	56	1	0	0	60	18
9:45-10:00	0	0	0	0	4	54	0	0	0	58	17.5
10:00-10:15	0	0	0	0	5	51	1	0	0	57	18.75
10:15-10:30	0	0	0	0	5	59	0	0	0	64	19.75
Total	0	0	0	0	17	220	2	0	0	239	74

Art Gallery to Maitighar Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	3	13	0	0	0	16	6.25
9:45-10:00	0	0	0	0	3	14	0	0	0	17	6.5
10:00-10:15	0	0	0	0	5	11	0	0	0	16	7.75
10:15-10:30	0	0	0	0	1	9	0	0	0	10	3.25
Total	0	0	0	0	12	47	0	0	0	59	23.75

Art Gallery to DOR											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	13	41	0	0	0	54	23.25
9:45-10:00	0	0	0	0	12	39	0	0	0	51	21.75
10:00-10:15	0	0	0	0	12	49	0	0	0	61	24.25
10:15-10:30	0	0	0	0	9	39	0	0	0	48	18.75
Total	0	0	0	0	46	168	0	0	0	214	88

Art Gallery to Baneshwor Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	7	35	1	0	0	43	16.75
9:45-10:00	0	0	0	0	8	37	1	0	0	46	18.25
10:00-10:15	0	0	0	0	9	21	0	0	0	30	14.25
10:15-10:30	0	0	0	0	9	29	0	1	0	39	17.25
Total	0	0	0	0	33	122	2	1	0	158	66.5

Art Gallery to Baneshwor Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	15	62	0	1	0	78	31.5
9:45-10:00	0	0	0	0	14	67	3	1	0	85	34.75
10:00-10:15	0	0	0	0	15	59	0	1	0	75	30.75
10:15-10:30	0	0	0	0	18	65	0	1	0	84	35.25
Total	0	0	0	0	62	253	3	4	0	322	132.25

Maitighar to Baneshwor Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	2	2	94	402	10	2	2	514	219.5
9:45-10:00	0	1	0	2	90	345	14	2	0	454	198.75
10:00-10:15	0	0	1	3	105	410	16	1	0	536	235
10:15-10:30	0	0	1	2	112	422	14	0	5	556	244.5
Total	0	1	4	9	401	1579	54	5	7	2060	897.75

Maitighar to Baneshwor Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	30	10	35	80	5	0	12	172	187
9:45-10:00	0	0	36	10	43	95	8	0	13	205	220.75
10:00-10:15	0	0	32	15	50	120	12	0	10	239	235.5
10:15-10:30	0	0	40	10	40	108	9	0	15	222	236
Total	0	0	138	45	168	303	34	0	50	838	879.25

Maitighar to Art Gallery											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	8	32	0	0	0	40	16
9:45-10:00	0	0	0	0	5	35	1	0	0	41	14.75
10:00-10:15	0	0	0	0	10	45	1	0	0	56	22.25
10:15-10:30	0	0	0	0	6	37	0	0	0	43	15.25
Total	0	0	0	0	29	149	2	0	0	180	68.25

Maitighar to DOR											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	2	4	0	0	0	6	3
9:45-10:00	0	0	0	0	2	3	1	0	0	6	3.75
10:00-10:15	0	0	0	0	3	5	1	0	0	9	5.25
10:15-10:30	0	0	0	0	5	8	1	0	0	14	8
Total	0	0	0	0	12	20	3	0	0	35	20

A.3 PEAK DAY 3

Table A-3 Peak Hour Traffic Volume and PCU: Day 3

Baneshwor to Maitighar Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	1	0	0	1	56	433	2	3	0	496	174.75
9:45-10:00	0	0	0	0	48	414	1	1	0	464	153.5
10:00-10:15	1	0	0	5	51	420	2	5	0	484	178.5
10:15-10:30	0	1	4	0	67	416	2	1	0	491	187.5
Total	2	1	4	6	222	1683	7	10	0	1935	694.25

Baneshwor to Maitighar Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	2	34	11	39	196	2	3	9	296	234.5
9:45-10:00	0	0	37	13	43	204	0	1	11	309	249.5
10:00-10:15	0	0	32	10	54	191	1	1	4	293	228.75
10:15-10:30	1	0	36	11	40	198	0	1	10	297	239
Total	1	2	139	45	176	789	3	6	34	1195	951.75

Baneshwor to Art Gallery											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	26	73	1	1	0	101	46.25
9:45-10:00	0	0	0	0	25	68	0	0	0	93	42
10:00-10:15	0	0	0	0	24	84	0	1	5	114	51
10:15-10:30	0	0	0	0	27	76	1	1	3	108	51
Total	0	0	0	0	102	301	2	3	8	416	190.25

Baneshwor to DOR											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	3	2	59	151	0	0	0	215	110.75
9:45-10:00	0	0	4	0	61	153	0	2	0	220	113.25
10:00-10:15	0	0	0	1	57	150	0	1	0	209	98
10:15-10:30	0	0	0	1	52	142	0	0	0	195	90
Total	0	0	7	4	229	596	0	3	0	839	412

DOR to Art Gallery											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	1	8	0	0	0	9	3
9:45-10:00	0	0	0	0	6	15	0	0	0	21	9.75
10:00-10:15	0	0	0	0	2	19	0	1	0	22	7.75
10:15-10:30	0	0	0	0	2	7	0	0	0	9	3.75
Total	0	0	0	0	11	49	0	1	0	61	24.25

DOR To Baneshwor											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	4	3	0	0	0	7	4.75
9:45-10:00	0	0	0	0	4	8	0	0	0	12	6
10:00-10:15	0	0	0	0	2	10	1	0	0	13	5.5
10:15-10:30	0	0	0	0	3	14	0	0	0	17	6.5
Total	0	0	0	0	13	35	1	0	0	49	22.75

DOR to Maitighar											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	0	0	0	0	0	0	0
9:45-10:00	0	0	0	0	1	0	0	0	0	1	1
10:00-10:15	0	0	0	0	0	0	0	0	0	0	0
10:15-10:30	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	1	0	0	0	0	1	1

Art Gallery to Maitighar Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	2	61	0	0	0	63	17.25
9:45-10:00	0	0	0	0	5	64	0	0	0	69	21
10:00-10:15	0	0	0	0	6	57	0	0	0	63	20.25
10:15-10:30	0	0	0	0	5	59	0	0	0	64	19.75
Total	0	0	0	0	18	241	0	0	0	259	78.25

Art Gallery to Maitighar Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	4	12	0	0	0	16	7
9:45-10:00	0	0	0	0	2	14	0	0	0	16	5.5
10:00-10:15	0	0	0	0	4	15	0	0	0	19	7.75
10:15-10:30	0	0	0	0	6	13	0	0	0	19	9.25
Total	0	0	0	0	16	54	0	0	0	70	29.5

Art Gallery to DOR											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	9	46	0	0	0	55	20.5
9:45-10:00	0	0	0	0	6	54	0	0	0	60	19.5
10:00-10:15	0	0	0	0	9	48	0	0	0	57	21
10:15-10:30	0	0	0	0	4	49	0	0	0	53	16.25
Total	0	0	0	0	28	197	0	0	0	225	77.25

Art Gallery to Baneshwor Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	8	26	0	0	0	34	14.5
9:45-10:00	0	0	0	0	9	31	0	0	0	40	16.75
10:00-10:15	0	0	0	0	4	27	0	0	0	31	10.75
10:15-10:30	0	0	0	0	6	22	0	0	0	28	11.5
Total	0	0	0	0	27	106	0	0	0	133	53.5

Art Gallery to Baneshwor Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	13	46	0	0	0	59	24.5
9:45-10:00	0	0	0	0	10	51	2	0	0	63	24.75
10:00-10:15	0	0	0	0	16	54	0	0	0	70	29.5
10:15-10:30	0	0	0	0	14	44	0	0	0	58	25
Total	0	0	0	0	53	195	2	0	0	250	103.75

Maitighar to Baneshwor Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	1	0	1	0	90	408	10	2	2	514	212
9:45-10:00	0	0	0	0	82	430	9	0	0	521	198.5
10:00-10:15	0	1	0	0	98	415	12	1	3	530	219.25
10:15-10:30	0	0	1	1	95	395	7	0	2	501	208.25
Total	1	1	2	1	365	1648	38	3	7	2066	838

Maitighar to Baneshwor Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	45	10	35	107	5	0	10	212	236.75
9:45-10:00	0	0	40	12	41	105	7	0	12	217	236.25
10:00-10:15	0	0	39	8	47	93	13	1	8	209	229.25
10:15-10:30	0	0	33	13	40	120	9	0	14	229	224.5
Total	0	0	157	43	163	425	34	1	44	867	926.75

Maitighar to Art Gallery											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	13	38	1	0	0	52	23.5
9:45-10:00	0	0	0	0	5	34	0	0	0	39	13.5
10:00-10:15	0	0	0	0	4	40	2	0	0	46	16
10:15-10:30	0	0	0	0	8	33	1	0	0	42	17.25
Total	0	0	0	0	30	145	4	0	0	179	70.25

Maitighar to DOR											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	0	3	0	0	0	3	0.75
9:45-10:00	0	0	0	0	1	2	0	0	0	3	1.5
10:00-10:15	0	0	0	0	1	3	0	0	0	4	1.75
10:15-10:30	0	0	0	0	1	3	0	0	0	4	1.75
Total	0	0	0	0	3	11	0	0	0	14	5.75

A.4 OFF PEAK DAY 1

Table A-4 Off Peak Hour Traffic Volume and PCU: Day 1

Baneshwor to Maitighar Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	55	300	6	3	0	364	139
1:15-1:30	0	0	0	0	61	314	0	2	0	377	141.5
1:30-1:45	0	3	0	0	64	295	5	4	0	371	151.25
1:45-2:00	0	3	0	0	58	328	6	5	0	400	155.5
Total	0	6	0	0	238	1237	17	14	0	1512	587.25

Baneshwor to Maitighar Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	32	11	32	162	9	3	9	258	217
1:15-1:30	0	0	27	9	26	158	3	4	11	238	187
1:30-1:45	0	0	33	10	56	179	5	6	7	296	242.75
1:45-2:00	0	3	30	9	51	174	5	7	6	285	229.5
Total	0	3	122	39	165	673	22	20	33	1077	876.25

Baneshwor to DOR											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	5	0	6	11	0	0	0	22	23.75
1:15-1:30	0	0	0	0	5	12	0	0	0	17	8
1:30-1:45	0	0	0	0	5	9	0	0	0	14	7.25
1:45-2:00	0	0	0	0	5	11	0	0	0	16	7.75
Total	0	0	5	0	21	43	0	0	0	69	46.75

Baneshwor to Art Gallery											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	17	48	0	0	0	65	29
1:15-1:30	0	0	0	0	14	36	0	0	0	50	23
1:30-1:45	0	0	0	0	13	36	1	0	0	50	23
1:45-2:00	0	0	0	0	14	32	0	1	0	47	23
Total	0	0	0	0	58	152	1	1	0	212	98

DOR to Art Gallery											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	5	7	0	0	0	12	6.75
1:15-1:30	0	0	0	0	5	6	0	0	0	11	6.5
1:30-1:45	0	0	0	0	2	8	0	1	0	11	5
1:45-2:00	0	0	0	0	3	10	0	1	0	14	6.5
Total	0	0	0	0	15	31	0	2	0	48	24.75

DOR To Baneshwor											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	6	11	0	0	0	17	8.75
1:15-1:30	0	0	0	0	3	7	0	0	0	10	4.75
1:30-1:45	0	0	0	0	3	8	0	0	0	11	5
1:45-2:00	0	0	0	0	4	9	0	0	0	13	6.25
Total	0	0	0	0	16	35	0	0	0	51	24.75

DOR to Maitighar											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	4	8	0	0	0	12	6
1:15-1:30	0	0	0	0	2	5	0	1	0	8	4.25
1:30-1:45	0	0	0	0	1	4	0	0	0	5	2
1:45-2:00	0	0	0	0	3	6	0	0	0	9	4.5
Total	0	0	0	0	10	23	0	1	0	34	16.75

Art Gallery to Maitighar Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	9	22	0	1	0	32	15.5
1:15-1:30	0	1	0	0	6	29	1	0	0	37	15.75
1:30-1:45	0	0	0	0	7	28	1	0	0	36	15
1:45-2:00	0	1	0	0	10	23	0	1	0	35	18.25
Total	0	2	0	0	32	102	2	2	0	140	64.5

Art Gallery to Maitighar Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	2	0	0	11	18	1	0	0	32	19.5
1:15-1:30	0	0	0	0	8	13	0	0	0	21	11.25
1:30-1:45	0	0	0	0	9	14	1	0	0	24	13.5
1:45-2:00	0	1	0	0	7	11	1	0	0	20	12.25
Total	0	3	0	0	35	56	3	0	0	97	56.5

Art Gallery to DOR											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	14	29	1	0	0	44	22.25
1:15-1:30	0	0	0	0	11	19	0	0	0	30	15.75
1:30-1:45	0	0	0	0	9	21	0	0	0	30	14.25
1:45-2:00	0	0	0	0	7	23	0	0	0	30	12.75
Total	0	0	0	0	41	92	1	0	0	134	65

Art Gallery to Baneshwor Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	18	29	0	0	0	47	25.25
1:15-1:30	0	0	0	0	14	19	0	0	0	33	18.75
1:30-1:45	0	0	0	0	12	23	0	1	0	36	18.75
1:45-2:00	0	0	0	0	10	21	1	0	0	32	16.25
Total	0	0	0	0	54	92	1	1	0	148	79

Art Gallery to Baneshwor Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	19	66	1	0	0	86	36.5
1:15-1:30	0	0	0	0	24	61	0	0	0	85	39.25
1:30-1:45	0	0	0	0	11	53	1	1	0	66	26.25
1:45-2:00	0	0	0	0	9	57	0	1	0	67	24.25
Total	0	0	0	0	63	237	2	2	0	304	126.25

Maitighar to Baneshwor Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	18	8	20	48	11	10	9	124	136
1:15-1:30	0	0	10	6	18	40	9	13	7	103	102
1:30-1:45	0	0	35	15	15	65	6	6	10	152	195.75
1:45-2:00	0	0	40	14	25	80	5	8	8	180	221
Total	0	0	103	43	78	233	31	37	34	559	654.75

Maitighar to Baneshwor Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	1	3	5	50	258	8	5	3	333	153.5
1:15-1:30	0	1	1	1	58	282	5	10	2	360	152.5
1:30-1:45	0	0	0	4	65	315	6	4	0	394	163.75
1:45-2:00	0	0	0	2	48	305	10	5	2	372	146.25
Total	0	2	4	12	221	1160	29	24	7	1459	616

Maitighar to DOR											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	1	3	0	0	0	4	1.75
1:15-1:30	0	0	0	0	2	3	2	0	0	7	4.75
1:30-1:45	0	0	0	0	3	4	0	0	0	7	4
1:45-2:00	0	0	0	0	4	5	1	0	0	10	6.25
Total	0	0	0	0	10	15	3	0	0	28	16.75

Maitighar to Art Gallery											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	5	28	0	5	0	38	17
1:15-1:30	0	0	0	0	0	20	2	2	0	24	9
1:30-1:45	0	0	0	0	4	15	1	7	0	27	15.75
1:45-2:00	0	0	0	0	3	28	1	2	0	34	13
Total	0	0	0	0	12	63	4	16	0	123	54.75

A.5 OFF PEAK DAY 2

Table A-5 Off Peak Hour Traffic Volume and PCU: Day 2

Baneshwor to Maitighar Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	63	333	6	3	0	405	155.25
1:15-1:30	0	0	0	2	51	321	3	0	0	377	139.25
1:30-1:45	0	2	0	0	61	314	6	4	0	387	152.5
1:45-2:00	0	3	0	0	58	350	4	4	0	419	158
Total	0	5	0	2	233	1318	19	11	0	1588	605

Baneshwor to Maitighar Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	25	11	40	174	9	4	8	271	207
1:15-1:30	0	0	24	8	31	136	3	4	8	214	172
1:30-1:45	0	0	30	9	50	170	5	4	7	275	221
1:45-2:00	0	1	29	10	56	181	6	4	8	295	232.75
Total	0	1	108	38	177	661	23	16	31	1055	832.75

Baneshwor to DOR											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	5	0	5	14	0	1	0	25	24.5
1:15-1:30	0	0	0	0	7	5	1	0	0	13	9.25
1:30-1:45	0	0	0	0	4	8	0	0	0	12	6
1:45-2:00	0	0	0	0	5	12	0	0	0	17	8
Total	0	0	5	0	21	39	1	1	0	67	47.75

Baneshwor to Art Gallery											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	18	32	1	0	0	51	27
1:15-1:30	0	0	0	0	19	37	1	0	0	57	29.25
1:30-1:45	0	0	0	0	13	33	1	0	0	47	22.25
1:45-2:00	0	0	0	0	12	31	1	1	0	45	21.75
Total	0	0	0	0	62	133	4	1	0	200	100.25

DOR to Art Gallery											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	5	8	1	0	0	14	8
1:15-1:30	0	0	0	0	2	11	0	0	0	13	4.75
1:30-1:45	0	0	0	0	3	7	0	1	0	11	5.75
1:45-2:00	0	0	0	0	2	13	0	0	0	15	5.25
Total	0	0	0	0	12	39	1	1	0	53	23.75

DOR To Baneshwor											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	4	10	0	1	0	15	7.5
1:15-1:30	0	0	0	0	5	6	1	0	0	12	7.5
1:30-1:45	0	0	0	0	5	8	0	0	0	13	7
1:45-2:00	0	0	0	0	3	9	0	0	0	12	5.25
Total	0	0	0	0	17	33	1	1	0	52	27.25

DOR to Maitighar											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	2	6	0	0	0	8	3.5
1:15-1:30	0	0	0	0	4	10	0	0	0	14	6.5
1:30-1:45	0	0	0	0	1	7	0	0	0	8	2.75
1:45-2:00	0	0	0	0	2	5	0	0	0	7	3.25
Total	0	0	0	0	9	28	0	0	0	37	16

Art Gallery to Maitighar Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	2	0	0	9	26	1	0	0	38	19.5
1:15-1:30	0	0	0	0	14	29	0	1	0	44	22.25
1:30-1:45	0	0	0	0	11	31	0	1	0	43	19.75
1:45-2:00	0	0	0	0	8	24	2	0	0	34	16
Total	0	2	0	0	42	110	3	2	0	159	77.5

Art Gallery to Maitighar Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	1	0	0	12	18	1	0	0	32	19
1:15-1:30	0	0	0	0	7	11	0	0	0	18	9.75
1:30-1:45	0	1	0	0	8	13	1	0	0	23	13.75
1:45-2:00	0	0	0	0	10	14	1	1	0	26	15.5
Total	0	2	0	0	37	56	3	1	0	99	58

Art Gallery to DOR											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	1	0	0	13	26	1	0	0	41	22
1:15-1:30	0	0	0	0	7	21	1	0	0	29	13.25
1:30-1:45	0	0	0	0	8	23	1	1	0	33	15.75
1:45-2:00	0	0	0	0	7	20	1	1	0	29	14
Total	0	1	0	0	35	90	4	2	0	132	65

Art Gallery to Baneshwor Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:15-1:30	0	1	0	0	14	29	0	0	0	44	22.75
1:30-1:45	0	1	0	0	12	30	1	0	0	44	22
1:45-2:00	0	0	0	0	11	31	1	1	0	44	20.75
Total	0	2	0	0	52	120	2	3	0	179	90

Art Gallery to Baneshwor Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	1	0	0	18	56	0	0	0	75	33.5
1:15-1:30	0	0	0	0	22	48	1	0	0	71	35
1:30-1:45	0	1	0	0	21	50	1	1	0	74	37
1:45-2:00	0	1	0	0	16	42	0	1	0	60	29
Total	0	3	0	0	77	196	2	2	0	280	134.5

Maitighar to Baneshwor Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	30	11	20	70	5	5	10	151	175
1:15-1:30	0	0	28	10	25	85	8	9	13	178	185.25
1:30-1:45	0	0	25	12	18	74	12	7	10	158	170.5
1:45-2:00	0	0	33	8	28	80	9	8	8	174	192
Total	0	0	116	41	91	309	34	29	41	661	722.75

Maitighar to Baneshwor Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	7	61	350	15	20	0	453	201
1:15-1:30	0	1	0	2	50	320	8	17	0	398	161.5
1:30-1:45	0	0	0	0	55	365	16	13	0	449	175.25
1:45-2:00	0	0	0	2	65	340	14	22	0	443	191
Total	0	1	0	11	231	1375	53	72	0	1743	728.75

Table A-6 Off Peak Hour Traffic Volume and PCU: Day 3

Maitighar to DOR											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	2	4	2	0	0	8	5
1:15-1:30	0	0	0	0	2	3	1	0	0	6	3.75
1:30-1:45	0	0	0	0	3	3	1	0	0	7	4.75
1:45-2:00	0	0	0	0	2	5	0	0	0	7	3.25
Total	0	0	0	0	9	15	4	0	0	28	16.75

Maitighar to Art Gallery											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	8	32	1	1	0	42	18
1:15-1:30	0	0	0	0	5	35	1	3	0	44	17.75
1:30-1:45	0	0	0	0	6	28	1	2	0	37	16
1:45-2:00	0	0	0	0	6	37	1	1	0	45	17.25
Total	0	0	0	0	25	132	4	7	0	168	69

A.6 OFF PEAK DAY 3

Table A-7 Off Peak Hour Traffic Volume and PCU: Day 3

Baneshwor to Maitighar Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	63	329	9	5	0	406	159.25
1:15-1:30	0	0	0	2	51	306	1	1	0	361	134.5
1:30-1:45	0	3	1	0	55	315	10	7	0	391	158.25
1:45-2:00	0	2	0	0	29	322	7	9	0	369	128.5
Total	0	5	1	2	198	1272	27	22	0	1527	580.5

Baneshwor to Maitighar Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	28	9	34	166	7	5	9	258	203
1:15-1:30	0	0	30	9	29	148	4	3	8	231	193.5
1:30-1:45	0	0	32	11	34	176	6	6	9	274	222.5
1:45-2:00	0	2	30	13	62	177	6	3	10	303	250.75
Total	0	2	120	42	159	667	23	17	36	1066	869.75

Baneshwor to DOR											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	2	0	8	11	1	1	0	23	18.75
1:15-1:30	0	0	0	0	4	9	0	0	0	13	6.25
1:30-1:45	0	0	0	0	3	7	0	0	0	10	4.75
1:45-2:00	0	0	0	1	4	11	0	0	0	16	9.25
Total	0	0	2	1	19	38	1	1	0	62	39

Baneshwor to Art Gallery											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	21	40	0	0	0	61	31
1:15-1:30	0	0	0	0	18	36	1	0	0	55	28
1:30-1:45	0	0	0	0	16	34	1	1	0	52	26.5
1:45-2:00	0	0	0	0	14	30	1	0	0	45	22.5
Total	0	0	0	0	69	140	3	1	0	213	108

DOR to Art Gallery											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	1	3	0	0	0	4	1.75
1:15-1:30	0	0	0	0	0	4	0	0	0	4	1
1:30-1:45	0	0	0	0	2	7	0	1	0	10	4.75
1:45-2:00	0	0	0	0	2	11	0	0	0	13	4.75
Total	0	0	0	0	5	25	0	1	0	31	12.25

DOR To Baneshwor											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	2	4	1	0	0	7	4
1:15-1:30	0	0	0	0	1	3	0	0	0	4	1.75
1:30-1:45	0	0	0	0	4	6	0	0	0	10	5.5
1:45-2:00	0	0	0	0	2	10	0	0	0	12	4.5
Total	0	0	0	0	9	23	1	0	0	33	15.75

DOR to Maitighar											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	3	3	0	0	0	6	3.75
1:15-1:30	0	0	0	0	1	7	1	0	0	9	3.75
1:30-1:45	0	0	0	0	0	5	0	0	0	5	1.25
1:45-2:00	0	0	0	0	1	5	0	0	0	6	2.25
Total	0	0	0	0	5	15	1	0	0	26	11

Art Gallery to Maitighar Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	1	7	32	0	0	0	40	17.5
1:15-1:30	0	1	0	0	10	23	0	0	0	34	17.25
1:30-1:45	0	0	0	1	8	30	1	1	0	41	20
1:45-2:00	0	0	0	0	9	25	1	0	0	35	16.25
Total	0	1	0	2	34	110	2	1	0	150	71

Art Gallery to Maitighar Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
1:00-1:15	0	0	0	0	8	12	0	0	0	20	11
1:15-1:30	0	0	0	0	12	14	0	0	0	26	15.5
1:30-1:45	0	0	0	0	6	11	1	0	0	18	9.75
1:45-2:00	0	0	0	0	8	13	1	1	0	23	13.25
Total	0	0	0	0	34	50	2	1	0	87	49.5

Art Gallery to DOR											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	12	37	1	0	0	50	22.25
9:45-10:00	0	0	0	0	8	26	2	0	0	36	16.5
10:00-10:15	0	0	0	0	9	24	2	0	0	35	17
10:15-10:30	0	0	0	0	10	27	0	1	0	38	17.75
Total	0	0	0	0	39	114	5	1	0	159	73.5

Art Gallery to Baneshwor Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	16	32	2	1	0	51	27
9:45-10:00	0	0	0	0	11	22	0	0	0	33	16.5
10:00-10:15	0	0	0	0	14	38	1	2	0	55	26.5
10:15-10:30	0	0	0	0	13	29	2	1	0	45	23.25
Total	0	0	0	0	54	121	5	4	0	184	93.25

Art Gallery to Baneshwor Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	1	15	70	1	0	0	87	36
9:45-10:00	0	0	0	0	18	56	0	0	0	74	32
10:00-10:15	0	0	0	0	22	88	1	1	0	112	46
10:15-10:30	0	0	0	0	18	66	1	0	0	85	35.5
Total	0	0	0	1	73	280	2	1	0	358	149.5

Maitighar to Baneshwor Service Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	35	8	25	82	2	6	8	166	186.5
9:45-10:00	0	0	30	5	21	91	3	8	7	165	164.25
10:00-10:15	0	0	28	10	33	93	7	15	8	194	195.25
10:15-10:30	0	0	33	4	28	108	6	10	12	201	192
Total	0	0	126	27	107	374	18	39	35	726	738

Maitighar to Baneshwor Main Lane											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	1	0	52	351	3	5	2	414	152.75
9:45-10:00	0	0	0	0	68	325	9	3	0	405	161.25
10:00-10:15	0	0	0	0	62	295	6	6	3	372	150.75
10:15-10:30	0	0	1	1	48	365	7	8	2	432	161.75
Total	0	0	2	1	230	1336	25	22	7	1623	626.75

Maitighar to DOR											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	0	3	0	0	0	3	0.75
9:45-10:00	0	0	0	0	3	2	0	0	0	5	3.5
10:00-10:15	0	0	0	0	2	3	0	0	0	5	2.75
10:15-10:30	0	0	0	0	1	3	0	0	0	4	1.75
Total	0	0	0	0	6	11	0	0	0	17	8.75

Maitighar to Art Gallery											
Time	**Heavy Truck**	**Mini Truck**	**Bus**	**Micro Bus**	**Car**	**Bike**	**LUV**	**Pick up**	**Tempo**	**Total**	**PCU**
9:30-9:45	0	0	0	0	10	30	1	2	0	43	20.5
9:45-10:00	0	0	0	0	5	34	0	6	0	45	19.5
10:00-10:15	0	0	0	0	4	25	2	5	0	36	17.25
10:15-10:30	0	0	0	0	8	33	1	3	0	45	20.25
Total	0	0	0	0	27	122	4	16	0	169	77.75

B ANNEX II (RESULT COMPARISON)

B.1 PEAK DAY 1 RESULT COMPARISON

Table B-1 Queue Delay Comparision: Peak Day 1

Queue Delay			
Directions	scenario 1	scenario 2	scenario 3
Art Gallery to Anamnagar	46.17	53.50	53.63
Art Gallery to Maitighar Service	39.39	44.19	48.07
Art Gallery to Babarmahal Service	42.25	51.30	52.44
Art Gallery to Babarmahal Main	48.25	54.27	57.16
Art Gallery to Maitighar Main	52.51	50.83	60.12
Maitighar Service to Anamnagar	28.43	30.49	26.09
Maitighar Service to Babarmahal Service	45.05	44.57	31.40
Maitighar Main to Art Gallery	139.64	136.07	98.80
Maitighar Main to Babarmahal Main	51.40	52.32	34.55
Anamnagar to Art Gallery	79.21	83.77	60.14
Anamnagar to Babarmahal Service	50.00	55.28	32.18
Anamnagar to Maitighar Main	44.59	36.73	46.01
Babarmahal Service to Art Gallery	41.74	42.46	30.56
Babarmahal Service to Maitighar Service	48.31	49.32	34.99
Babarmahal Main to Anamnagar	107.91	125.67	71.54
Babarmahal Main to Maitighar Main	67.17	75.65	46.90
Overall Intersection	59.60	64.16	43.73

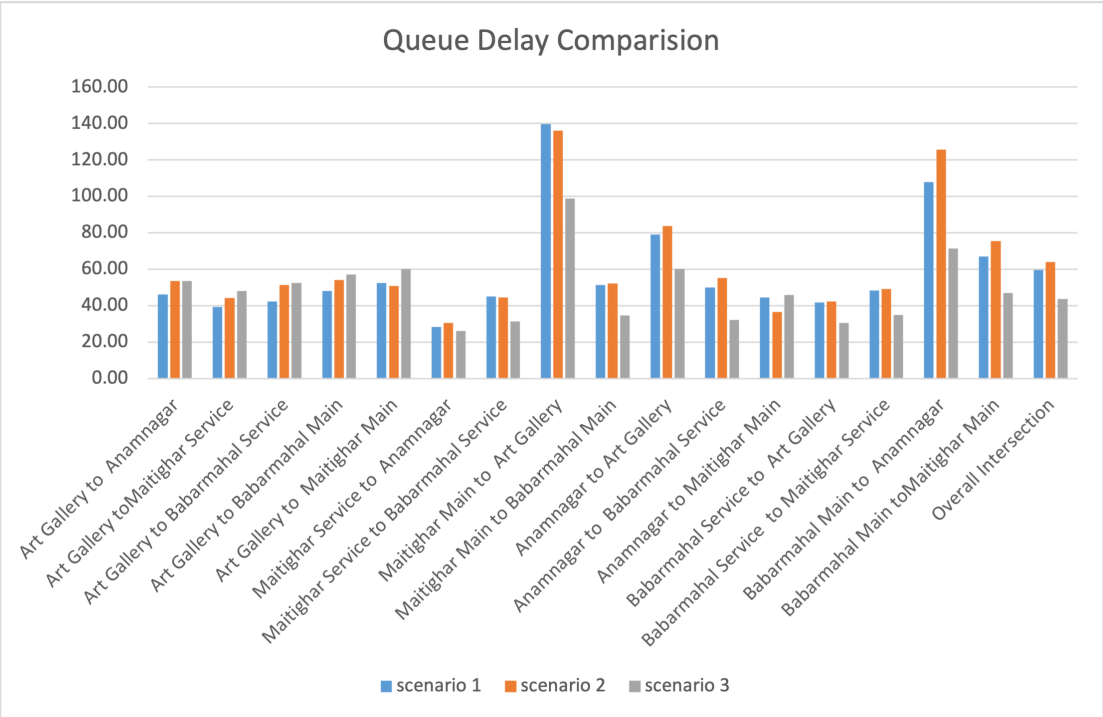


Figure B-1 Queue Delay Comparision: Peak Day 1

Table B-2 Queue Length Comparision: Peak Day 1

Queue Length			
Directions	scenario 1	scenario 2	scenario 3
Art Gallery to Intersection	20.63	23.56	26.24
Babarmahal Service to Intersection	31.31	31.46	21.15
Anamnagar to Intersection	7.22	7.50	5.15
Maitighar Service to Babarmahal Service	19.67	19.59	13.99
Maitighar Main to Intersection	39.18	39.83	26.17
Babarmahal Main to Anamnagar	54.47	63.96	36.01
Babarmahal Main to Maitighar Main	71.64	82.75	45.92

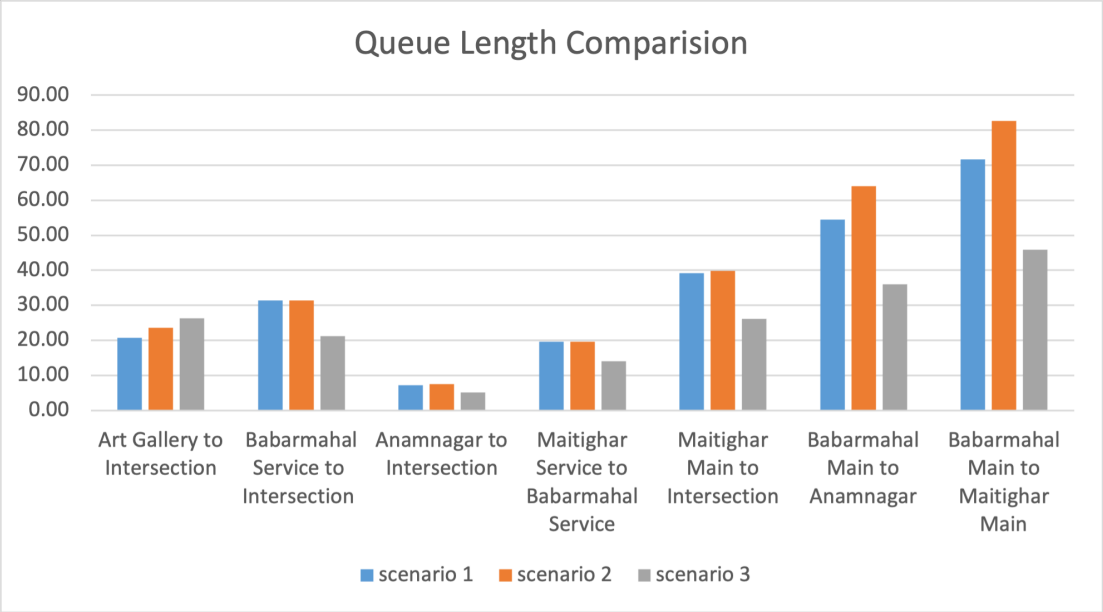


Figure B-2 Queue Length Comparision: Peak Day 1

Table B-3 Vehicle Travel Time Comparision: Peak Day 1

Vehicle Travel Time			
Directions	scenario 1	scenario 2	scenario 3
Babarmahal Main to Maitighar Main	57.72	63.19	48.73
Babarmahal Main to Anamnagar	103.68	120.09	81.53
Babarmahal Service to Maitighar Service	59.00	60.41	47.51
Maitighar Main to Art Gallery	144.55	142.49	110.29
Maitighar Main to Babarmahal Main	52.71	51.46	44.17
Maitighar Service to Babarmahal Service	57.89	55.77	45.71
Anamnagar to Art Gallery	93.14	91.56	73.91
Anamnagar to Maitighar Main	61.52	48.82	61.94
Art Gallery to Anamnagar	57.23	49.89	65.44
Art Gallery to Maitighar Main	63.70	39.31	70.05
Art Gallery to Babarmahal Main	60.24	42.41	69.17
Art Gallery to Babarmahal Service	54.37	45.31	62.77

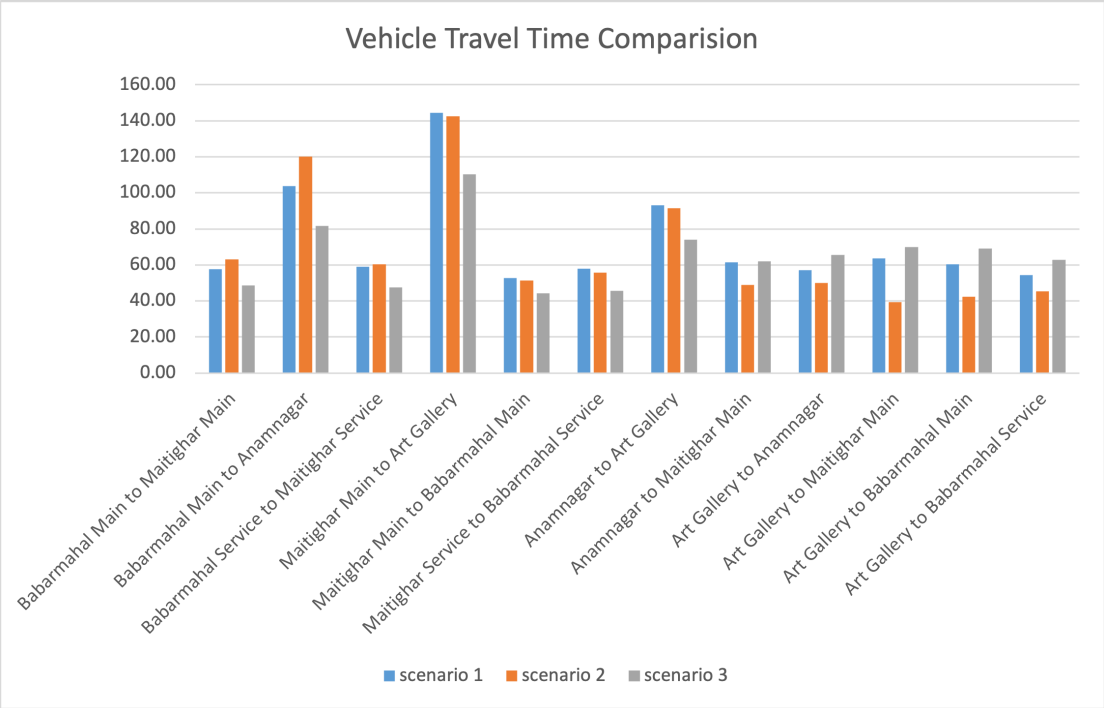


Figure B-3 Vehicle Travel Time Comparision: Peak Day 1

Table B-4 LOS Comparision: Peak Day 1

LOS			
Directions	scenario 1	scenario 2	scenario 3
Art Gallery to Anamnagar	LOS_D	LOS_D	LOS_D
Art Gallery toMaitighar Service	LOS_D	LOS_D	LOS_D
Art Gallery to Babarmahal Service	LOS_D	LOS_D	LOS_D
Art Gallery to Babarmahal Main	LOS_D	LOS_D	LOS_E
Art Gallery to Maitighar Main	LOS_D	LOS_D	LOS_E
Maitighar Service to Anamnagar	LOS_C	LOS_C	LOS_C
Maitighar Service to Babarmahal Service	LOS_D	LOS_D	LOS_C
Maitighar Main to Art Gallery	LOS_F	LOS_F	LOS_F
Maitighar Main to Babarmahal Main	LOS_D	LOS_D	LOS_C
Anamnagar to Art Gallery	LOS_E	LOS_F	LOS_E
Anamnagar to Babarmahal Service	LOS_D	LOS_E	LOS_C
Anamnagar to Maitighar Main	LOS_D	LOS_D	LOS_D
Babarmahal Service to Art Gallery	LOS_D	LOS_D	LOS_C
Babarmahal Service to Maitighar Service	LOS_D	LOS_D	LOS_C
Babarmahal Main to Anamnagar	LOS_F	LOS_F	LOS_E
Babarmahal Main toMaitighar Main	LOS_E	LOS_E	LOS_D
Overall Intersection	LOS_E	LOS_E	LOS_D

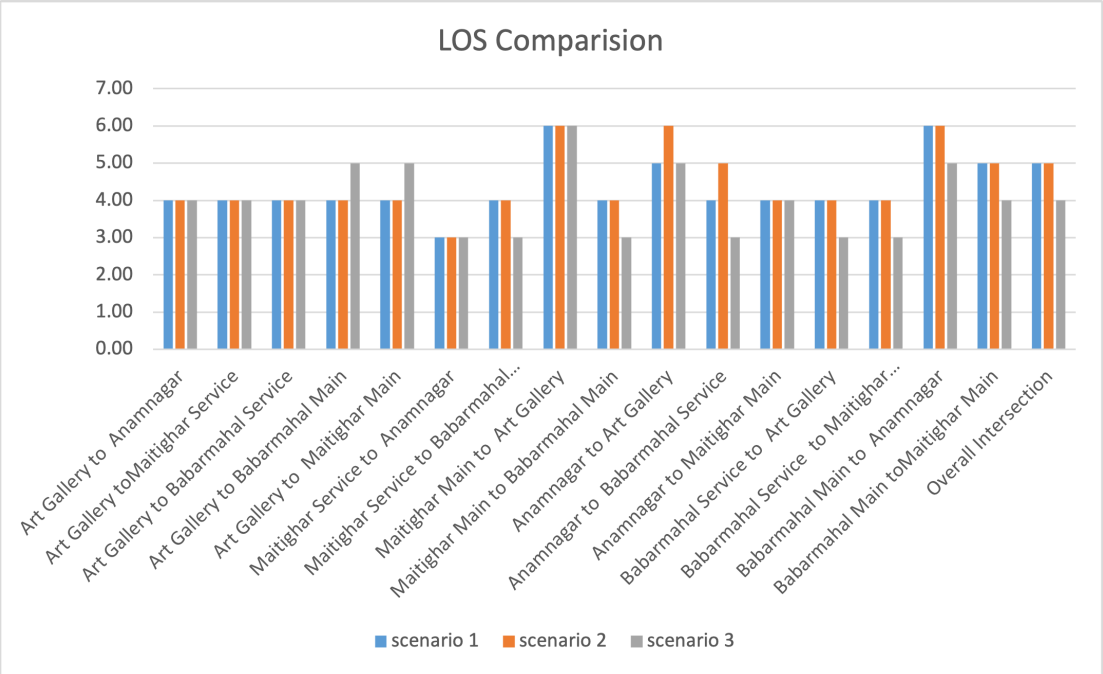


Figure B-4 LOS Comparision

B.2 PEAK DAY 2 RESULT COMPARISION

Table B-5 Queue Delay Comparision: Peak Day 2

Queue Delay			
Directions	scenario 1	scenario 2	scenario 3
Art Gallery to Anamnagar	83.927	53.50	46.112
Art Gallery toMaitighar Service	74.487	44.19	37.148
Art Gallery to Babarmahal Service	72.738	51.30	36.699
Art Gallery to Babarmahal Main	82.446	54.27	49.890
Art Gallery to Maitighar Main	81.719	50.83	49.847
Maitighar Service to Anamnagar	21.723	30.49	13.788
Maitighar Service to Babarmahal Service	36.147	44.57	32.289
Maitighar Main to Art Gallery	114.367	136.07	93.399
Maitighar Main to Babarmahal Main	35.509	52.32	35.961
Anamnagar to Art Gallery	59.620	83.77	74.915
Anamnagar to Babarmahal Service	29.259	55.28	40.494
Anamnagar to Maitighar Main	87.627	36.73	85.363
Babarmahal Service to Art Gallery	33.654	42.46	34.984
Babarmahal Service to Maitighar Service	27.986	49.32	26.996
Babarmahal Main to Anamnagar	269.808028	125.67	72.861
Babarmahal Main toMaitighar Main	41.454424	75.65	35.926
Overall Intersection	62.384129	64.16	39.757

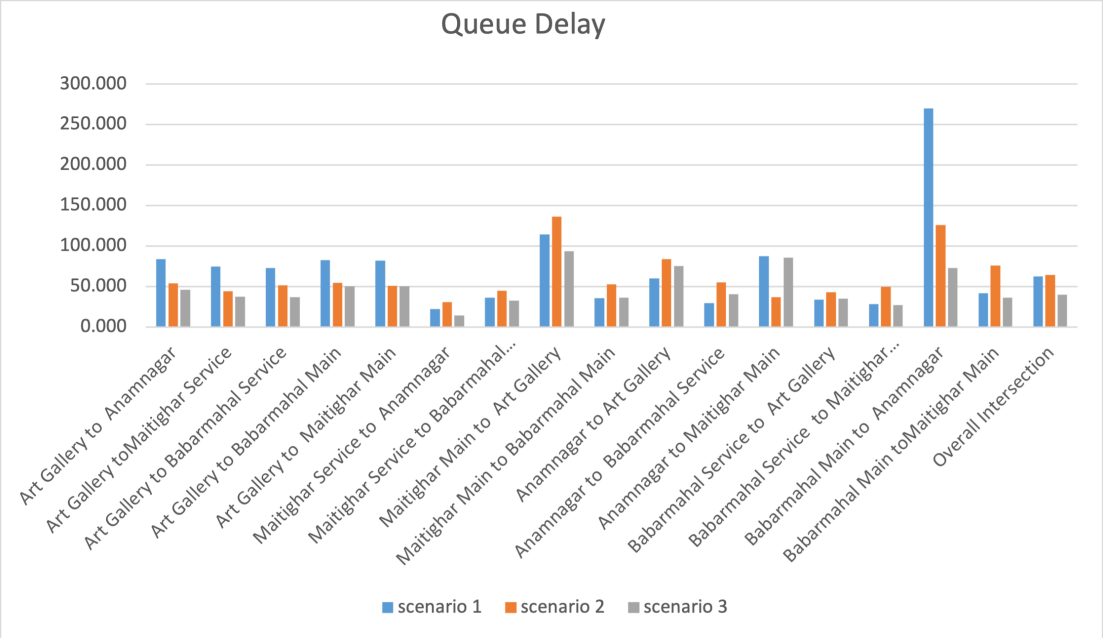


Figure B-5 Queue Delay Comparision: Peak Day 2

Table B-6 Queue Length Comparision: Peak Day 2

Queue Length			
Directions	scenario 1	scenario 2	scenario 3
Art Gallery to Intersection	38.42	17.45	21.15
Babarmahal Service to Intersection	19.88	34.02	18.21
Anamnagar to Intersection	5.40	7.74	7.02
Maitighar Service to Babarmahal Service	18.74	25.18	16.71
Maitighar Main to Intersection	27.19	31.15	23.64
Babarmahal Main to Anamnagar	155.46	41.12	38.24
Babarmahal Main to Maitighar Main	42.28	61.57	33.17

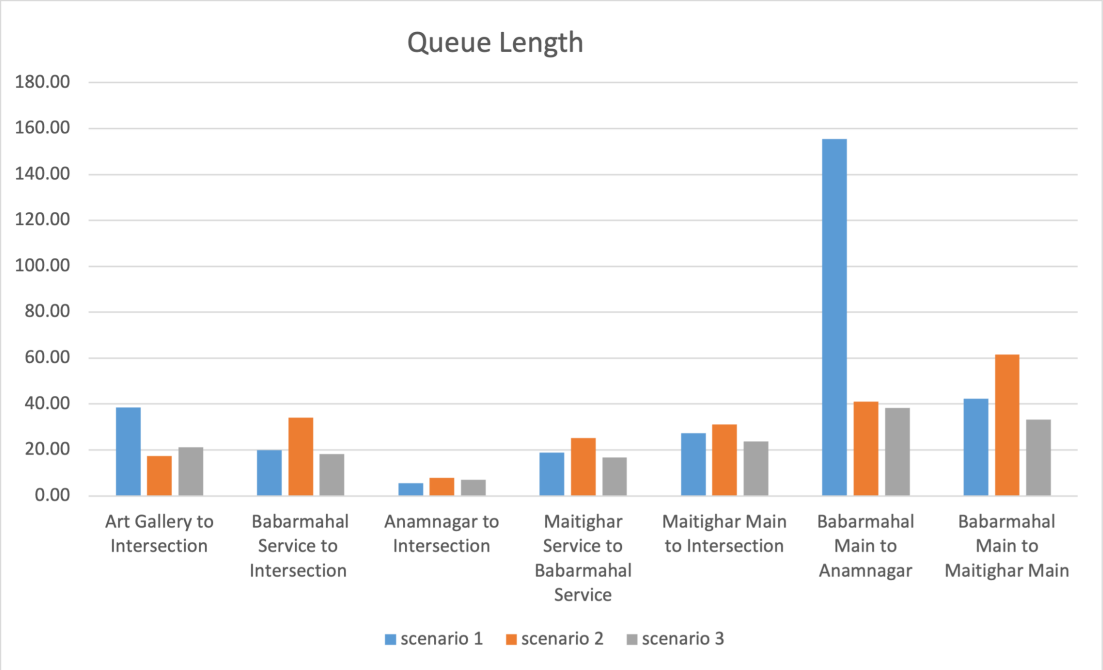


Figure B-6 Queue Length Comparision: Peak Day 2

Table B-7 Vehicle Travel Time Comparision: Peak Day 2

Vehicle Travel Time			
Directions	scenario 1	scenario 2	scenario 3
Babarmahal Main to Maitighar Main	43.05	46.91	41.06
Babarmahal Main to Anamnagar	140.49	69.57	80.30
Babarmahal Service to Maitighar Service	126.53	56.09	105.84
Maitighar Main to Art Gallery	45.53	139.99	46.02
Maitighar Main to Babarmahal Main	48.32	60.34	45.86
Maitighar Service to Babarmahal Service	73.03	59.75	88.44
Anamnagar to Art Gallery	106.32	118.49	103.97
Anamnagar to Maitighar Main	92.57	0.00	65.80
Art Gallery to Anamnagar	89.75	54.02	65.52
Art Gallery to Maitighar Main	81.79	57.23	53.07
Art Gallery to Babarmahal Main	41.19	53.80	39.49
Art Gallery to Babarmahal Service	89.23	57.46	61.45

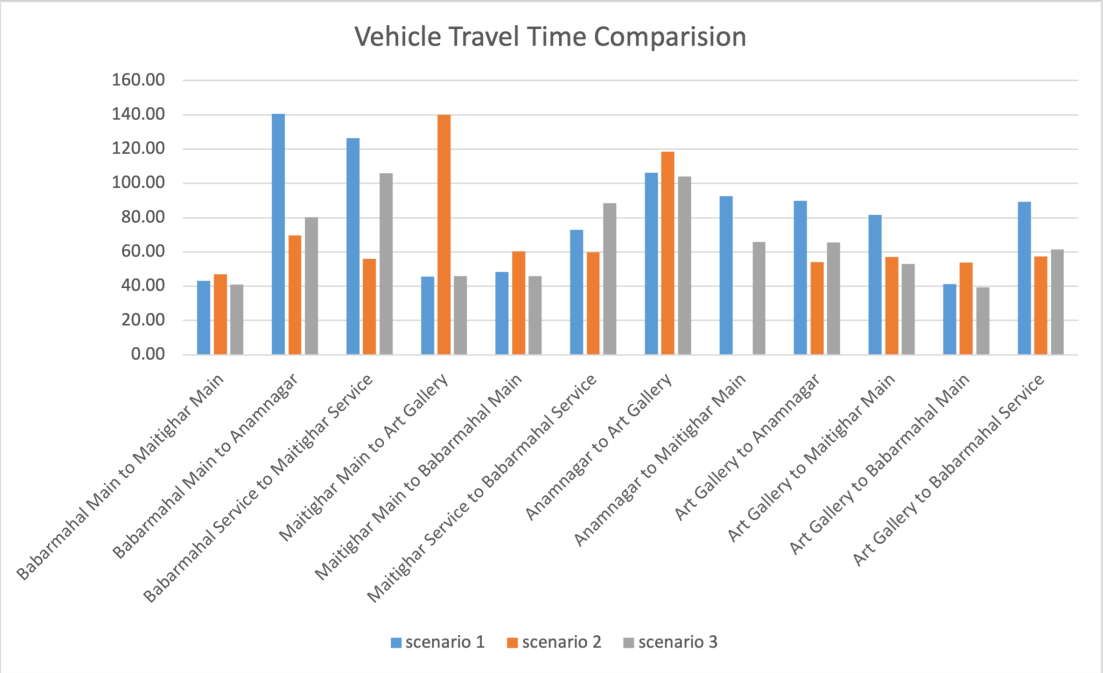


Figure B-7 Vehicle Travel Time Comparision: Peak Day 2

Table B-8 LOS Comparision: Peak Day 2

LOS			
Directions	scenario 1	scenario 2	scenario 3
Art Gallery to Anamnagar	LOS_F	LOS_D	LOS_D
Art Gallery toMaitighar Service	LOS_E	LOS_D	LOS_D
Art Gallery to Babarmahal Service	LOS_E	LOS_D	LOS_D
Art Gallery to Babarmahal Main	LOS_F	LOS_D	LOS_D
Art Gallery to Maitighar Main	LOS_F	LOS_D	LOS_D
Maitighar Service to Anamnagar	LOS_C	LOS_C	LOS_B
Maitighar Service to Babarmahal Service	LOS_D	LOS_D	LOS_C
Maitighar Main to Art Gallery	LOS_F	LOS_F	LOS_F
Maitighar Main to Babarmahal Main	LOS_D	LOS_D	LOS_D
Anamnagar to Art Gallery	LOS_E	LOS_F	LOS_E
Anamnagar to Babarmahal Service	LOS_C	LOS_E	LOS_D
Anamnagar to Maitighar Main	LOS_F	LOS_D	LOS_F
Babarmahal Service to Art Gallery	LOS_C	LOS_D	LOS_C
Babarmahal Service to Maitighar Service	LOS_C	LOS_D	LOS_C
Babarmahal Main to Anamnagar	LOS_F	LOS_F	LOS_E
Babarmahal Main toMaitighar Main	LOS_D	LOS_E	LOS_D
Overall Intersection	LOS_E	LOS_E	LOS_D

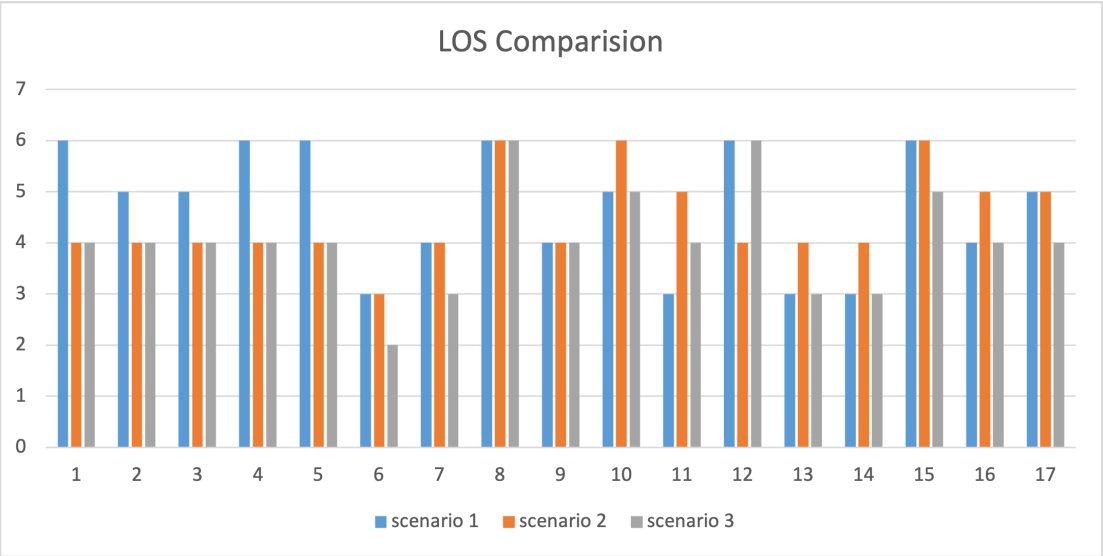


Figure B-8 LOS Comparision: Peak Day 2

B.3 PEAK DAY 3 RESULT COMPARISON

Table B-9 Queue Delay Comparision: Peak Day 3

Queue Delay			
Directions	scenario 1	scenario 2	scenario 3
Art Gallery to Anamnagar	80.23	40.59	51.72
Art Gallery toMaitighar Service	67.92	33.95	48.01
Art Gallery to Babarmahal Service	74.53	44.47	54.56
Art Gallery to Babarmahal Main	79.76	40.74	54.16
Art Gallery to Maitighar Main	96.58	44.37	52.37
Maitighar Service to Anamnagar	11.98	40.36	14.41
Maitighar Service to Babarmahal Service	32.96	47.10	32.56
Maitighar Main to Art Gallery	125.94	125.99	95.16
Maitighar Main to Babarmahal Main	37.44	48.59	33.97
Anamnagar to Art Gallery	77.27	105.16	75.21
Anamnagar to Babarmahal Service	43.87	55.50	35.54
Anamnagar to Maitighar Main	0.00	0.00	0.00
Babarmahal Service to Art Gallery	28.35	49.74	31.60
Babarmahal Service to Maitighar Service	36.10	51.09	35.50
Babarmahal Main to Anamnagar	332.17	75.89	94.72
Babarmahal Main toMaitighar Main	47.81	64.16	44.91
Overall Intersection	71.96	56.44	46.05

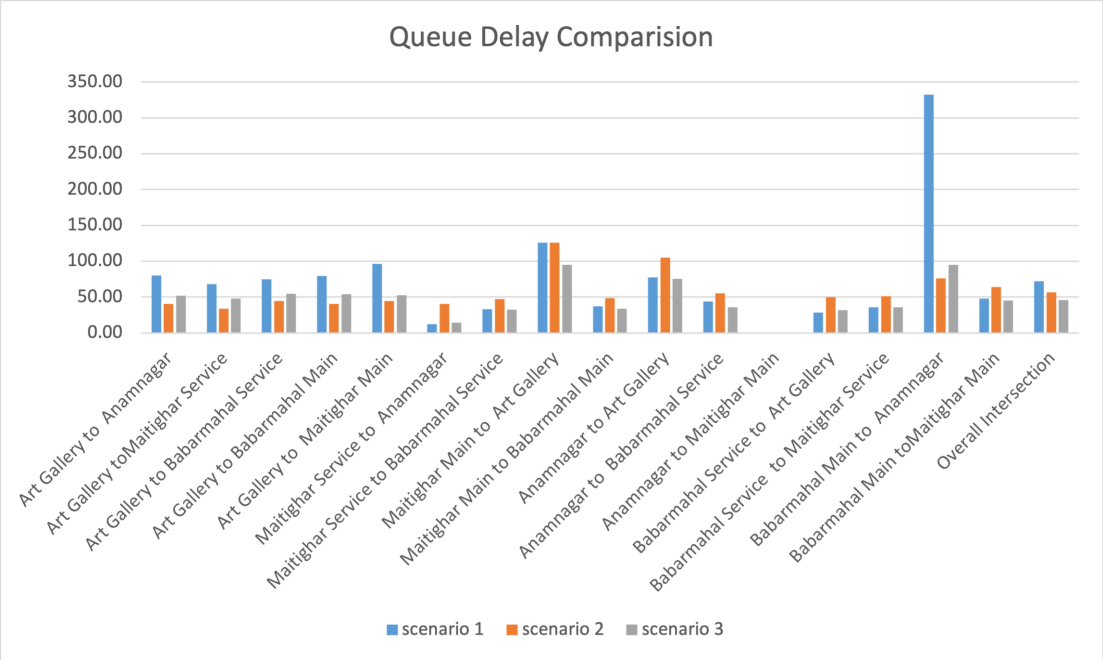


Figure B-9 Queue Delay Comparision

Table B-10 Queue Length Comparision: Peak Day 3

Queue Length			
Directions	scenario 1	scenario 2	scenario 3
Art Gallery to Intersection	35.67	17.45	23.40
Babarmahal Service to Intersection	20.50	34.02	21.28
Anamnagar to Intersection	5.83	7.74	5.41
Maitighar Service to Babarmahal Service	15.74	25.18	16.18
Maitighar Main to Intersection	29.77	31.15	22.50
Babarmahal Main to Anamnagar	224.82	41.12	56.35
Babarmahal Main to Maitighar Main	50.32	61.57	44.29

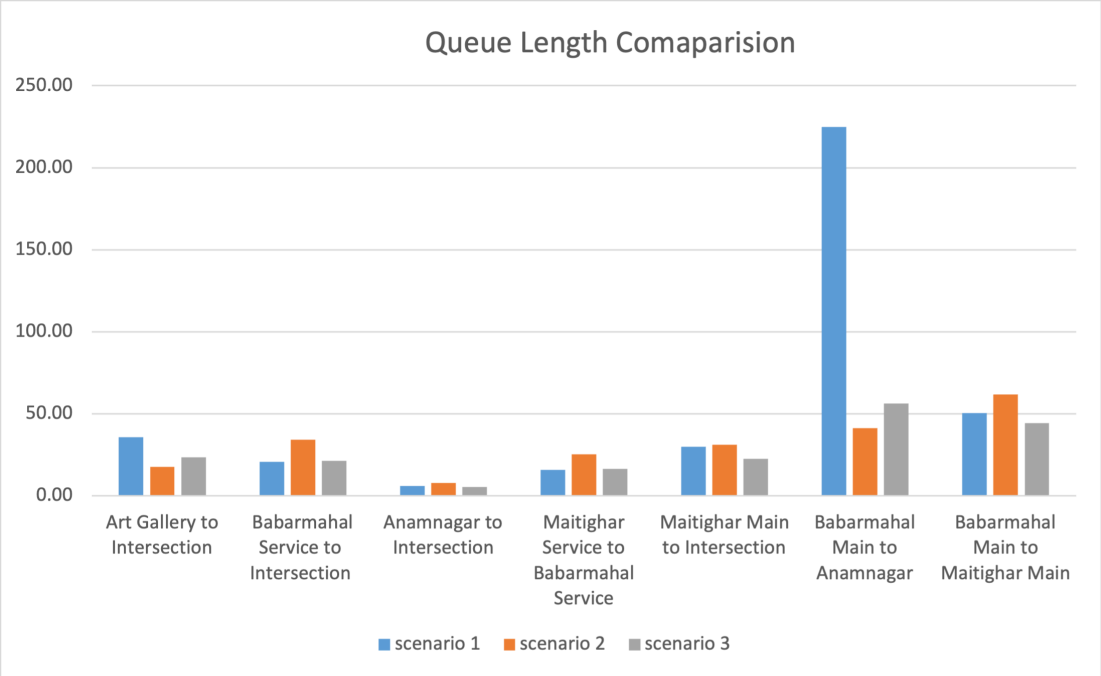


Figure B-10 Queue Length Comparision

Table B-11 Vehicle Travel Time Comparision: Peak Day 3

Vehicle Travel Time			
Directions	scenario 1	scenario 2	scenario 3
Babarmahal Main to Maitighar Main	46.46	46.91	45.88
Babarmahal Main to Anamnagar	147.02	69.57	93.11
Babarmahal Service to Maitighar Service	48.61	56.09	48.02
Maitighar Main to Art Gallery	136.59	139.99	108.61
Maitighar Main to Babarmahal Main	46.80	60.34	44.87
Maitighar Service to Babarmahal Service	46.92	59.75	46.66
Anamnagar to Art Gallery	91.19	118.49	88.99
Anamnagar to Maitighar Main	0.00	0.00 0.	00
Art Gallery to Anamnagar	91.72	54.02	66.84
Art Gallery to Maitighar Main	106.67	57.23	68.25
Art Gallery to Babarmahal Main	92.28	53.80	70.45
Art Gallery to Babarmahal Service	87.54	57.46	70.12

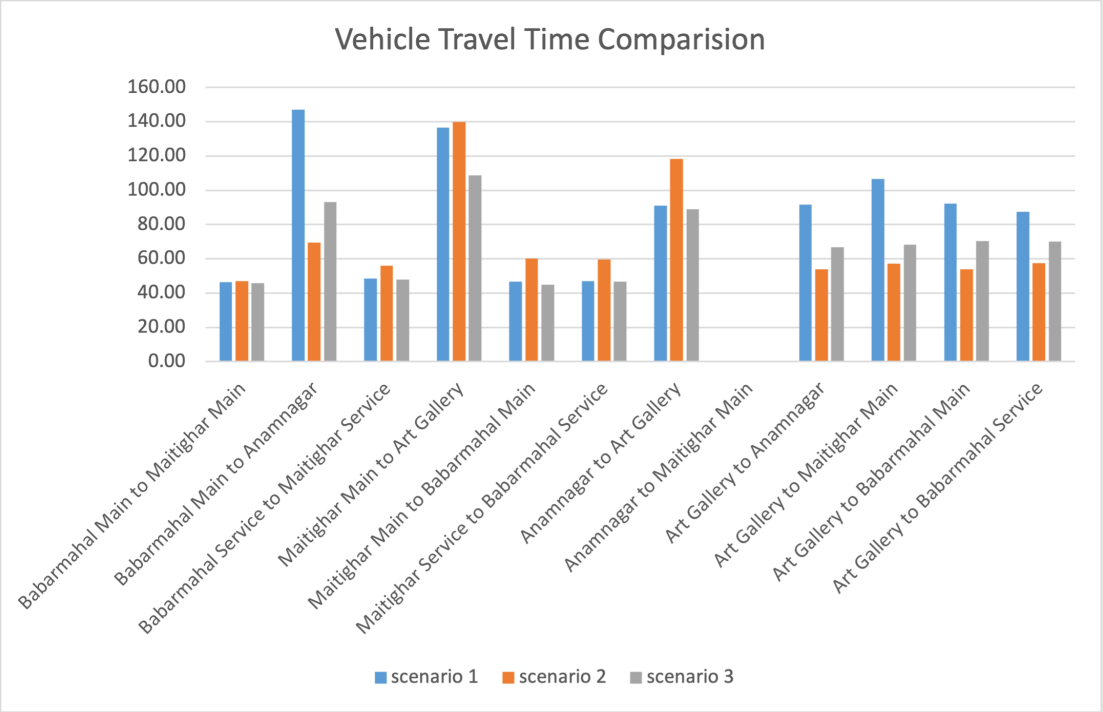


Figure B-11 Vehicle Travel Time Comparision

Table B-12 LOS Comparision: Peak Day 3

LOS			
Directions	scenario 1	scenario 2	scenario 3
Art Gallery to Anamnagar	LOS_F	LOS_D	LOS_D
Art Gallery toMaitighar Service	LOS_E	LOS_C	LOS_D
Art Gallery to Babarmahal Service	LOS_E	LOS_D	LOS_D
Art Gallery to Babarmahal Main	LOS_E	LOS_D	LOS_D
Art Gallery to Maitighar Main	LOS_F	LOS_D	LOS_D
Maitighar Service to Anamnagar	LOS_B	LOS_D	LOS_B
Maitighar Service to Babarmahal Service	LOS_C	LOS_D	LOS_C
Maitighar Main to Art Gallery	LOS_F	LOS_F	LOS_F
Maitighar Main to Babarmahal Main	LOS_D	LOS_D	LOS_C
Anamnagar to Art Gallery	LOS_E	LOS_F	LOS_E
Anamnagar to Babarmahal Service	LOS_D	LOS_E	LOS_D
Anamnagar to Maitighar Main	LOS_A	LOS_A	LOS_A
Babarmahal Service to Art Gallery	LOS_C	LOS_D	LOS_C
Babarmahal Service to Maitighar Service	LOS_D	LOS_D	LOS_D
Babarmahal Main to Anamnagar	LOS_F	LOS_E	LOS_F
Babarmahal Main toMaitighar Main	LOS_D	LOS_E	LOS_D
Overall Intersection	LOS_E	LOS_E	LOS_D

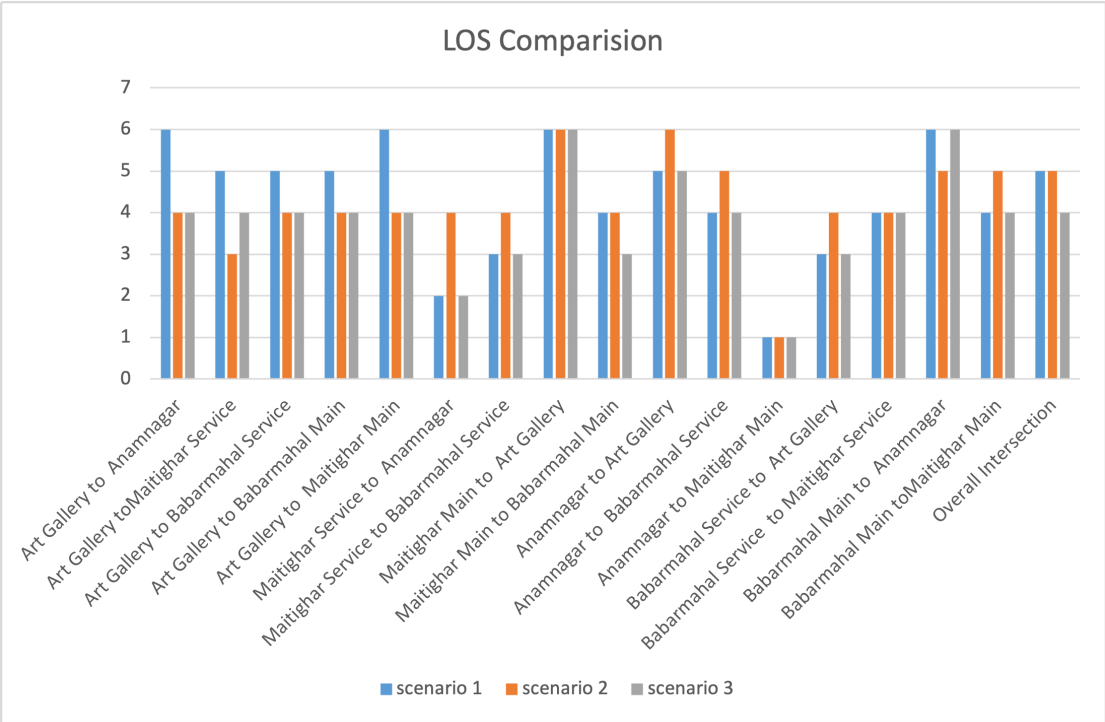


Figure B-12 LOS Comparision

B.4 OFF PEAK DAY 1 RESULT COMPARISON

Table B-13 Queue Delay Comparision: Off Peak Day 1

Queue Delay			
Directions	scenario 1	scenario 2	scenario 3
Art Gallery to Anamnagar	79.14	59.38	47.19
Art Gallery toMaitighar Service	68.53	43.35	36.68
Art Gallery to Babarmahal Service	76.47	48.45	47.41
Art Gallery to Babarmahal Main	71.43	42.48	46.20
Art Gallery to Maitighar Main	74.84	48.98	47.58
Maitighar Service to Anamnagar	16.71	27.70	7.78
Maitighar Service to Babarmahal Service	26.68	40.29	15.47
Maitighar Main to Art Gallery	105.69	107.9	0 29.68
Maitighar Main to Babarmahal Main	30.83	44.03	16.13
Anamnagar to Art Gallery	59.87	80.24	37.30
Anamnagar to Babarmahal Service	30.09	37.24	10.72
Anamnagar to Maitighar Main	70.54	81.18	32.80
Babarmahal Service to Art Gallery	27.44	37.52	15.16
Babarmahal Service to Maitighar Service	34.16	46.64	18.10
Babarmahal Main to Anamnagar	72.30	54.97	22.64
Babarmahal Main toMaitighar Main	40.81	54.84	23.09
Overall Intersection	41.49	48.83	22.51

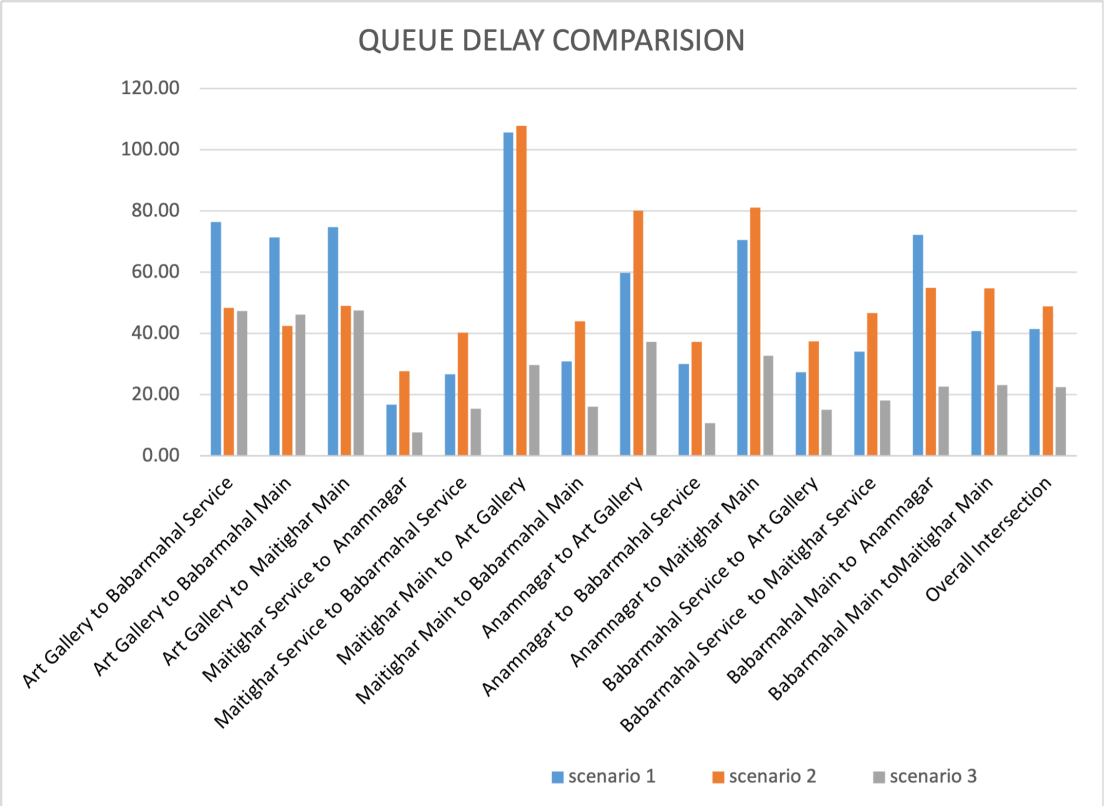


Figure B-13 Queue Delay Comparision

Table B-14 Queue Length Comparision: Off Peak Day 1

Queue Length			
Directions	scenario 1	scenario 2	scenario 3
Art Gallery to Intersection	35.84	22.45	22.16
Babarmahal Service to Intersection	20.21	28.31	11.34
Anamnagar to Intersection	4.13	5.13	1.80
Maitighar Service to Babarmahal Service	10.62	17.08	6.57
Maitighar Main to Intersection	17.14	22.11	2.72
Babarmahal Main to Anamnagar	3.88	2.75	0.07
Babarmahal Main to Maitighar Main	30.84	40.83	13.66

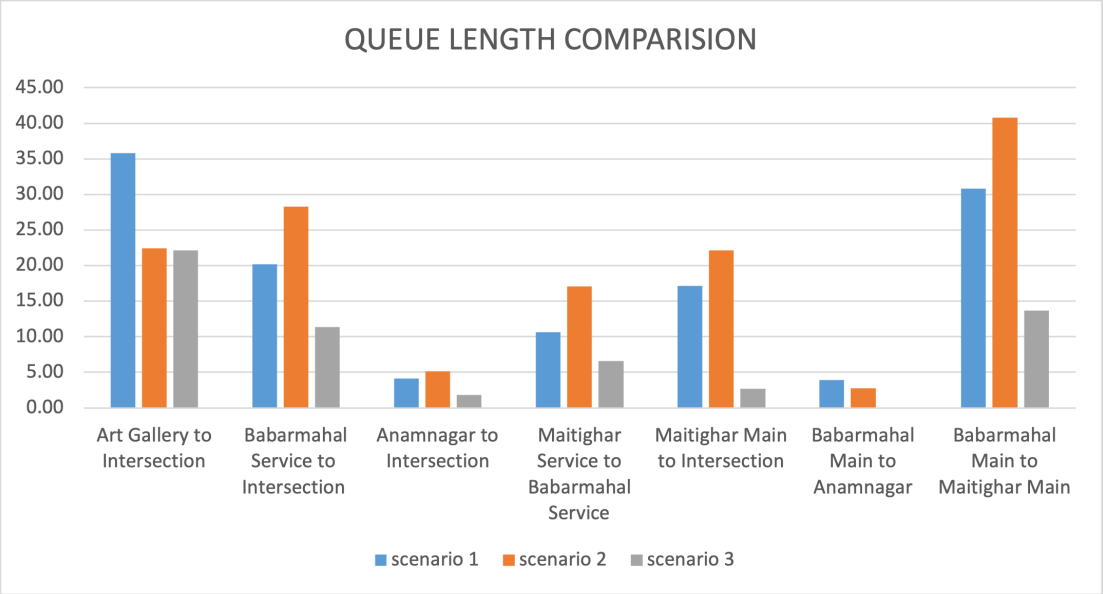


Figure B-14 Queue Length Comparision

Table B-15 Vehicle Travel Time Comparision: Off Peak Day 1

Vehicle Travel Time			
Directions	scenario 1	scenario 2	scenario 3
Babarmahal Main to Maitighar Main	40.86	62.06	33.58
Babarmahal Main to Anamnagar	88.43	71.01	38.82
Babarmahal Service to Maitighar Service	46.14	58.95	32.22
Maitighar Main to Art Gallery	120.34	109.79	44.60
Maitighar Main to Babarmahal Main	43.38	48.81	29.08
Maitighar Service to Babarmahal Service	42.57	49.66	31.56
Anamnagar to Art Gallery	74.60	94.69	51.85
Anamnagar to Maitighar Main	89.34	99.60	51.57
Art Gallery to Anamnagar	69.92	67.38	60.67
Art Gallery to Maitighar Main	89.34	62.08	61.85
Art Gallery to Babarmahal Main	55.27	50.88	58.83
Art Gallery to Babarmahal Service	66.20	58.91	55.05

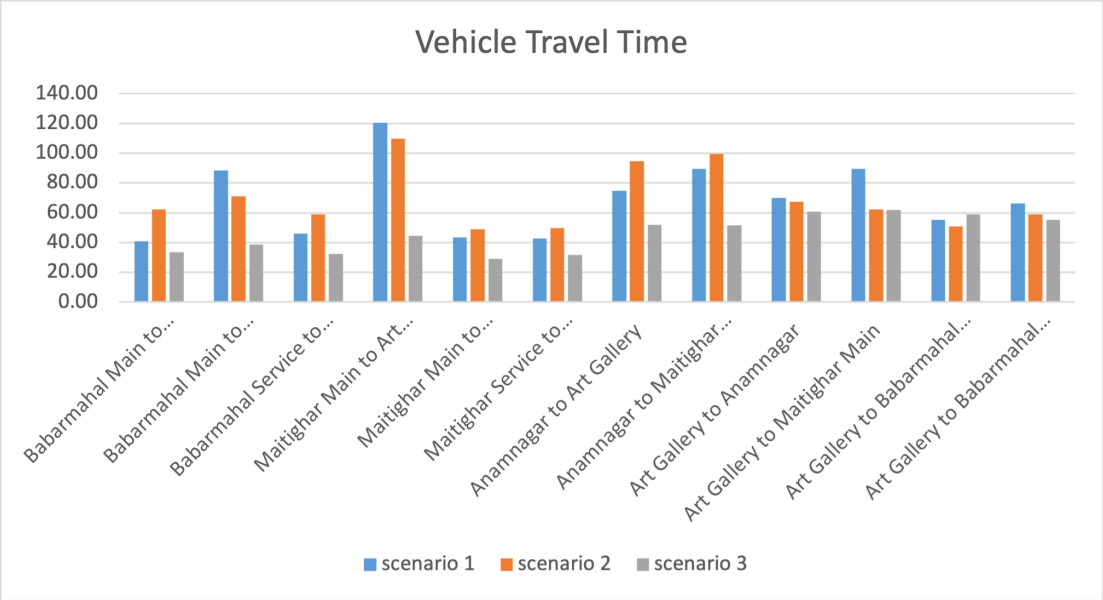


Figure B-15 Vehicle Travel Time Comparision

Table B-16 LOS Comparision: Off Peak Day 1

LOS			
Directions	scenario 1	scenario 2	scenario 3
Art Gallery to Anamnagar	LOS_E	LOS_E	LOS_D
Art Gallery toMaitighar Service	LOS_E	LOS_D	LOS_D
Art Gallery to Babarmahal Service	LOS_E	LOS_D	LOS_D
Art Gallery to Babarmahal Main	LOS_E	LOS_D	LOS_D
Art Gallery to Maitighar Main	LOS_E	LOS_D	LOS_D
Maitighar Service to Anamnagar	LOS_B	LOS_C	LOS_A
Maitighar Service to Babarmahal Service	LOS_C	LOS_D	LOS_B
Maitighar Main to Art Gallery	LOS_F	LOS_F	LOS_C
Maitighar Main to Babarmahal Main	LOS_C	LOS_D	LOS_B
Anamnagar to Art Gallery	LOS_E	LOS_F	LOS_D
Anamnagar to Babarmahal Service	LOS_C	LOS_D	LOS_B
Anamnagar to Maitighar Main	LOS_E	LOS_F	LOS_C
Babarmahal Service to Art Gallery	LOS_C	LOS_D	LOS_B
Babarmahal Service to Maitighar Service	LOS_C	LOS_D	LOS_B
Babarmahal Main to Anamnagar	LOS_E	LOS_D	LOS_C
Babarmahal Main toMaitighar Main	LOS_D	LOS_D	LOS_C
Overall Intersection	LOS_D	LOS_D	LOS_C

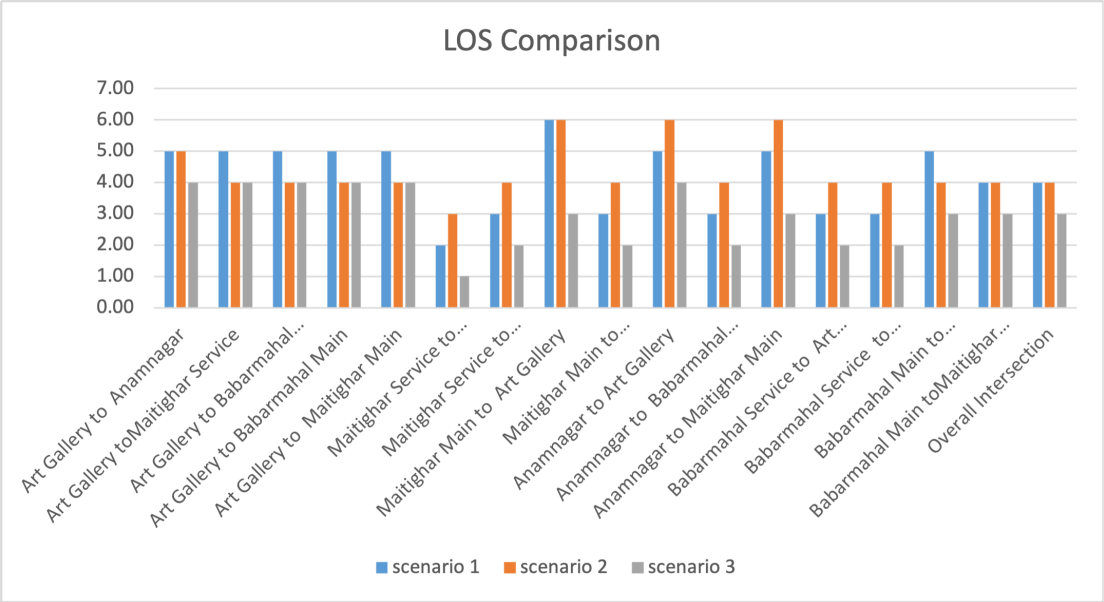


Figure B-16 LOS Comparision

B.5 OFF PEAK DAY 2

Table B-17 Queue Delay Comparision: Off Peak Day 2

Queue Delay			
Directions	scenario 1	scenario 2	scenario 3
Art Gallery to Anamnagar	100.92	53.14	80.25
Art Gallery toMaitighar Service	90.40	41.62	69.80
Art Gallery to Babarmahal Service	107.71	53.55	79.62
Art Gallery to Babarmahal Main	101.05	53.85	80.09
Art Gallery to Maitighar Main	91.80	46.38	67.29
Maitighar Service to Anamnagar	18.22	35.16	5.82
Maitighar Service to Babarmahal Service	32.06	50.20	15.21
Maitighar Main to Art Gallery	115.77	120.77	30.55
Maitighar Main to Babarmahal Main	34.31	57.74	16.58
Anamnagar to Art Gallery	61.39	75.54	40.88
Anamnagar to Babarmahal Service	37.33	44.51	15.38
Anamnagar to Maitighar Main	89.22	82.17	33.90
Babarmahal Service to Art Gallery	28.77	46.77	13.68
Babarmahal Service to Maitighar Service	34.97	54.61	17.31
Babarmahal Main to Anamnagar	55.85	45.02	21.89
Babarmahal Main toMaitighar Main	37.48	65.49	23.71
Overall Intersection	45.96	58.79	6.34

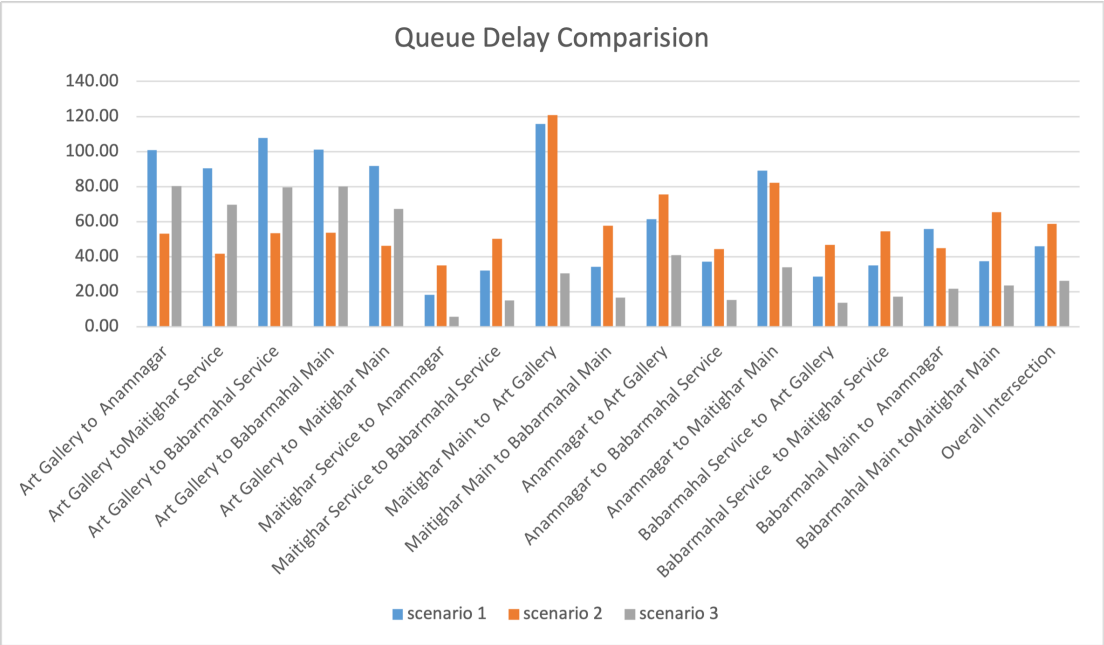


Figure B-17 Queue Delay Comparision

Table B-18 Queue Length Comparision: Off Peak Day 2

Queue Length			
Directions	scenario 1	scenario 2	scenario 3
Art Gallery to Intersection	52.82	27.12	39.74
Babarmahal Service to Intersection	19.56	31.09	9.86
Anamnagar to Intersection	4.44	4.99	2.26
Maitighar Service to Babarmahal Service	17.11	26.90	7.46
Maitighar Main to Intersection	24.66	37.41	5.34
Babarmahal Main to Anamnagar	3.63	2.56	1.05
Babarmahal Main to Maitighar Main	27.45	56.77	14.84

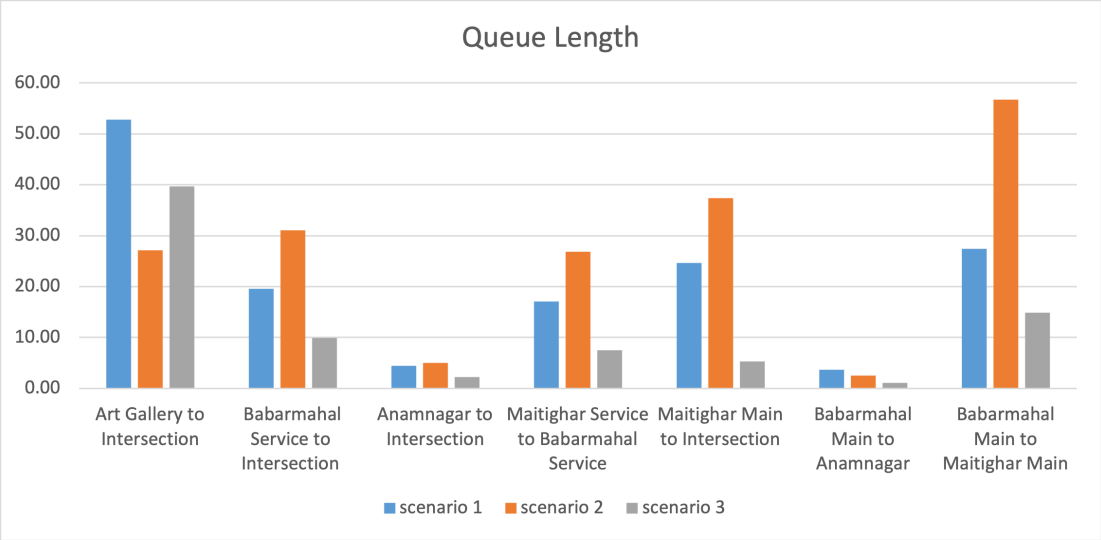


Figure B-18 Queue Length Comparision

Table B-19 Vehicle Travel Time Comparision: Off Peak Day 2

Vehicle Travel Time			
Directions	scenario 1	scenario 2	scenario 3
Babarmahal Main to Maitighar Main	46.33	46.33	34.02
Babarmahal Main to Anamnagar	48.67	48.67	37.64
Babarmahal Service to Maitighar Service	43.40	43.40	31.44
Maitighar Main to Art Gallery	45.48	45.48	45.01
Maitighar Main to Babarmahal Main	76.27	76.27	29.16
Maitighar Service to Babarmahal Service	106.93	106.93	31.41
Anamnagar to Art Gallery	71.67	71.67	55.71
Anamnagar to Maitighar Main	101.04	101.04	51.39
Art Gallery to Anamnagar	97.05	97.05	77.16
Art Gallery to Maitighar Main	103.83	103.83	74.24
Art Gallery to Babarmahal Main	111.73	111.73	77.27
Art Gallery to Babarmahal Service	126.62	126.62	76.12

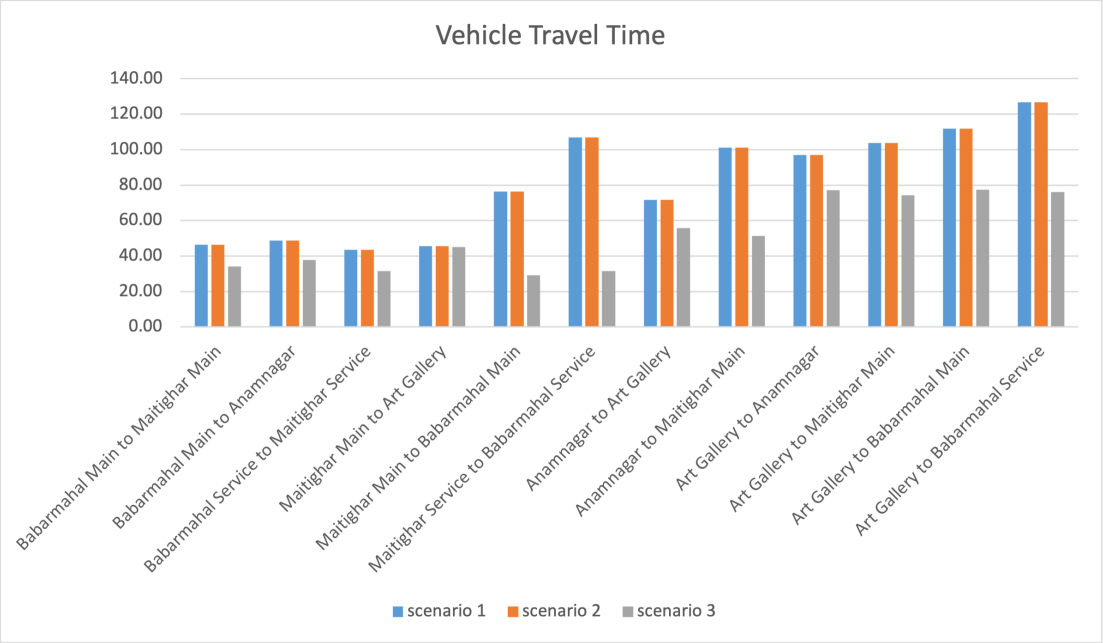


Figure B-19 Vehicle Travel Time Comparision

Table B-20 LOS Comparision: Off Peak Day 2

LOS			
Directions	scenario 1	scenario 2	scenario 3
Art Gallery to Anamnagar	LOS_F	LOS_D	LOS_F
Art Gallery toMaitighar Service	LOS_F	LOS_D	LOS_E
Art Gallery to Babarmahal Service	LOS_F	LOS_D	LOS_E
Art Gallery to Babarmahal Main	LOS_F	LOS_D	LOS_F
Art Gallery to Maitighar Main	LOS_F	LOS_D	LOS_E
Maitighar Service to Anamnagar	LOS_B	LOS_D	LOS_A
Maitighar Service to Babarmahal Service	LOS_C	LOS_D	LOS_B
Maitighar Main to Art Gallery	LOS_F	LOS_F	LOS_C
Maitighar Main to Babarmahal Main	LOS_C	LOS_E	LOS_B
Anamnagar to Art Gallery	LOS_E	LOS_E	LOS_D
Anamnagar to Babarmahal Service	LOS_D	LOS_D	LOS_B
Anamnagar to Maitighar Main	LOS_F	LOS_F	LOS_C
Babarmahal Service to Art Gallery	LOS_C	LOS_D	LOS_B
Babarmahal Service to Maitighar Service	LOS_C	LOS_D	LOS_B
Babarmahal Main to Anamnagar	LOS_E	LOS_D	LOS_C
Babarmahal Main toMaitighar Main	LOS_D	LOS_E	LOS_C
Overall Intersection	LOS_D	LOS_E	LOS_C

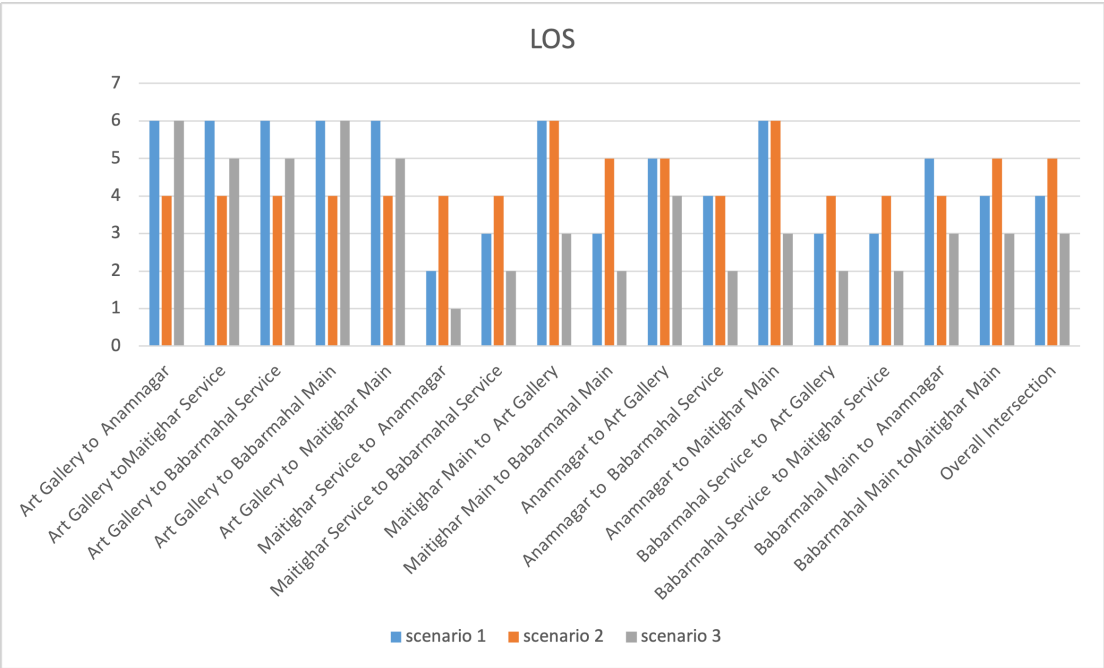


Figure B-20 LOS Comparision

B.6 OFF PEAK DAY 3

Table B-21 Queue Delay Comparision: Off Peak Day 3

Queue Delay			
Directions	scenario 1	scenario 2	scenario 3
Art Gallery to Anamnagar	102.919	49.282	77.780
Art Gallery toMaitighar Service	96.946	43.191	70.020
Art Gallery to Babarmahal Service	110.762	52.287	81.767
Art Gallery to Babarmahal Main	111.002	48.701	84.982
Art Gallery to Maitighar Main	105.248	49.590	75.511
Maitighar Service to Anamnagar	9.681	24.780	3.560
Maitighar Service to Babarmahal Service	31.584	51.039	16.271
Maitighar Main to Art Gallery	111.670	102.962	26.840
Maitighar Main to Babarmahal Main	31.277	53.079	16.185
Anamnagar to Art Gallery	52.778	84.744	42.679
Anamnagar to Babarmahal Service	25.370	33.039	8.740
Anamnagar to Maitighar Main	50.642	85.138	42.000
Babarmahal Service to Art Gallery	30.459	50.343	13.213
Babarmahal Service to Maitighar Service	33.267	54.474	16.307
Babarmahal Main to Anamnagar	68.904969	52.177	23.002
Babarmahal Main to Maitighar Main	37.664242	69.570	22.745
Overall Intersection	46.497304	57.854	26.911

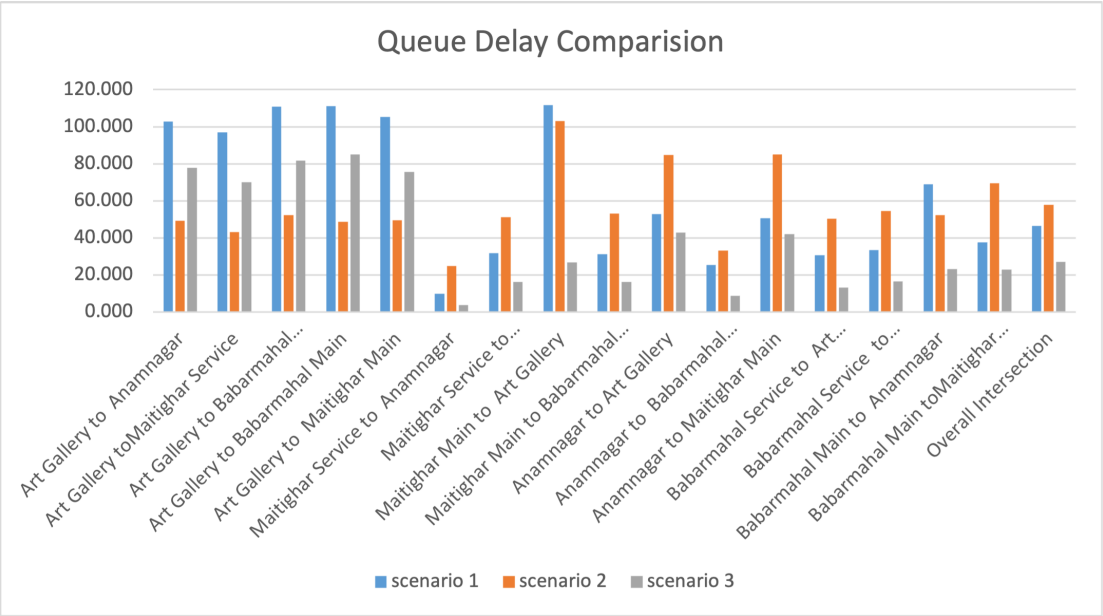


Figure B-21 Queue Delay Comparision

Table B-22 Queue Length Comparision: Off Peak Day 3

Queue Length			
Directions	scenario 1	scenario 2	scenario 3
Art Gallery to Intersection	56.71	24.87	42.51
Babarmahal Service to Intersection	19.08	33.53	9.75
Anamnagar to Intersection	2.57	4.09	1.83
Maitighar Service to Babarmahal Service	13.97	22.98	5.98
Maitighar Main to Intersection	21.07	27.53	3.12
Babarmahal Main to Anamnagar	3.37	2.36	1.02
Babarmahal Main to Maitighar Main	28.76	59.70	14.35

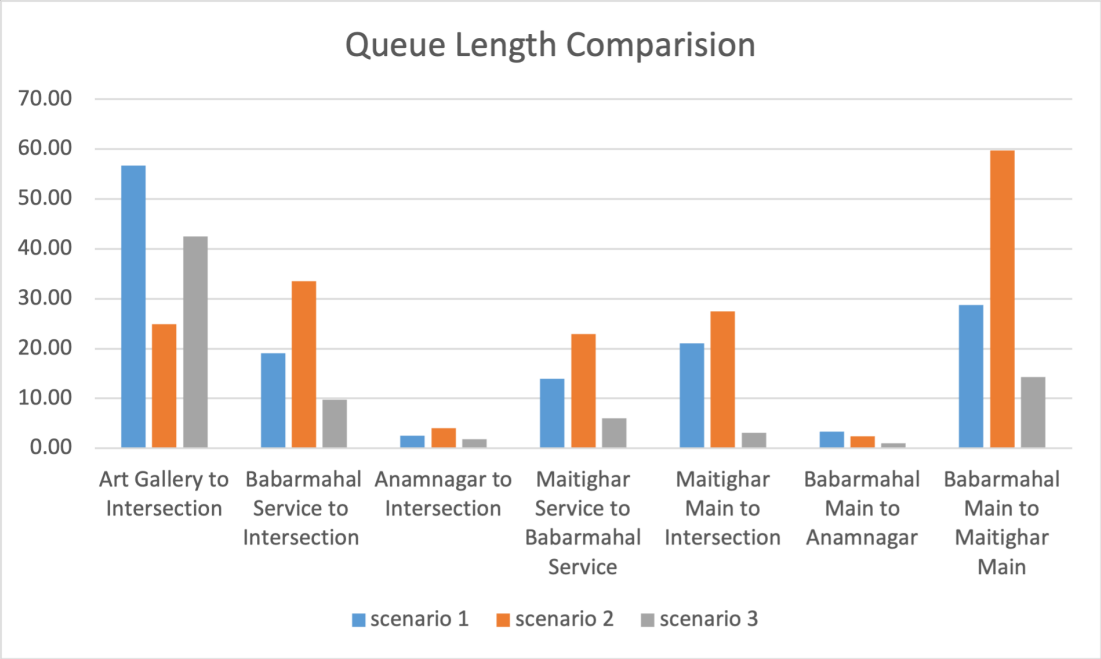


Figure B-22 Queue Length Comparision

Table B-23 Vehicle Travel Time Comparision: Off Peak Day 3

Vehicle Travel Time			
Directions	scenario 1	scenario 2	scenario 3
Babarmahal Main to Maitighar Main	45.626	65.02	33.15
Babarmahal Main to Anamnagar	84.211	67.53	38.40
Babarmahal Service to Maitighar Service	46.984	65.62	30.73
Maitighar Main to Art Gallery	125.246	114.37	41.76
Maitighar Main to Babarmahal Main	43.948	63.38	28.79
Maitighar Service to Babarmahal Service	45.439	61.80	31.48
Anamnagar to Art Gallery	63.396	96.01	55.23
Anamnagar to Maitighar Main	68.527	102.13	59.80
Art Gallery to Anamnagar	43.062	39.93	46.71
Art Gallery to Maitighar Main	49.774	44.22	51.57
Art Gallery to Babarmahal Main	55.911	40.98	48.53
Art Gallery to Babarmahal Service	49.233	44.78	48.03

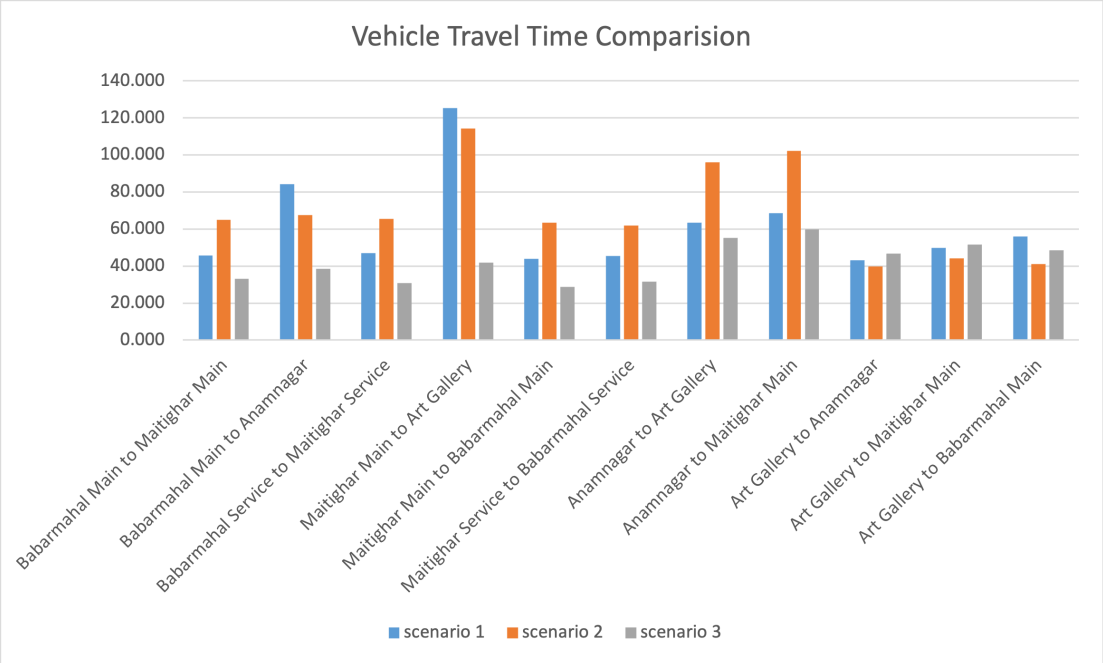


Figure B-23 Vehicle Travel Time Comparision

Table B-24 LOS Comparision: Off Peak Day 3

LOS			
Directions	scenario 1	scenario 2	scenario 3
Art Gallery to Anamnagar	LOS_F	LOS_F	LOS_E
Art Gallery toMaitighar Service	LOS_F	LOS_F	LOS_E
Art Gallery to Babarmahal Service	LOS_F	LOS_F	LOS_F
Art Gallery to Babarmahal Main	LOS_F	LOS_F	LOS_F
Art Gallery to Maitighar Main	LOS_F	LOS_F	LOS_E
Maitighar Service to Anamnagar	LOS_A	LOS_A	LOS_A
Maitighar Service to Babarmahal Service	LOS_C	LOS_C	LOS_B
Maitighar Main to Art Gallery	LOS_F	LOS_C	LOS_C
Maitighar Main to Babarmahal Main	LOS_C	LOS_C	LOS_B
Anamnagar to Art Gallery	LOS_D	LOS_F	LOS_D
Anamnagar to Babarmahal Service	LOS_C	LOS_C	LOS_A
Anamnagar to Maitighar Main	LOS_D	LOS_D	LOS_D
Babarmahal Service to Art Gallery	LOS_C	LOS_C	LOS_B
Babarmahal Service to Maitighar Service	LOS_C	LOS_D	LOS_B
Babarmahal Main to Anamnagar	LOS_E	LOS_E	LOS_C
Babarmahal Main toMaitighar Main	LOS_D	LOS_D	LOS_C
Overall Intersection	LOS_D	LOS_D	LOS_C

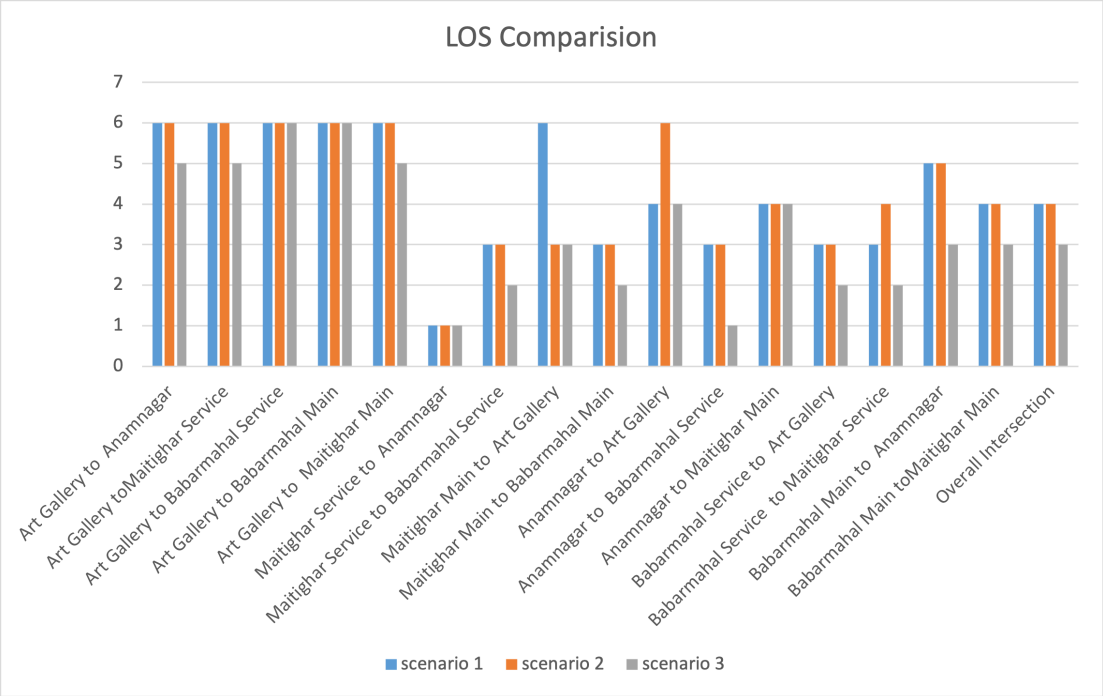


Figure B-24 LOS Comparision

C ANNEX III (GRAPHS AND CHARTS)

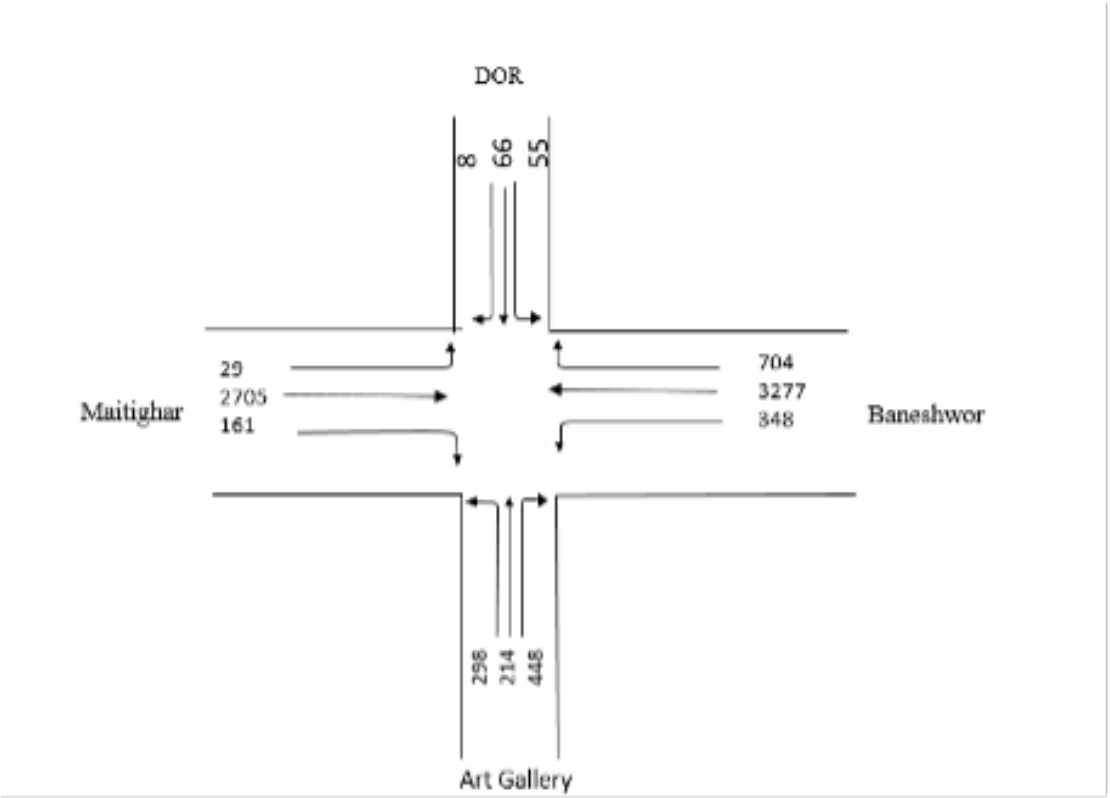


Figure C-1 Traffic Flow Diagram: Day 1 Peak

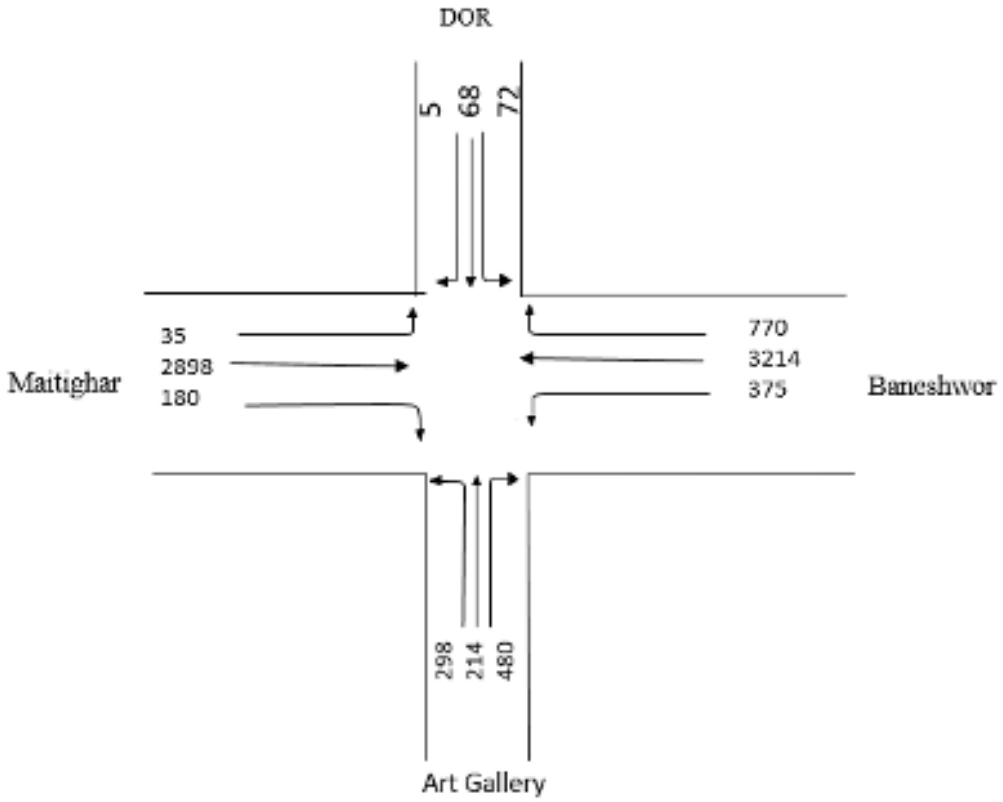


Figure C-2 Traffic Flow Diagram: Day 2 Peak

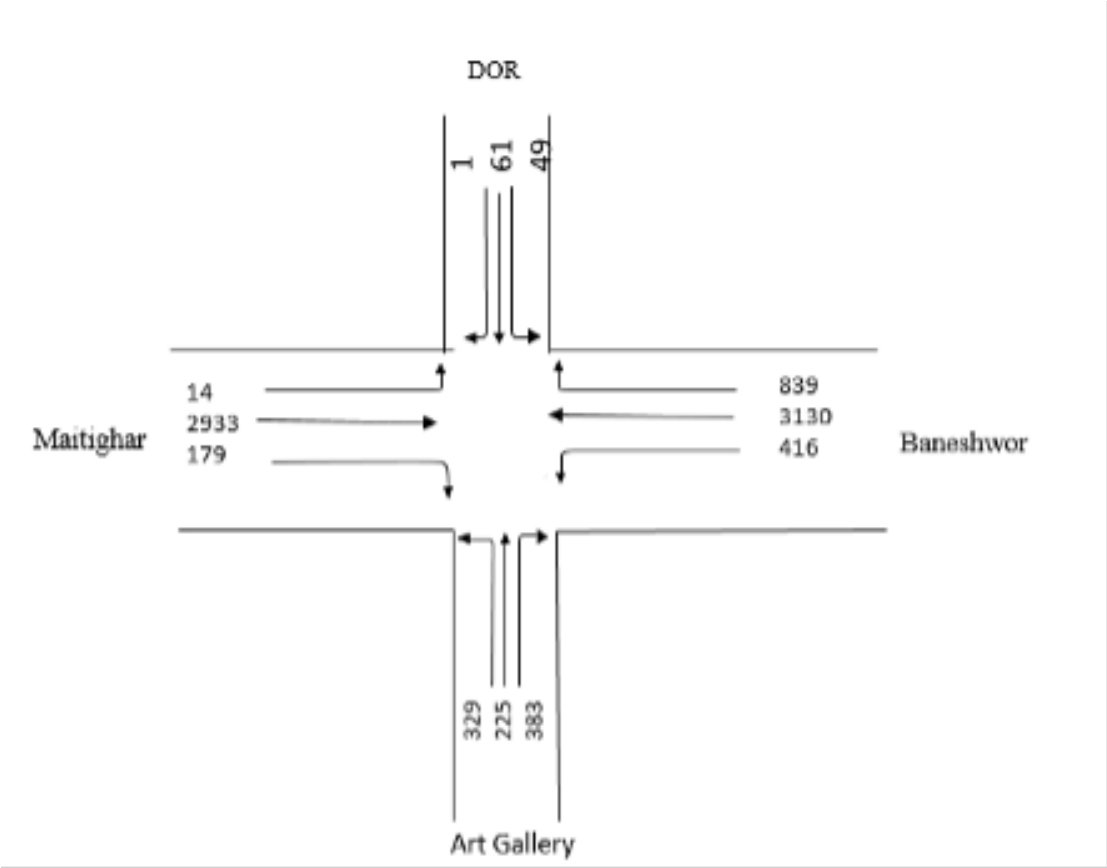


Figure C-3 Traffic Flow Diagram: Day 3 Peak

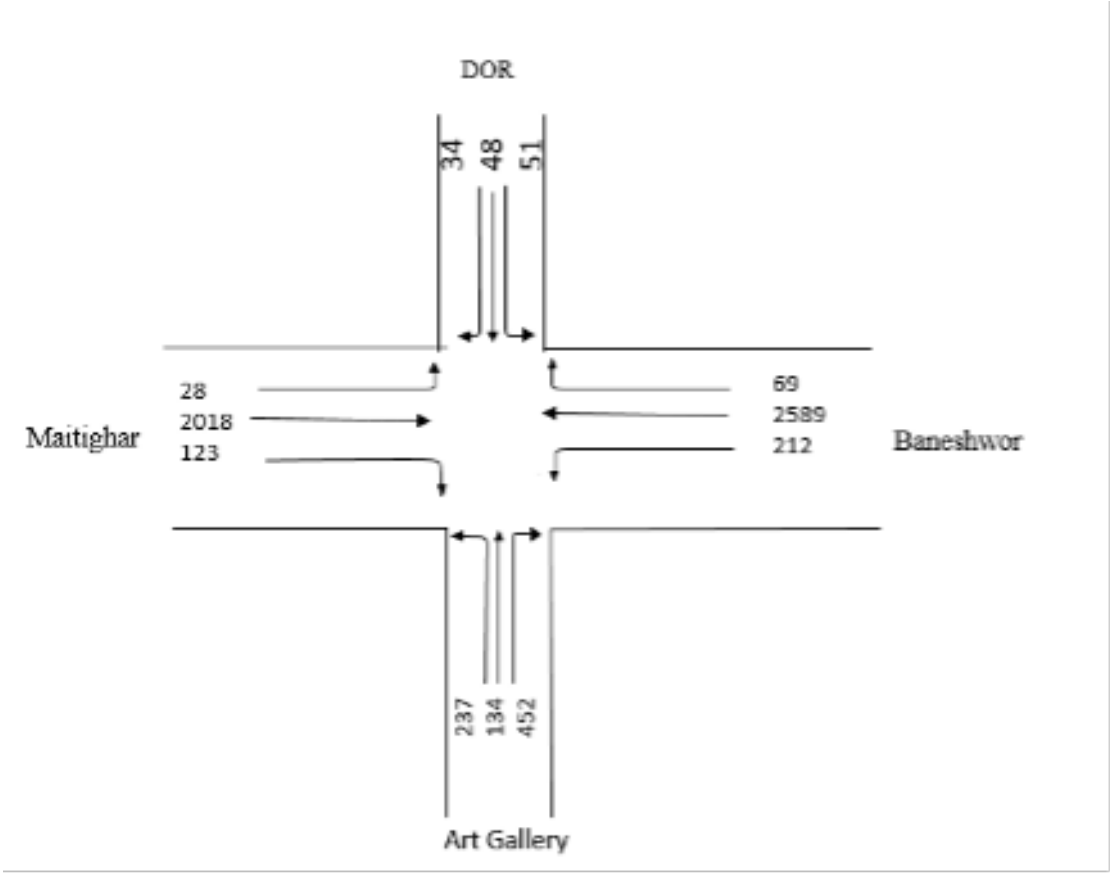


Figure C-4 Traffic Flow Diagram: Day 1 Off Peak

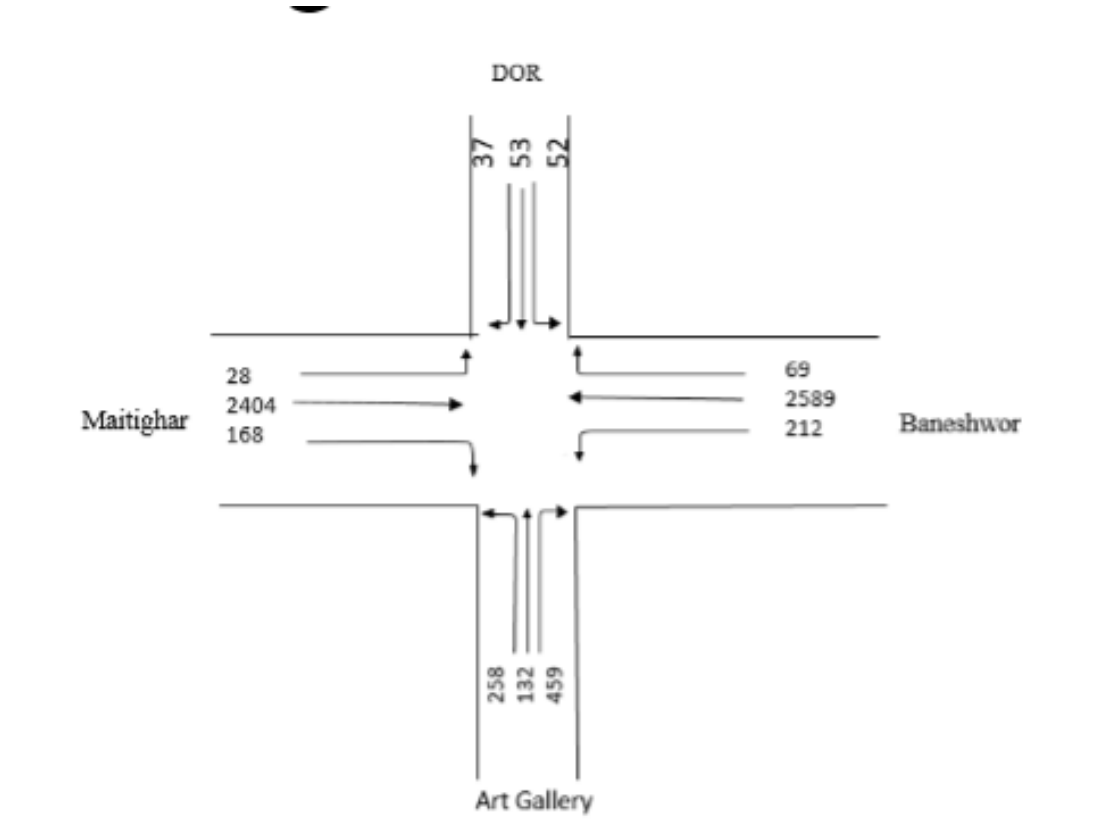


Figure C-5 Traffic Flow Diagram: Day 2 Off Peak

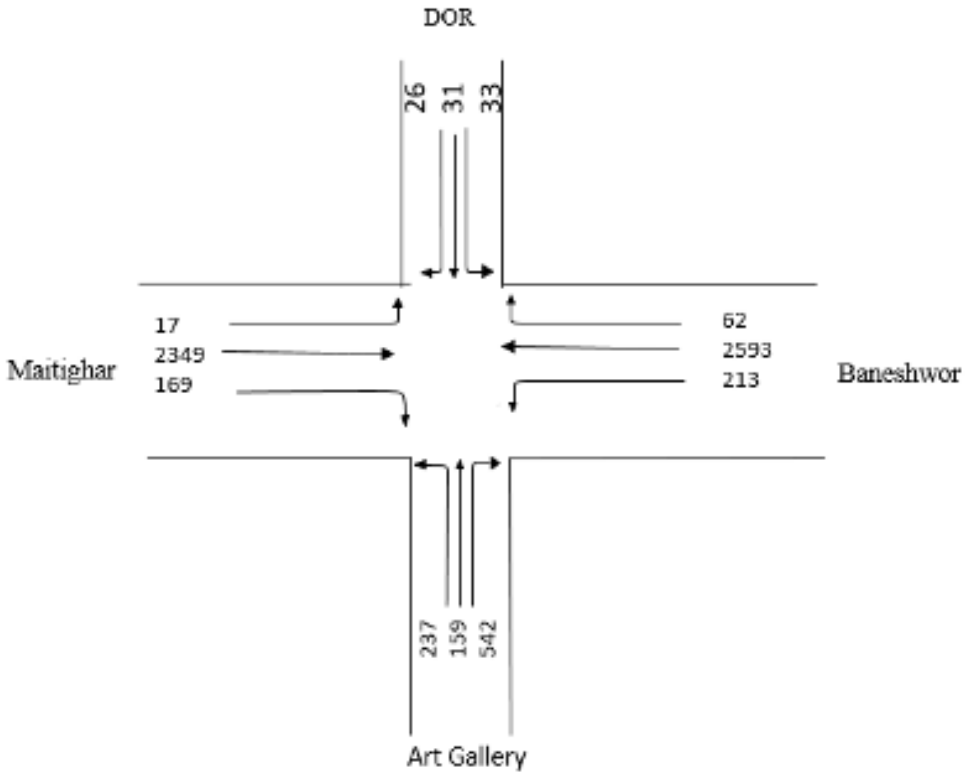


Figure C-6 Traffic Flow Diagram: Day 3 Off Peak

Table C-1 Average Total Flow through Baneshwor leg

Baneshwor Leg			
Through	MT To BN main	872.75	657.08
	MT to BN service	861.50	705.17
Left	BN to ART	172.92	102.08
Right	BN to DOR	383.09	44.50

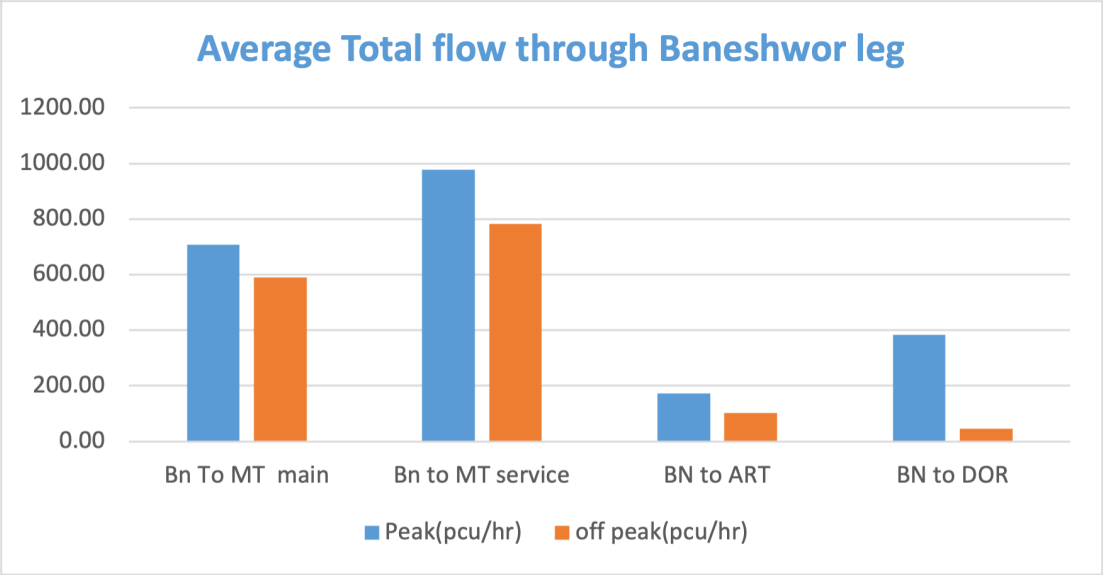


Figure C-7 Average Total flow through Baneshwor leg

Table C-2 Average Total Flow through DOR leg

DOR leg			
Movement	Direction	Peak(pcuhr)	off peak(pcuhr)
Through	DOR TO ART	26.00	20.25
Left	DOR TO MAITI	2.42	14.58
Right	DOR TO BN	25.92	22.58

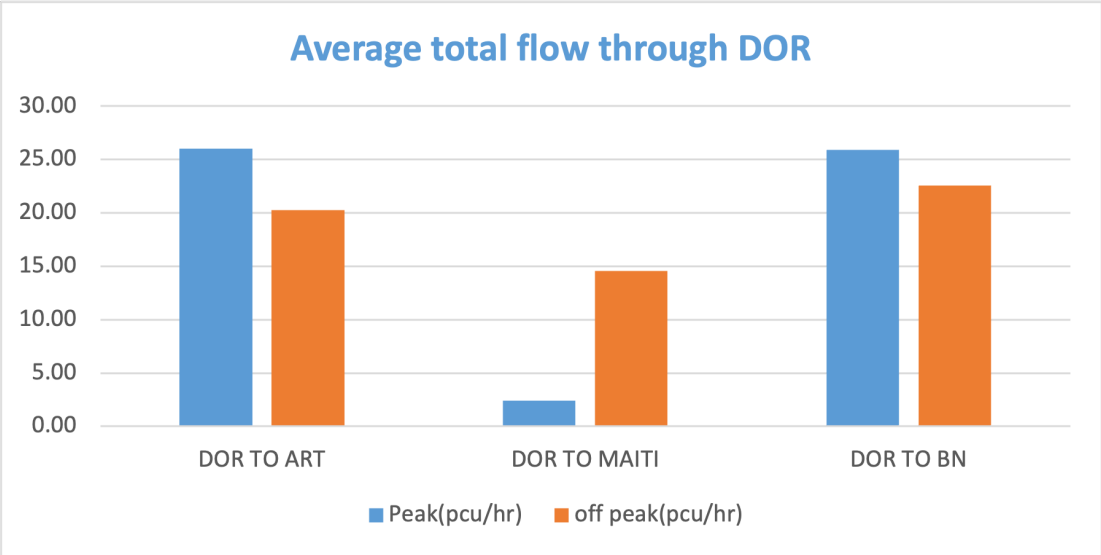


Figure C-8 Average Total flow through DOR leg

Table C-3 Average Total Flow through Art Gallery leg

Art Gallery leg			
Movement	Direction	Peak(pcu/hr)	off peak(pcu/hr)
Through	ART To DOR	80.67	67.83
Left	ART TO MAITI MAIN	23.92	54.67
	ART TO MAITI SERVICE	77.92	71
Right	ART TO BAN MAIN	59.17	87.42
	ART TO BAN SERVICE	118.08	136.75

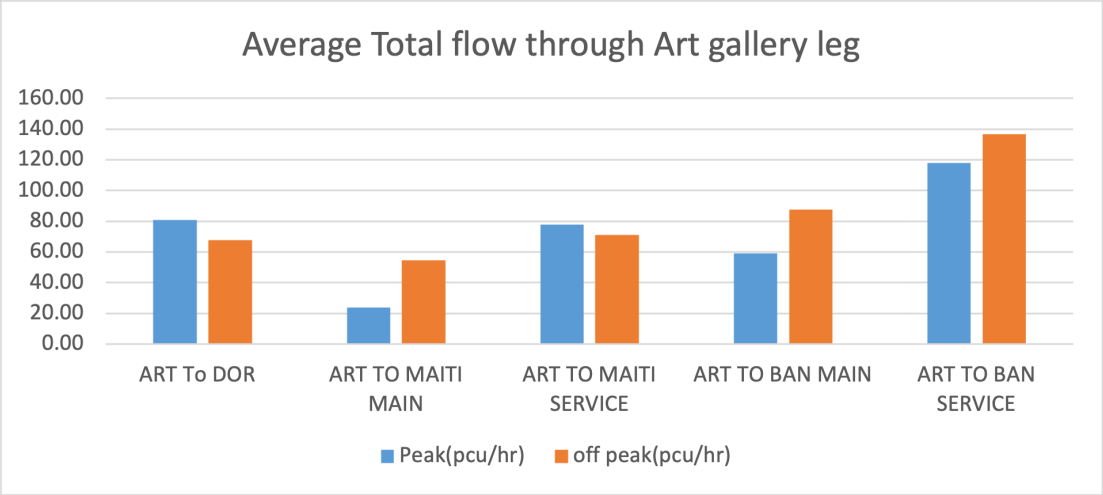


Figure C-9 Average Total flow through Art Gallery leg

Table C-4 Average Total Flow through Maitighar leg

Maitighar leg			
Movement	Direction	Peak(pcu/hr)	off peak(pcu/hr)
Through	MT To BN main	872.75	657.08
	MT to BN service	861.50	705.17
Left	MT to DOR	13.75	14.08
Right	MT to ART	64.58	67.08

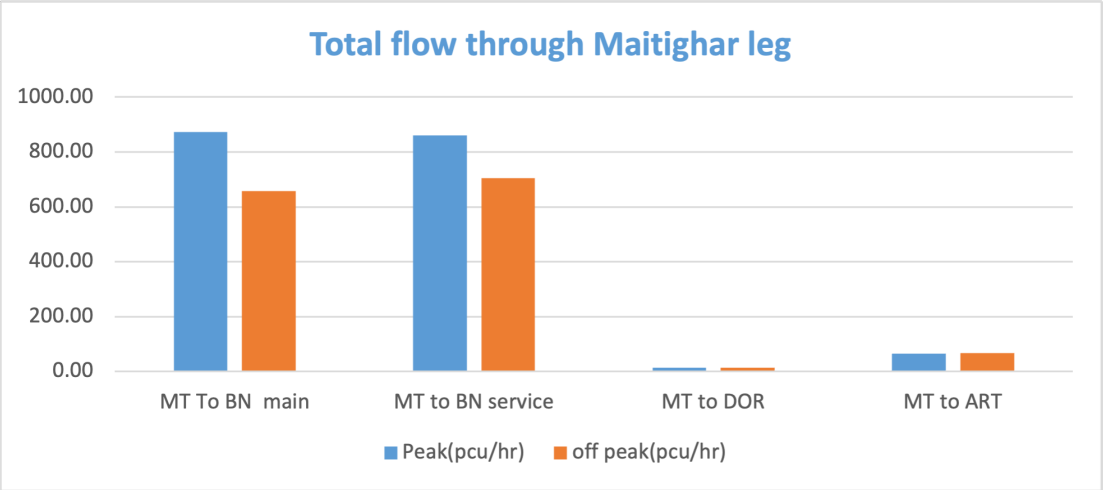


Figure C-10 Average Total flow through Maitighar leg

C.1 Pie-Chart Representations

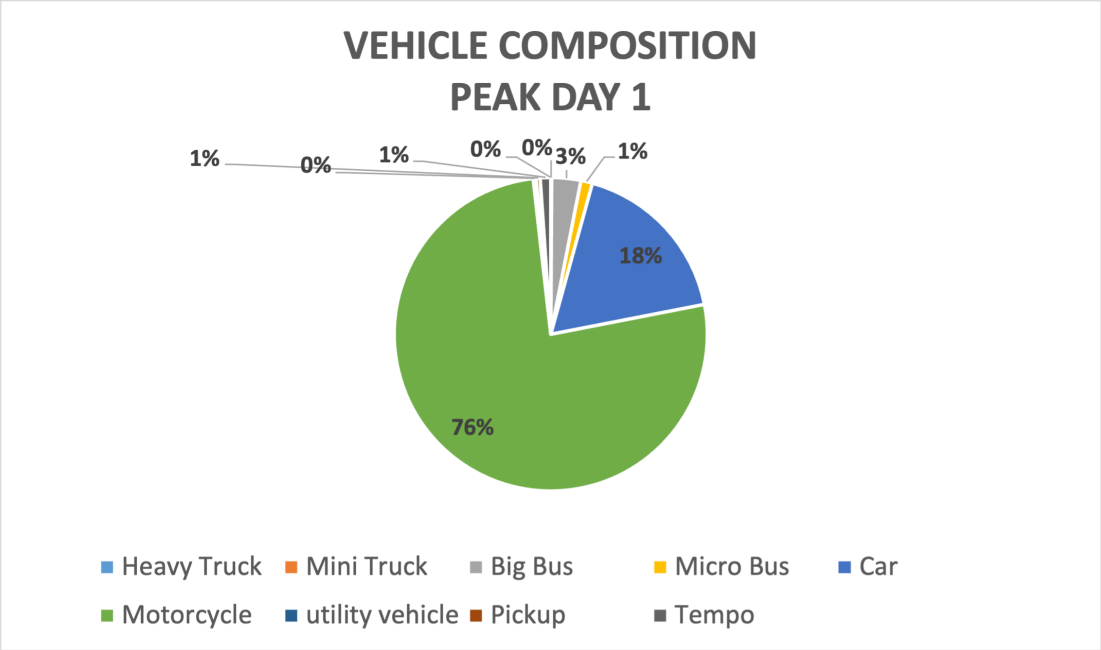


Figure C-11 Vehicle composition : Day 1 Peak

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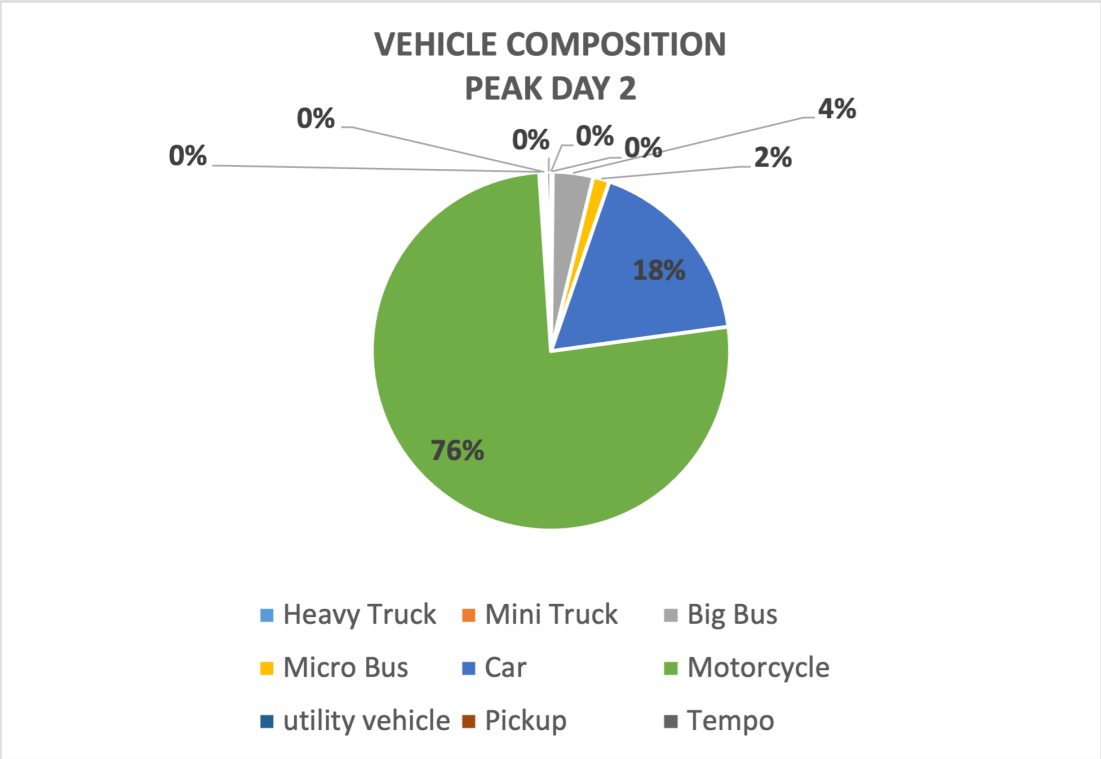

Figure C-12 Vehicle composition : Day 2 Peak

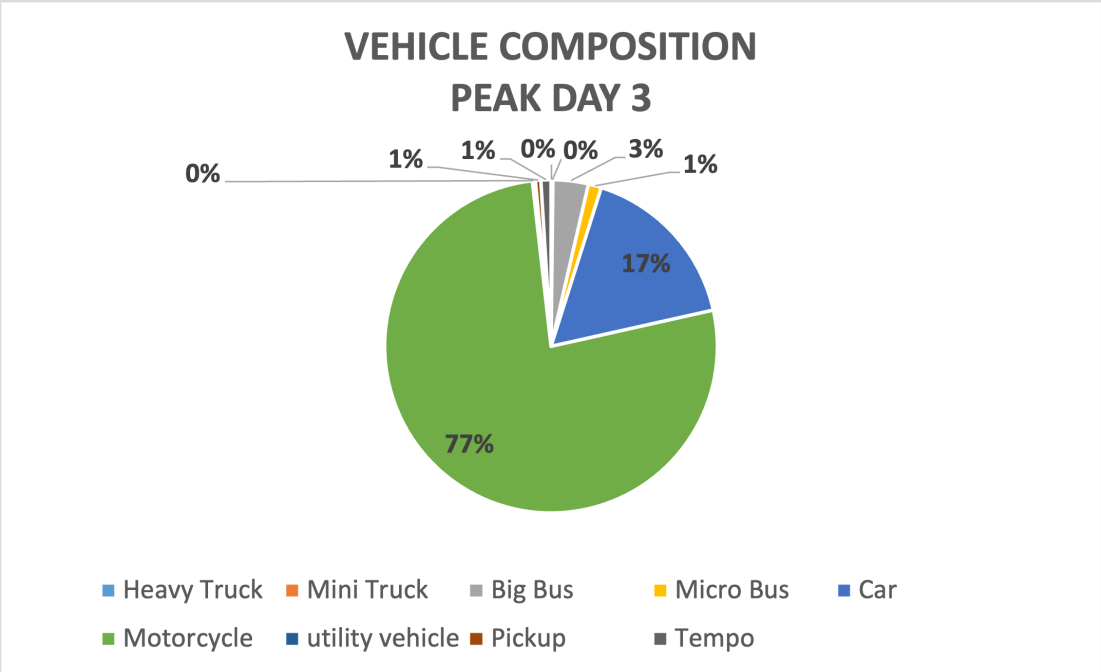

Figure C-13 Vehicle composition : Day 3 Peak

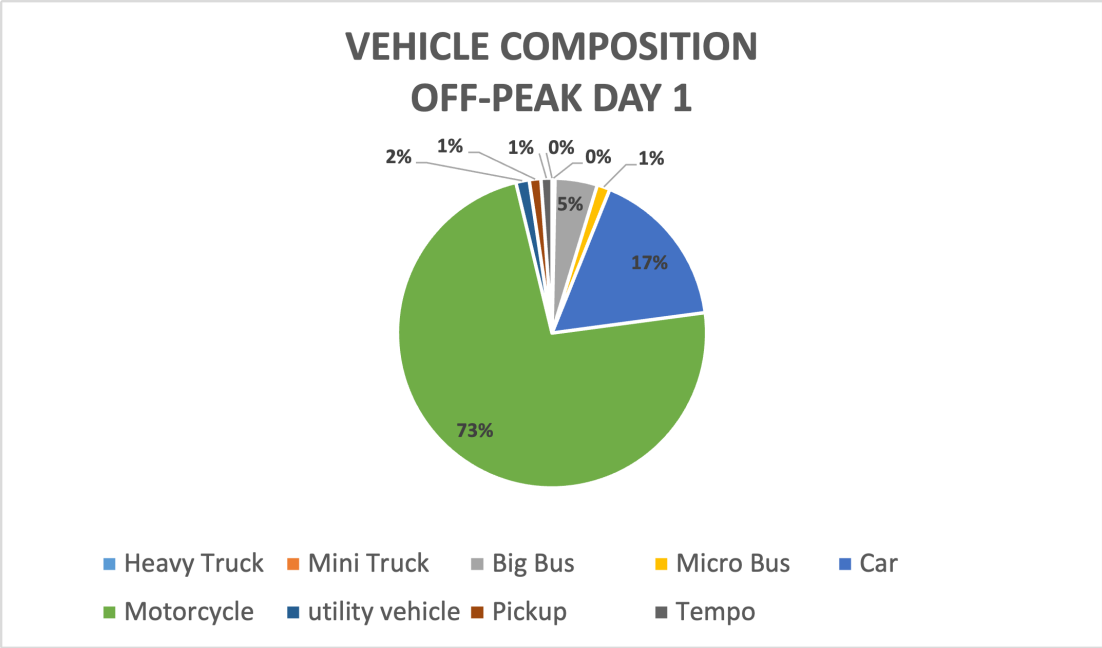

Figure C-14 Vehicle composition : Day 1 Off Peak

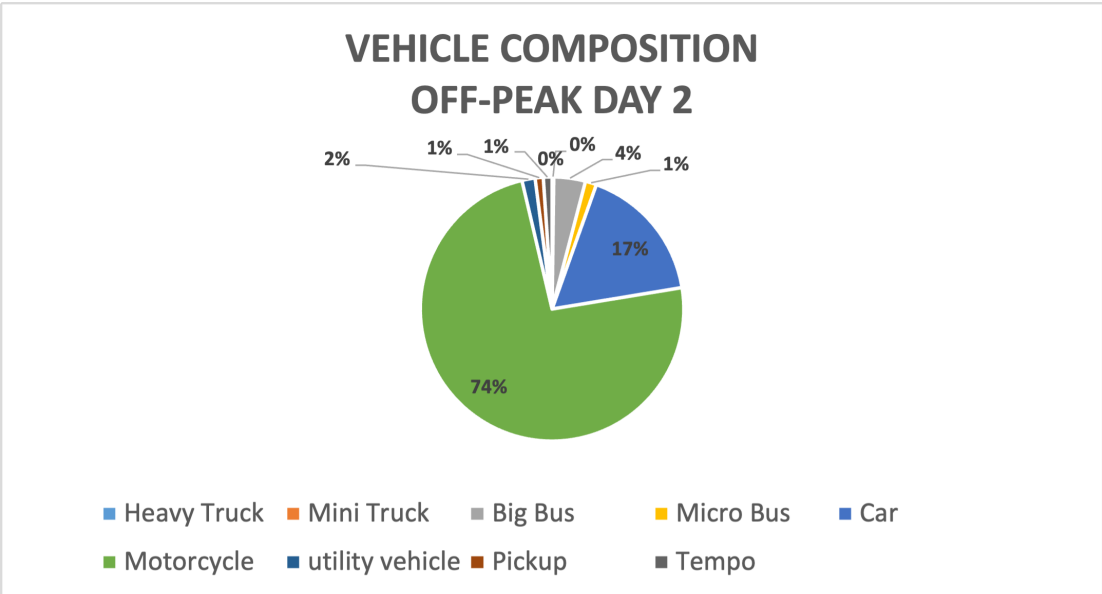

Figure C-15 Vehicle composition : Day 2 Off Peak

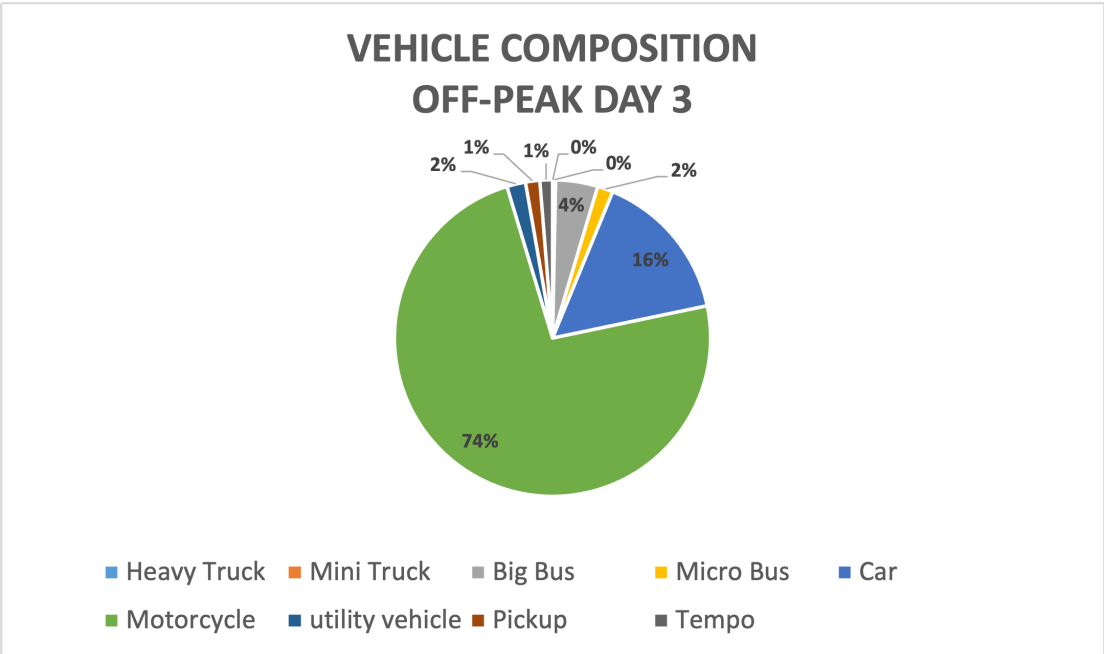

Figure C-16 Vehicle composition : Day 3 Off Peak

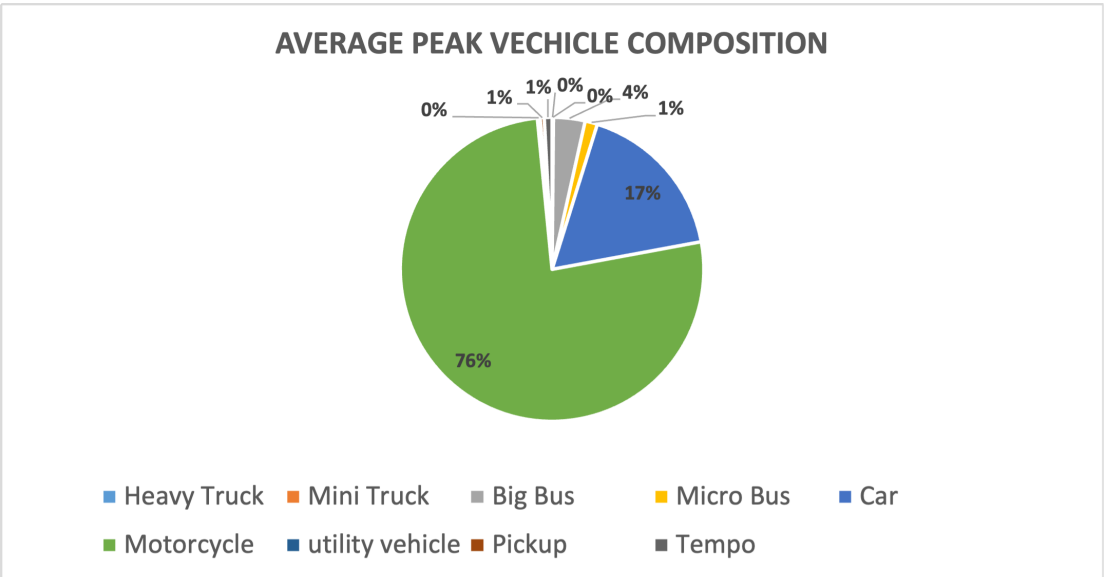

Figure C-17 Average Peak Vehicle composition

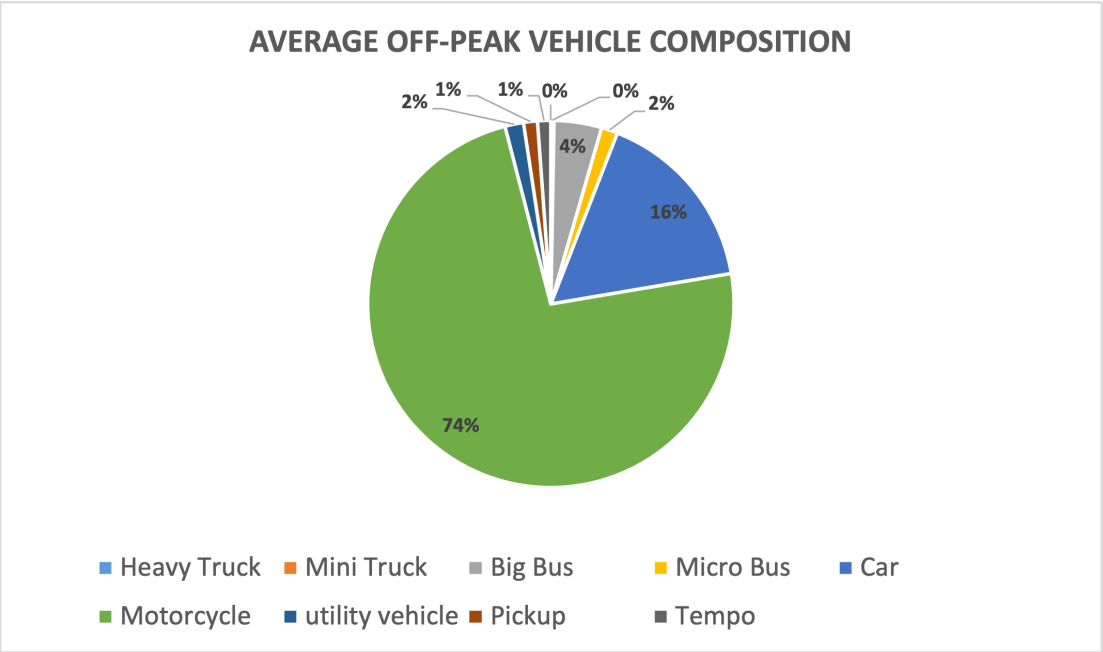

Figure C-18 Average Off Peak Vehicle composition

D ANNEX V (SPEED DISTRIBUSTION)

D.1 MAITIGHAR LEG

Table D-1 Speed Distribution of Cars

SN	Vehicle Type	Time Taken (sec)	Speed (Km/h)
1	Car	4	27
2	Car	4	27
3	Car	4.8	22.5
4	Car	4.6	23.5
5	Car	3.1	34.7
6	Car	3.9	27.6
7	Car	2.7	40
8	Car	4	27
9	Car	3.2	33.8
10	Car	4.2	25.9
11	Car	4.8	22.5
12	Car	4	27
13	Car	4	27
14	Car	3.5	30.8
15	Car	3.1	34.6
16	Car	3.2	33.8
17	Car	3.1	35
18	Car	4.2	25.7
19	Car	3.1	34.8
20	Car	4.5	24

Table D-2 Speed Distribution of Buses

SN	Vehicle Type	Time Taken (sec)	Speed (Km/h)
1	Bus	5.3	20.4
2	Bus	4.4	24.5
3	Bus	4.4	24.5
4	Bus	4.6	23.5
5	Bus	4.3	25.1
6	Bus	4.2	25.7
7	Bus	4	27
8	Bus	5	21.6
9	Bus	5.3	20.4
10	Bus	4.4	24.5
11	Bus	4.8	22.5
12	Bus	4.7	23
13	Bus	4.5	24
14	Bus	4	27
15	Bus	4.5	24

Table D-3 Speed Distribution of Bikes

SN	Vehicle Type	Time Taken (sec)	Speed (Km/h)
1	Bike	2.9	37.2
2	Bike	3.4	31.8
3	Bike	3.2	33.3
4	Bike	3	36
5	Bike	3.7	29.2
6	Bike	2.3	47
7	Bike	3.7	29.2
8	Bike	2.8	38.6
9	Bike	2.6	41.5
10	Bike	3.3	32.7
11	Bike	2.4	45
12	Bike	3.3	32.7
13	Bike	2.9	37.1
14	Bike	3.4	31.8
15	Bike	3.2	33.8
16	Bike	3	36
17	Bike	2.9	37.2
18	Bike	3	36
19	Bike	2.6	41.5
20	Bike	1.8	60
21	Bike	3.5	30.8
22	Bike	3.5	30.9
23	Bike	4	27
24	Bike	2.8	38.6
25	Bike	2.5	43.2
26	Bike	2.6	41.5
27	Bike	2.4	45
28	Bike	3.5	30.9
29	Bike	3.4	31.7
30	Bike	3.2	33.8
31	Bike	3.2	33.8
32	Bike	3	36
33	Bike	2.4	45
34	Bike	2.7	40
35	Bike	2.8	38.4
36	Bike	2.4	45
37	Bike	2.8	38.6
38	Bike	2.3	47
39	Bike	4.2	25.7
40	Bike	2.7	40

D.2 BANESHOWR LEG

Table D-4 Speed Distribution of Buses

SN	Vehicle Type	Time Taken (sec)	Speed (Km/h)
1	Car	3.09	35
2	Car	3.23	33.4
3	Car	3.32	32.5
4	Car	3.33	32.4
5	Car	3.46	31.2
6	Car	3.46	31.2
7	Car	3.59	30.1
8	Car	3.59	30.1
9	Car	3.59	30.1
10	Car	3.69	29.3
11	Car	3.69	29.3
12	Car	3.80	28.4
13	Car	3.93	27.5
14	Car	3.93	27.5
15	Car	3.93	27.5
16	Car	4.32	25
17	Car	4.32	25
18	Car	4.32	25
19	Car	4.46	24.2
20	Car	4.46	24.2

Table D-5 Speed Distribution of Buses

SN	Vehicle Type	Time Taken (sec)	Speed (Km/h)
1	Bus	5.00	21.6
2	Bus	4.41	24.5
3	Bus	4.41	24.5
4	Bus	4.60	23.5
5	Bus	4.30	25.1
6	Bus	4.20	25.7
7	Bus	3.86	28
8	Bus	5.00	21.6
9	Bus	5.29	20.4
10	Bus	4.41	24.5
11	Bus	4.80	22.5
12	Bus	4.62	23.4
13	Bus	4.15	26
14	Bus	4.01	26.9
15	Bus	4.50	24

Table D-6 Speed Distribution of Bike

SN	Vehicle Type	Time Taken (sec)	Speed (Km/h)
1	Bike	4.00	27
2	Bike	3.67	29.4
3	Bike	3.03	35.6
4	Bike	3.21	33.6
5	Bike	2.78	38.8
6	Bike	2.64	40.9
7	Bike	2.58	41.8
8	Bike	2.94	36.7
9	Bike	3.18	34
10	Bike	2.47	43.7
11	Bike	2.40	45
12	Bike	2.25	48
13	Bike	2.14	50.5
14	Bike	2.28	47.4
15	Bike	2.54	42.6
16	Bike	1.86	58
17	Bike	2.04	53
18	Bike	2.70	40
19	Bike	2.88	37.5
20	Bike	2.74	39.4
21	Bike	3.70	29.2
22	Bike	2.80	38.6
23	Bike	2.60	41.5
24	Bike	3.30	32.7
25	Bike	2.40	45
26	Bike	3.30	32.7
27	Bike	2.91	37.1
28	Bike	3.40	31.8
29	Bike	3.20	33.8
30	Bike	3.00	36
31	Bike	3.51	30.8
32	Bike	3.50	30.9
33	Bike	4.00	27
34	Bike	2.80	38.6
35	Bike	2.50	43.2
36	Bike	2.60	41.5
37	Bike	2.40	45
38	Bike	3.50	30.9
39	Bike	3.41	31.7
40	Bike	3.20	33.8
41	Bike	3.20	33.8
42	Bike	3.00	36
43	Bike	3.19	33.9

D.3 ART GALLERY LEG

Table D-7 Speed Distribution of Buses

SN	Vehicle Type	Time Taken (sec)	Speed (Km/h)
1	Car	4.54	23.8
2	Car	4.06	26.6
3	Car	4.15	26
4	Car	4.44	24.3
5	Car	4.00	27
6	Car	4.46	24.2
7	Car	4.35	24.8
8	Car	4.25	25.4
9	Car	4.91	22
10	Car	4.35	24.8
11	Car	4.93	21.9
12	Car	4.84	22.3
13	Car	3.86	28
14	Car	5.09	21.2
15	Car	4.70	23
16	Car	4.25	25.4
17	Car	4.50	24
18	Car	4.93	21.9
19	Car	4.54	23.8
20	Car	3.86	28

Table D-8 Speed Distribution of Bike

SN	Vehicle Type	Time Taken (sec)	Speed (Km/h)
1	Bike	4.0	27
2	Bike	3.1	35
3	Bike	4.3	25.1
4	Bike	4.0	27
5	Bike	4.7	23.2
6	Bike	4.3	25.1
7	Bike	3.4	32
8	Bike	3.3	33
9	Bike	4.0	27
10	Bike	3.7	29.2
11	Bike	3.7	29.1
12	Bike	2.8	38
13	Bike	2.6	42
14	Bike	2.4	45
15	Bike	3.1	35.4
16	Bike	2.2	48.5
17	Bike	3.4	32
18	Bike	3.8	28.4
19	Bike	3.1	34.7
20	Bike	2.8	38.6

D.4 DOR LEG

Table D-9 DOR Leg

	Tempo	Micro Bus	Pickup	Utility Vehicle	BUS
MIN	20	22	23	23	20
MAX	35	38	35	40	30

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E ANNEX IV (PEDESTRAIN VOLUME COUNT)

E.1 PEAK DAY

Table E-1 Pedestrain Volume Count at Maitighar Approach (Towards Art Gallery)

Maitighar Approach (Towards Art Gallery)				
Time	Day 1	Day 2	Day 3	Average
9:30-9:45	82	62	75	73
9:45-10:00	68	72	82	74
10:00-10:15	75	55	68	66
10:15-10:30	92	90	97	93

Table E-2 Pedestrain Volume Count at Maitighar Approach (Towards DOR)

Maitighar Approach (Towards DOR)				
Time	Day 1	Day 2	Day 3	Average
9:30-9:45	82	62	75	73
9:45-10:00	68	72	82	74
10:00-10:15	75	55	68	66
10:15-10:30	92	90	97	93

Table E-3 Pedestrain Volume Count at Art Gallery Approach (Towards Maitighar)

Art Gallery Approach (Towards Maitighar)				
Time	Day 1	Day 2	Day 3	Average
9:30-9:45	29	36	31	32
9:45-10:00	25	24	26	25
10:00-10:15	30	25	44	33
10:15-10:30	25	31	37	31

Table E-4 Pedestrain Volume Count at Art Gallery Approach (Towards Baneshwor)

Art Gallery Approach (Towards Baneshwor)				
Time	Day 1	Day 2	Day 3	Average
9:30-9:45	21	18	24	21
9:45-10:00	20	14	20	18
10:00-10:15	17	19	18	18
10:15-10:30	13	15	23	17

Table E-5 Pedestrain Volume Count at DOR Approach (Towards Maitighar)

DOR Approach (Towards Maitighar)				
Time	Day 1	Day 2	Day 3	Average
9:30-9:45	14	20	19	17.66667
9:45-10:00	18	24	21	21
10:00-10:15	16	22	17	18.33333
10:15-10:30	13	16	20	16.33333

Table E-6 Pedestrain Volume Count at Maitighar Approach (Towards DOR)

DOR Approach (Towards Baneshwor)				
Time	Day 1	Day 2	Day 3	Average
9:30-9:45	27	22	20	23
9:45-10:00	16	25	21	20.66666667
10:00-10:15	17	20	21	19.33333333
10:15-10:30	20	16	18	18

E.2 OFF-PEAK DAY

Table E-7 Pedestrain Volume Count at Maitighar Approach

Maitighar Approach				
Time	Day 1	Day 2	Day 3	Average
1:00-1:15	56	70	75	67
1:15-1:30	44	56	62	54
1:30-1:45	65	55	51	57
1:45-2:00	52	63	80	65

Table E-8 Pedestrain Volume Count at Art Gallery Approach (Towards Maitighar)

Art Gallery Approach (Towards Maitighar)				
Time	Day 1	Day 2	Day 3	Average
1:00-1:15	19	11	14	14.66666667
1:15-1:30	13	10	12	11.66666667
1:30-1:45	16	9	11	12
1:45-2:00	17	13	15	15

Table E-9 Pedestrain Volume Count at Art Gallery Approach (Towards Baneshwor)

Art Gallery Approach (Towards Baneshwor)				
Time	Day 1	Day 2	Day 3	Average
1:00-1:15	11	9	13	11
1:15-1:30	10	14	11	11.66667
1:30-1:45	9	15	12	12
1:45-2:00	13	12	14	13

Table E-10 Pedestrain Volume Count at DOR Approach (Towards Maitighar)

DOR Approach (Towards Maitighar)				
Time	Day 1	Day 2	Day 3	Average
1:00-1:15	14	13	11	12.66667
1:15-1:30	17	16	20	17.66667
1:30-1:45	21	25	19	21.66667
1:45-2:00	17	14	13	14.66667

Table E-11 Pedestrain Volume Count at DOR Approach (Towards Baneshwor)

DOR Approach (Towards Baneshwor)				
Time	Day 1	Day 2	Day 3	Average
1:00-1:15	14	13	11	12.66667
1:15-1:30	17	16	20	17.66667
1:30-1:45	21	25	19	21.66667
1:45-2:00	17	14	13	14.66667

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REFERENCES

[1] H. Tiwari, S. Luitel, and A. Pokhrel, "Optimizing performance at signalized intersections through signal coordination in two intersections of nepal," *Journal of Transportation Systems*, vol. 8, no. 1, pp. 22–32, 2023.

[2] Z. Cakici, Y. S. Murat, and M. M. Aydin, "Design of an efficient vehicle-actuated signal control logic for signalized intersections," *Scientia Iranica*, 2021.

[3] I. Tomar, S. Indu, and N. Pandey, "Traffic signal control methods: Current status, challenges, and emerging trends," in *Proceedings of Data Analytics and Management*. Springer Nature Singapore, 2022, vol. 90, pp. 151–163.

[4] R. Duraku and D. Boshnjaku, "Enhancing traffic sustainability: An analysis of isolation intersection effectiveness through fixed time and logic control design using visvap algorithm," *Sustainability*, vol. 16, no. 7, p. 2930, 2024.

[5] F. H. Administration, "Traffic signal timing manual," U.S. Department of Transportation, Tech. Rep., 2008.

[6] M. Eom and B.-I. Kim, "The traffic signal control problem for intersections: A review," *European Transport Research Review*, vol. 12, no. 1, p. 50, 2020.

[7] G. R. Richardson, P. Matthews, and P. Guest, *Traffic Engineering Design*, 2nd ed. CRC Press, 2005.

[8] National Research Council, *Highway Capacity Manual 2000*. Transportation Research Board, 2000.

[9] F. H. Administration, "Signal timing," U.S. Department of Transportation, Tech. Rep., 2007.

[10] T. Urbanik, A. Tanaka, B. Lozner, E. Lindstrom, K. Lee, S. Quayle, S. Beaird, S. Tsoi, P. Ryus, D. Gettman, S. Sunkari, K. Balke, and D. Bullock, *Signal Timing Manual (Second Edition)*. Transportation Research Board, 2015.

[11] D. Grether, J. Bischoff, and K. Nagel, "Traffic actuated signal control: Simulation of the user benefits in a big event real-world scenario," in *Proceedings of the 2nd International Conference on Models and Technologies for Intelligent Transportation Systems*, 2011, pp. 1–4.

[12] B. C. Costa, S. S. Leal, P. E. Almeida, and E. G. Carrano, "Fixed-time traffic signal optimization using a multi-objective evolutionary algorithm and microsimulation

of urban networks," *Transactions of the Institute of Measurement and Control*, vol. 40, no. 4, pp. 1092–1101, 2018.

[13] R. Akcelik, "Estimation of green times and cycle time for vehicle actuated signals," *Transportation Research Record*, vol. 1457, pp. 63–72, 1994.

[14] P. Ravikumar, "Area traffic control system," C-DAC, Tech. Rep., 2012.

[15] A. Stevanovic, "Adaptive traffic control systems: Domestic and foreign state of practice," Transportation Research Board, Tech. Rep., 2010.

[16] X. B. Wang, K. Yin, and H. Liu, "Vehicle actuated signal performance under general traffic at an isolated intersection," *Transportation Research Part C: Emerging Technologies*, vol. 95, pp. 582–598, 2018.

[17] IEEE, "Ieee author center," https://ieeeauthorcenter.ieee.org/, 2022, accessed: 2025-12-15.

[18] F. H. Administration, *Manual on Uniform Traffic Control Devices for Streets and Highways*, U.S. Department of Transportation, 2009.

[19] ——, "Fhwa-hop-08-024," n.d., pDF document.

[20] Sinowatcher, "How traffic-actuated signals work," accessed: n.d. [Online]. Available: https://www.trafficsolution.cn/item/how-traffic-actuated-signals-work

[21] A. Stevanovic and P. T. Martin, "Split-cycle offset optimization technique and coordinated actuated traffic control evaluated through microsimulation," 2008, unpublished manuscript.

[22] M. B. Trabia, M. S. Kaseko, and M. Ande, "A two-stage fuzzy logic controller for traffic signals," *Transportation Research Part C: Emerging Technologies*, vol. 7, pp. 353–367, 1999.

[23] Transportation Research Board, *Highway Capacity Manual*. Washington, DC, USA: National Academies Press, 2022.

[24] D. Ni, *Signalized Intersections: Fundamentals to Advanced Systems*. Cham, Switzerland: Springer Nature, 2020.

[25] R. P. Roess, E. S. Prassas, and W. R. McShane, *Traffic Engineering*, 4th ed. Upper Saddle River, NJ, USA: Pearson/Prentice Hall, 2011.

[26] PTV Planung Transport Verkehr AG, *VISVAP User Manual*, PTV, Düsseldorf, Germany, 2005.