ANALYSIS OF THE EFFECTS OF THREE WHEELERS ON PERFORMANCE MEASUREMENT PARAMETERS OF INTERSECTIONS:

A CASE STUDY: ROUNDABOUTS AND SIGNALIZED INTERSECTIONS IN HOSSANA CITY

MSc THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

DECEMBER , 2020

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A CASE STUDY: ROUNDABOUTS AND SIGNALIZED INTERSECTIONS IN HOSSANA CITY

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ADVISORS’ APPROVAL SHEET

This is to certify that the thesis entitled: "**Analysis of The Effects of Three wheelers on Performance Measurement Parameters of Intersections: A Case Study: Roundabouts and Signalized Intersections in Hosanna City”** submitted in partial fulfillment of the requirements for the Degree of masters with specialization in Road and transport engineering the graduate program of the department of civil engineering and has been carried out by **Dawit Damissie Ergicho, Id number GPRO/009/11** under my own supervision, therefore, I recommended that the student has fulfilled the requirements and hence hereby can submit the thesis to the department office.

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SCHOOL OF GRADUATE STUDIES

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EXAMINERS' APPROVAL SHEET-1

We, the undersigned, members of the Board of Examiners of the final open defense by Dawit Damissie Ergicho, have read and evaluated his thesis entitled *"Analysis of the effects of Three wheelers on Performance Measurement Parameters of Intersections: A Case Study: Roundabouts and Signalized Intersections in Hosanna City,"* and examined the candidate. Therefore, this is to certify that the thesis has been accepted in partial fulfillment of the requirements for the Degree.

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DECLARATION

I hereby declare that this MSc thesis entitled **"Analysis of The Effects of Three wheelers on Performance Measurement Parameters of Intersections: A Case Study: Roundabouts and Signalized Intersections in Hosanna City,"** is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

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ABBREVIATIONS

FHWA= Federal Highways of America

HCM= Highway Capacity Manual

LOS= Level of Service

PCU= Passenger Car Equivalent

SNNPR= Southern Nations Nationalities and Peoples Region

SIDRA= Signalized and Un-Signalized Intersection Design and Research Aid

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ABSTRACT

Traffic intersections are complex locations on highways. This is because vehicles moving in different direction want to occupy same space at the same time. Traffic volume is one of the variables that have the biggest effect on intersection performances. The traffic volume of Menharya and Maryam signalized intersections, Bezabh Petros and Eyerusalem roundabouts at Hosanna city is highly occupied by three wheelers. So it is vital to study the effects of three wheelers on performance measurement parameters of intersections. The other purposes of the study were, analysis of existing intersection performances, evaluation of the consequences of three wheelers with performance parameters and comparing the performance change of intersections by replacing three wheelers with a minibus. All data were collected by using video camera for traffic data and measuring tape for geometric data. By taking peak hour volume, the performance measurement parameters of intersections were done using HCM 2010 methodologies incorporated in SIDRA Intersection Software 5.1. The effects of three wheelers on intersection performances were evaluated by excluding three wheelers from analysis and by comparing each performance parameter changes with and without three wheelers. By replacing three wheelers with minibus of 12 seats, the performance changes of intersections were evaluated and compared well. From the result of the study, Menharya signalized intersection is operating above its capacity because, the degree of saturation of this intersection is 1.374 which is greater than one and Maryam signalized intersection also shows congested condition with degree of saturation 0.852. 70.5% cause for delay, 85.5% cause for a degree of saturation, and 93.8% cause for the queue distance of Menharya signalized intersection is the presence of three wheelers. In the same manner for Maryam signalized intersection, 17.1% cause of delay. 82.2% cause of degree of saturation, and 90.7% cause of queue length is three wheeler's presence. The performances of both roundabouts are also affected highly due to presence of three wheelers. For Menharya signalized intersection, 54.1% Average delay, 31.7% degree of saturation and 59.5% queue distance, For Maryam signalized intersection, 19.3% Average delay, 32.4% degree of saturation and 45.6% queue distance is improved when Three wheelers replaced by minibus.

Keywords:*, Intersection, Performance, Roundabout, SIDRA intersection software, Three wheelers.*

1. INTRODUCTION

1.1. Background of the Study

Intersection is an area shared by two or more roads. This area is designated for the vehicles to change their flow course to different directions to reach their desired destinations. Its main function is to guide vehicles to their respective directions. Traffic intersections are complex locations on any highway. This is because vehicles moving in different direction want to occupy same space at the same time. In addition, the pedestrians also seek same space for crossing (Roess, 2004).

The high volume of vehicles, the inadequate infrastructure and the irrational distribution of the development are the main reasons for decreasing intersection performances. From the above factors, Traffic volume is the variable that has the biggest effect on intersection performances and associated with the characteristics of the traffic stream on the intersections of the highway. These include the distribution of the different types of vehicles in the traffic stream or traffic composition such as cars, trucks, buses etc. and the directional and lane distribution of the traffic volume on intersections including peaking characteristics and proportions of turning movements on it (Ahmed, 2018).

Hosanna city is one of the most pursued after cities in the country with traffic conformation of pedestrian and motorized vehicles such as three wheelers, taxi, bus, and truck etc. The City has about two signalized intersections and two roundabouts. During peak hours, it is becoming common to see congestion, long queues and delay at some of these intersections. Their capacity and level of service was not well studied and the effects of vehicles on intersection performances were also not studied. The belongings of different vehicle categories on the performance of intersections are very dissimilar in nature. Therefore, analyses of the effects of vehicle on intersection performance are essential in the study of traffic flows. Specifically, the relationship between three wheelers composition and performance parameters are needed to be studied since three wheelers mode of transportation is major public transportation mode in Hosanna city (Transportation office of Hosanna city, 2019). So the assessment of the effects of three wheelers on performance parameters of selected intersections is important to know the extent of problems and for improvement measures to be taken.

1.2 Statement of the Problem

Traffic intersections are complex locations on any highway. This is because vehicles moving in different direction want to occupy same space at the same time. The high volume of vehicles, the inadequate infrastructure and the irrational distribution of the development are the main reasons for decreasing intersection performances. From the above factors, Traffic volume is the variable that has the biggest effect on intersection performances and associated with the characteristics of the traffic stream on the intersections of the highway. So it is very essential to study the performance evaluation of intersections related with vehicle types (Ahmed, 2018).

Hosanna is the City which has intersections with high traffic flows. Because of that, during peak hours, it is becoming common to see congestion, long queues and delay at some of these intersections and the intersections are highly occupied with High number of three wheelers because 75 % of the city's transportation mode is covered by three wheelers (Transportation office of Hosanna City, 2019). Since, three wheeler is the main public transportation mode in Hosanna city, it is very essential to analyze the effects of three wheelers on intersection performance parameters and performance evaluations of intersections to improve junctions by assessing solutions.

Most of the researches related to performance evaluation of intersection in Ethiopia are focused only on highly congested junction areas in Addis Ababa. And there is no sufficient study on the performance of intersections in other cities of the country to handle the problem of congestion, delay, accident and emissions in the intersection areas before they become congested like in Addis Ababa (Nurhussen, 2015). Regarding this topic, (Syoum.B, 2018) Conducted study on effects of three wheelers on of performance measurement parameters of unsignalized intersections only in Harar City of Ethiopia. So this research can partially fill this gap.

1.3 Research Questions

The basic research questions are:-

1. What are the parameters to evaluate the performance of intersections under the given traffic and road conditions?
2. What are the consequences of three wheelers with intersection Performance measurement parameters?
3. Are there any possible measures to improve the performance of intersections?

1.4 Objectives of the Research

1.4.1 General Objective

This research aims to study the effects of three wheelers on performance measurement parameters of selected intersections in Hosanna city.

1.4.2 Specific Objectives

The specific objectives of this research are the following:

- ✓ To analyze the intersection performance measurement parameters, capacity, Degree of saturation, control delay, queue length, and level of service for intersection approaches.
- ✓ To evaluate the consequence of three wheel drive with performance parameters.
- ✓ To compare the performance change of intersections by replacing three wheel drive with a minibus.

1.5. Scope and limitations of the Research

This research is carried on two roundabouts and two signalized intersections which are located in Hosanna city. These intersections are considered as the major intersections in the city and located on the major road within the city. The findings of this research are specific to these selected intersections. The study analyzes the effect of three wheelers on intersection performance parameters (capacity, degree of saturation, control delay, queue length and level of service). In comparing the effect of three wheelers and minibus taxis on intersections, the comparison is from traffic performance point of view only. Detail cost benefit analysis of the comparison is not discussed in this research. The analysis methods used in this research are based on Highway Capacity Manual (HCM 2010) procedures incorporated with SIDRA intersection software. There are some used assumed input values including PCU which may not fit exactly in a local condition. In addition, the data collection period is limited to a single day for an intersection and only for six hours per day based on the recommendations from FDOT manuals. It may be difficult to capture the actual fluctuation of traffic flows for the intersections during this time periods.

1.6. Significance of the Study.

The research result helps to counter on the problems on signalized intersections and roundabouts by recommending a number of countermeasures and gives notice to the policy developers to put some plans of policy on the transportation infrastructures especially on urban road networks and intersections. If the objective of this study was achieved the following advantages can be attained: reducing the congestion on the traffic junctions especially during peak hours, reducing the cost of traveling for the public, increasing the efficiency of the road network, improving traffic flow and traffic operations.

1.7. Structure of the thesis

This thesis consists of five chapters: The first chapter of this thesis gives a general introduction of the overall thesis content and the general background of parameters involved in the analysis. The problem statements and objectives are discussed in this chapter .The second chapter reviews the relevant literatures related capacity and other performance analysis of roundabouts and signalized intersections. Chapter three discusses the study methodology carried out for this study. The relevant data collected for this research, the methodologies and equipments used for data collection are discussed. Chapter four discusses data analysis and results. The findings and theirs interpretation are discussed in this chapter. Chapter five is about conclusion of the findings and recommendations based on the findings of this thesis.

2. LITERATURE REVIEW

2.1. General Overview

Intersection is an area shared by two or more roads. This area is designated for the vehicles to turn to deferent directions to reach their desired destinations. Its main function is to guide vehicles to their respective directions. Traffic intersections are complex locations on any highway. This is because vehicles moving in different direction want to occupy same space at the same time. In addition, the pedestrians also seek same space for crossing. Intersections are generally classified into three general categories: At-grade intersections, Grade separated without ramps and Grade-separated with ramps (commonly known as interchanges). Most highways intersect at grade, and the intersection area should be designed to provide adequately for turning and crossing movements, with due consideration to sight distance, signs, and alignments. The basic types of at-grade intersections are T, Y or three-leg intersections, which consist of three approaches; four-leg or cross intersections, which consist of four approaches; multi leg intersections, which consist of five or more approaches; and roundabouts. At grade intersections can be also classified as signalized and unsignalized intersections based on the traffic control mechanisms. Intersections at grade can be eliminated by the use of grade separation structures that permit the cross flow of traffic at different levels without interruption. The advantage of such separation is the freedom from cross interference with resultant saving of time and increase in safety for traffic movements (Kumar, 2014).

Intersection design is a complex process where factors related to operational efficiency such as capacity, delay and emissions are an important consideration along with safety features and geometrical constraints. A poorly designed intersection may contribute to traffic congestion, increase in vehicular emissions and road accidents. The operational efficiency of intersections largely depends on the prevailing road, traffic and control conditions. In recent years, vehicular emissions have also been a major factor in intersection design. Environmentally-friendly alternatives are more important than ever before to minimize carbon footprints contributed by transport sector (Borkloe et al, 2013).

2.2 Roundabouts

Roundabouts are a type of circular intersections in which traffic travels counterclockwise (in right-hand traffic countries) around a central island. Specific design and traffic control features define and distinguish roundabouts from traffic circles. These features include yield control of all entering traffic, channelized approaches that deflect traffic flow, and appropriate geometric curvature to ensure that travel speeds on the circulatory roadway within the specified limit (FHWA, 2000). Roundabout is Suitable for relatively balanced approach volumes, safer for vehicular travel, can result in less delay and emissions, can accommodate aesthetic treatments, lower injury and fatality rates, less suitable for high volume/multilane approaches, less intuitive for pedestrians/bicycle lists than other intersection type (MASS HIGHWAY, 2006).

The key geometric elements of Roundabouts are shown in Figure 2.1.Roundabouts introduces an entry curve to slow entering traffic down to give-way to circulating traffic. The entry and exit curves are separated by a raised median called a splitter island, which is designed to deflect and slow entering traffic in conjunction with the entry curve. The vehicles then enter the roundabout when a sufficient gap is presented, then travels within the circulating carriageway until they reach their desired exit. Roundabouts are becoming more popular based on the multiple opportunities to improve safety and operational efficiency, and provide other benefits. Of course, roundabouts are not always feasible and do not always provide the optimal solution for every problem. But it is more useful for traffic safety, increasing operational performances, providing environmental benefits, pedestrian safety, Aesthetics, Land Use and Access Management (FHWA, 2009).

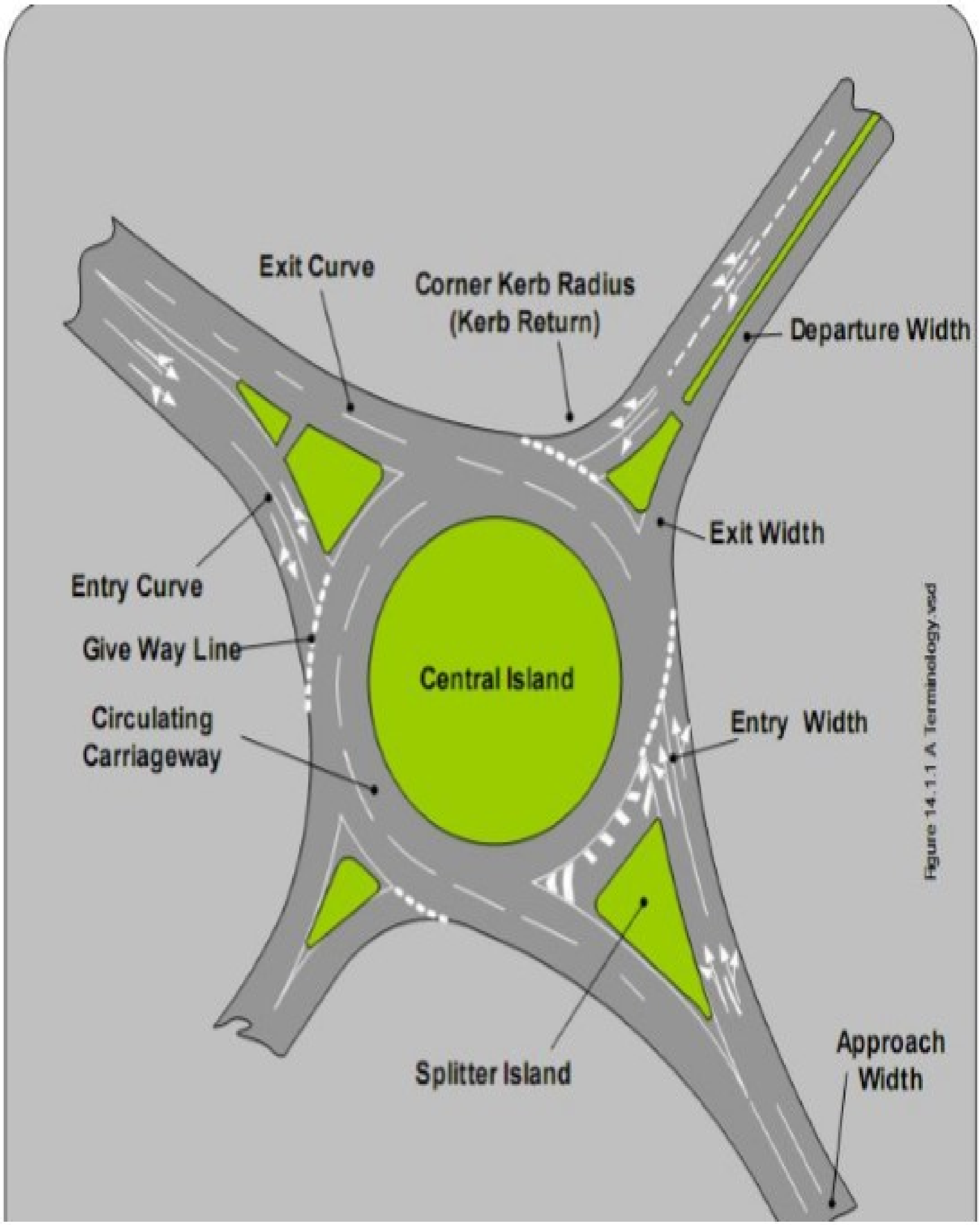


Figure 2.2 Geometric elements of roundabout (AACRA Manual, 2004).

Table 2.4 Description of key roundabout features. (AACRA Manual, 2004)

Feature	Description
Approach Curve	Approach Curve is used to slow down the operating speed of vehicles coming from a high speed environment
Entry Curve	Entry Curve is used to deflect and slow entering vehicles to an appropriate Speed to safely circulate the roundabout.
Entry Width	Entry Width is the width of the entry where it meets the circulating carriage way.
Holding Line	Holding Line is pavement marking that defines where the vehicles have to give way to the circulating traffic. It is generally marked along the inscribed circle.
Circulating Carriageway	Circulating Carriageway is a curved path used by vehicles to travel around the Central island. This is defined by line marking.
Circulating Carriageway Width	Circulating Carriageway Width defines the roadway width for vehicle circulation Around central island. The Circulating Carriageway Width has to be wide enough to accommodate the largest design vehicles turning path.
Exit Width	Exit Width is the width of the exit where it meets the circulating carriageway.
Exit Curve	Exit Curve is generally bigger/flatter than the entry curve to allow vehicles to exit at faster speed to improve traffic capacity and flow.

2.2.1 Performance Analysis of roundabout

An operational analysis produces two kinds of estimates: (1) the capacity of a facility, i.e., the ability of the facility to accommodate various streams of users, and (2) the level of performance, often measured in terms of one or more measures of effectiveness, such as degree of saturation, delay and queues. The Highway Capacity Manual (HCM) defines the capacity of a facility as "the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions". While capacity is a specific measure that can be defined and estimated, level of service (LOS) is a qualitative measure that characterizes operational conditions within a traffic stream and their perception by motorists and passengers. To quantify level of service, the HCM defines specific measures of effectiveness for each highway facility type (TRB, 2000). The capacity of each entry to a roundabout is the maximum rate at which vehicles can reasonably be expected to enter the roundabout from an approach during a given time period under prevailing traffic and roadway (geometric) conditions. Roundabout approach capacity is dependent on the conflicting circulating flow and the roundabout's geometric elements (FHWA, 2000).

2.2.2 Capacity and Degree of saturation

Capacity is the maximum sustainable flow rate that can be achieved during a specified time period under given (prevailing) road, traffic and control conditions (HCM, 2010)
According to HCM 2010 capacity of roundabout is calculated as follows.

Cp= $Ae^{(-BVc)}$……………………………………………………………….equation 2.1

Where: $A = \frac{3600}{tf}$

B= $\frac{tc-(\frac{tf}{2})}{3600}$

Cp=Capacity (pc/h)

Vc=traffic flow (pc/h)

tc=critical Gap, s

tf=follow up times, s

According to HCM 2010 degree of saturation can also be evaluated by using the following formulas

Xi=$\frac{Vi}{Ci}$……………………………………………………………………..equation 2.2

Where:

Xi =degree of saturation.

vi =Demand flow (the recorded peak vehicle flow/hr.)

ci=Capacity.

2.2.3 Queue Length Control delay

Based on HCM 2010 Queue Length can be calculated as follows

$$Q_{95}=900T\left[\frac{Vx}{Cm,x}-1+\sqrt{\left(\frac{Vx}{Cm.x}-1\right)^2+\frac{\left(\frac{3600}{Cm,x}\right)\left(\frac{Vx}{Cm,x}\right)}{150T}}\right]\left(\frac{Cm,x}{3600}\right) \quad \text{.......equation 2.3}$$

Control delay can also be calculated as follows

$$d=\frac{3600}{Cm,x}+900T\left[\frac{Vx}{Cm,x}-1+\sqrt{\left(\frac{Vx}{Cm.x}-1\right)^2+\frac{\left(\frac{3600}{Cm,x}\right)\left(\frac{Vx}{Cm,x}\right)}{450T}}\right]+5 \quad \text{.......equation 2.4}$$

Where:

d = average control delay (s/veh),

vx = flow volume of a subject lane (veh/h),

Cm,x= capacity of the subject lane (veh/h), and

T= time period (h) (T= 0.25 h for a 15 – min analysis)

2.2.4 Level of service

By using the following table the level of service of intersection approaches can be identified.

Table 2.5 level of service for roundabout (source HCM 2010)

Control Delay (s/veh)	LOS by volume to capacity ratio	
	v/c ≤1.0	v/c > 1.0
0-10	A	F
>10-15	B	F
>15-25	C	F
>25-35	D	F
>35-50	E	F
>50	F	F

2.3 Signalized Intersection.

Signalized intersections are intersections where vehicle and pedestrian movements are controlled by traffic signals. A traffic signal is a signal that controls vehicle and pedestrian traffic at an intersection or in a road by means of red, yellow, green or white light displays, and includes circular and arrow signals, pedestrian signals, bicycle crossing signals, bus signals, light rail or tram signals, and overhead lane control signals. This system is controlled by an automatic device so called traffic signal controller that regulates the sequence and duration of illumination of red, yellow, green and white vehicle signal aspects and pedestrian walk and don't walk signal aspects (Akçelik, 2017).

Reducing crashes should always be one of the objectives whenever the design or operational characteristics of a signalized intersection are modified. As described by the Federal Highway Administration (FHWA), the "mission is not simply to improve mobility and productivity, but to ensure that improved mobility and productivity comes with improved safety" In general, two types of traffic signal controller unit are in use today. They are broadly categorized as pre timed or actuated according to the type of control they provide. These two types of control are described as follows:

- ✓ **Pretimed control** consists of a fixed sequence of phases that are displayed in repetitive order. The duration of each phase is fixed. However, the green interval duration can be changed by time of day or week to accommodate traffic variations. The combination of a fixed phase sequence and duration produces a constant cycle length.
- ✓ **Actuated control** consists of a defined phase sequence in which the presentation of each phase depends on whether the phase is on recall or the associated traffic movement has submitted a call for service through a detector. The green interval duration is determined by the traffic demand information obtained from the detector, subject to preset minimum and maximum limits. The termination of an actuated phase requires a call for service from a conflicting traffic movement. An actuated phase may be skipped if no demand is detected.

2.3.1. Performance evaluation of Signalized intersections.

Capacity, degree of saturation, delay, queue length, and level of service are the main performance measures of intersections (HCM, 2010). The updated procedures described in the HCM 2010 are used to evaluate the associated automobile performance measures for signalized intersection. They are;

2.3.1.1. Capacity and volume-to-capacity ratio

Capacity is the maximum sustainable flow rate that can be achieved during a specified time period under prevailing road, traffic and control conditions. The proviso "prevailing conditions" is important since capacity is not a constant value, but varies as a function of traffic flow levels. It is often estimated based on assumed values for saturation flow, and width of lanes, grades, and lane use allocations, as well as signalization conditions.

Capacity represents the service rate (queue clearance rate) in the performance (delay, queue length, stops) functions, and therefore is relevant to under saturated conditions. Conceptually, this is different from the "maximum volume that the intersection can handle" which is the practical capacity (based on a target degree of saturation) under increased demand volumes (e.g. in the future as relevant to design life analysis), not the capacity under prevailing conditions.

Two distinct methods are possible for measuring capacities at real-life intersections:
I. Measuring departure (saturation) flow rates during saturated (queued) portions of individual green periods at signals or gap-acceptance cycles at unsignalized intersections, and the associated proportion of time available for queue discharge, and
II. Measuring departure flow rates (volume counts) at the stop or give-way / yield line under continuous queuing (saturated) conditions over sufficiently long observation periods. Under the HCM 2010 procedure, intersection capacity is measured for critical lane groups (those lane groups that have the highest volume-to-capacity ratios). Critical intersection volume-to capacity ratios are based on flow ratio for the critical phase. A critical phase is one phase of a set of phases that occur in sequence and whose combined flow ratio is the largest for the signal cycle. The volume-to-capacity (v/c) ratio, also referred to as degree of saturation, represents the sufficiency of an intersection to accommodate the vehicular demand.

A v/c ratio less than 0.85 generally indicate that adequate capacity is available and vehicles are not expected to experience significant queues and delays. As the v/c ratio approaches 1.0, traffic flow may become unstable, and delay and queuing conditions may occur. Once the demand exceeds the capacity (a v/c ration greater than 1.0), traffic flow is unstable and excessive delay and queuing is expected (FWHA, 2009).

2.3.1.2 Delay

Delay is defined in the HCM 2010 as "the additional travel time experienced by a driver, passenger, bicyclist, or pedestrian beyond that is required to travel at the desired speed." In other words, it is the difference between interrupted and uninterrupted travel times through the intersection.

The signalized intersection chapter (Chapter 18) of the HCM 2010 provides equations for calculating control delay, the delay a motorist experiences that is attributable to the presence of the traffic signal and conflicting traffic. This includes time spent decelerating, in the queue, and accelerating. Expectation of delay at a signalized intersection is different than at an unsignalized intersection. The control delay equation comprises three elements: uniform delay, incremental delay, and initial queue delay. The primary factors that affect uniform delay are lane group volume, lane group capacity, cycle length, and effective green time. Two factors that account for incremental delay are

(a) the effect of random and cycle-by-cycle fluctuations in demand that occasionally exceed capacity, and sustained oversaturation during the analysis period, when the aggregate demand exceeds the aggregate capacity. The third component of the control delay illustrates the delay

(b) Due to an initial queue, as a result of unmet demand in the previous time period.

2.3.1.3. The Back-of-queue and Queue Storage Ratio

Practitioners should evaluate vehicle queuing, an important performance measure, as part of all signalized intersections analyses. Vehicle queue estimates help determine the amount of storage required for turn lanes and whether spillover occurs at upstream facilities (driveways, unsignalized intersections, signalized intersections, etc.). Queues that extend upstream from an intersection can spill back into and block upstream intersections, causing side streets to begin to queue back. The back-of-queue is the maximum backward extent of queued vehicles during a typical cycle.

This back-of-queue length depends on the arrival pattern of vehicles and the number of vehicles that do not clear the intersection during the previous cycle. Approaches that experience extensive queues also may experience an over-representation of rear-end collisions.

Vehicle queues for design purposes are typically estimated based on the 95-percentile queue that is expected during the design period. This is the length at which 95 percent of lane queues are less than in a given study period. The queue storage ratio represents the proportion of the available queue storage distance that is occupied at the point in the cycle when the back-of-queue position is reached. If this ratio exceeds1.0, then the storage space will overflow and queued vehicles may block other vehicles from moving forward. Volume 3 of the HCM 2010 provides procedures for calculating back-of-queue length and the queue storage ratio. In addition, all known simulation models provide ways of obtaining queue estimates (FHWA, 2009).

2.3.1.4. Level of service (LOS)

Level of Service (LOS) is a grading-scale based descriptor that attempts to relate relative operational quality (based on certain measures of effectiveness) to that of driver perception in simple fashion (FHWA, 2009). LOS can be characterized for the entire intersection, each intersection approach, and each lane group. Control delay alone is used to characterize LOS for the entire intersection or an approach. Control delay and volume-to-capacity ratio are used to characterize LOS for a lane group. Delay quantifies the increase in travel time due to traffic signal control. It is also a surrogate measure of driver discomfort and fuel consumption. The volume-to-capacity ratio quantifies the degree to which a phase's capacity is utilized by a lane group. HCM (2010) describes each LOS as follows LOS A describes operations with a control delay of 10s/veh or less and volume-to-capacity ration greater than 1.0. This level is typically assigned when volume-to-capacity is low and either progression is exponentially favorable or the cycle length is very short. If it is due to favorable progression, Most Vehicles Arrive during the green Indication and travel through the intersection without stopping.

LOS B describes operations with control delay between 10 and 20s/veh and a volume-to-capacity ratio no greater than 1.0. This level is typically assigned when volume-to-capacity is low and either progression is highly favorable or the cycle length is short. More vehicles stop than with LOS A.

LOS C describes operations with control delay between 20 and 35s/veh and a volume-to-capacity ratio no greater than 1.0. This level is typically assigned when progression is favorable or the cycle length is moderate. Individual cycle failures may begin to appear at this level.

LOS D describes operations with control delay between 35 and 55s/veh and a volume-to-capacity ratio no greater than 1.0. This level is typically assigned when volume-to-capacity is high and either progression is ineffective or cycle length is long. Many vehicles stop and individual cycle failures are noticeable.

LOS E describes operations with control delay between 55 and 80s/veh and a volume-to-capacity ratio no greater than 1.0. This level is typically assigned when volume-to-capacity ratio is high; progression in unfavorable and the cycle length is long. Individual cycle failures are frequent.

LOS F describes operations with control delay exceeding 80s/veh or a volume-to-capacity ratio greater than 1.0. This level is typically assigned when the volume-to-capacity is very high, progression is very poor, and the cycle length is long.

2.4. Factors which affect intersection performances.

The main factors which affect the traffic movements at intersections can be categorized as human factors, traffic factors and features of physical elements. Human factors includes driving habits, ability to make decisions, driver expectancy, decision and reaction time, conformance to natural paths of movement, and pedestrian use and habits. The following features also affects intersection performances; Number of lanes, design speed ,gradient lane, shoulder and median width, traffic volume and composition of highway users, including trucks and transit vehicles, turning volumes, Horizontal curve radii, sight distance, proximity of adjacent intersections and Types of adjacent intersections.

All roadway users are affected by intersection design as described below: (Nurhussien, 2015).

- ✓ **Pedestrians:** Key elements affecting intersection performance for pedestrians are: Amount of right-of-way provided for the pedestrian including both Sidewalk and crosswalk width, accuracy of slopes and cross slopes on curb, Cut ramps and walkways, audible and/or tactile cues for people with Limited sight, and absence of obstacles in accessible path, Crossing distance and resulting duration of exposure to conflicts with motor vehicle and bicycle traffic, Volume of conflicting traffic, and Speed and visibility of approaching traffic.
- ✓ **Bicyclists:** Key elements affecting intersection performance for bicycles are: Degree to which pavement is shared or used exclusively by bicycles, Relationship between turning and through movements for motor vehicle And bicycles, Traffic control for bicycles, Differential in speed between motor vehicle and bicycle traffic and Visibility of the bicyclist.
- ✓ **Motor vehicles:** Key elements affecting intersection performance for motor Vehicles are: Type Of traffic control, Vehicular capacity of the intersection, determined primarily from the Number of lanes and traffic control (although there are other factors), Ability to make turning movements, Visibility of approaching and crossing pedestrians and bicycles, and Speed, visibility of approaching and crossing motor vehicles.

- ✓ **Transit:** When transit Operations Involve buses, They Share the Same key characteristics as vehicles. In addition, transit operations may involve a transit stop at an intersection area, and influence pedestrian, bicycle, and motor vehicle flow and safety. In some cases, the unique characteristics of light-rail transit must be taken into account.

2.4.1. The Effect of Vehicle Types on Intersection Performance

Different Classes of vehicles such as cars, vans, Buses, trucks, auto rickshaw, motor cycles, by-cycles, etc. are found to use the common roadway facilities without segregation on most of the roads in developing countries .The flow of traffic with unrestricted mixing of different vehicle classes on the roadways forms the heterogeneous traffic flow or the mixed traffic flow. The different vehicle classes have a wide range of static characteristics such as length, width etc. and the dynamic characteristics such as speed and acceleration. As a result of this the performances of intersections can be affected highly at heterogeneous traffic condition than homogeneous traffic conditions (Saha.K, 2013).

A study made by Rao (2015) in India indicated that different vehicle categories have different effects on the traffic flow around the intersection. Mallikarjuna (2014) also showed that heavy vehicles and light vehicles have different kind of effects on performance parameters of intersections.

Heavy trucks influence their surrounding traffic characteristics. The space gaps between heavy trucks and their front/ rear vehicles are larger than the corresponding values in light trucks and passenger cars. The large space gaps in vicinity of Heavy trucks and the limitations in adjusting their speed according to surrounding vehicles' speed produce a disproportionate effect on traffic flows and this affects road performances (Moridpour.S, 2014).

2.4.1.1. The Effect of Three wheelers on Intersection Performances

There is not a much research conducted regarding this topic but Syoum (2018) took the research regarding the effects of vehicle compositions including three wheelers on performance measurement parameters of three unsignalized intersections in Harar city. The analysis was made in 15 minute interval over a range of 24 consecutive time series to indicate the trends of change of the performance of intersections in relation to the change of vehicle compositions and flow characteristics. Multiple regression was the analysis method applied to indicate the effects of vehicle classes in the study. According to the results of his study, the presences of three wheelers were significantly affecting the performances of unsignalized intersection highly in Harar City.

2.5. SIDRA Intersection Software

2.5.1. General Introduction about the SIDRA Intersection

The SIDRA Intersection software acronymed for Signalized & Unsignalized Intersection Design and Research Aid is for apply as an serve for design and evaluation of individual intersections and networks of intersections. It can be used to analyze signalized intersections (fixed-time / pretimed and actuated), signalized and unsignalized pedestrian crossings, roundabouts (unsignalized), roundabouts with metering signals, fully signalized roundabouts, two-way stop sign and give-way / yield sign control, all-way stop sign control, single point interchanges (signalized), freeway diamond interchanges (signalized, roundabout, sign control), diverging diamond interchanges. It can also be used for uninterrupted traffic flow conditions and merge analysis. SIDRA Intersection allows modeling of separate Movement Classes (Light Vehicles, Heavy Vehicles, Buses, Bicycles, Large Trucks, Light Rail / Trams and two User Classes) with different vehicle characteristics. These movements can be allocated to different lanes, lane segments and signal phases, for example for modeling bus priority lanes at signals. Signal timing calculations for single intersections and network timings including signal offsets for signal coordination are carried out. A unique method is used to determine signal timings for a number of intersections operating under a single signal controller (common control groups). SIDRA Intersection is an advanced micro-analytical traffic evaluation tool that employs lane-by lane and vehicle path (drive-cycle) models coupled with an iterative approximation method to provide estimates of capacity and performance statistics (delay, queue length, stop rate, etc). All input and output data and modeling are based on Origin-Destination movements. This improves handling of movements at intersections with diagonal legs and U turns. The SIDRA Network model determines the backward spread of congestion as queues on downstream lanes block upstream lanes (queue spillback), and applies capacity constraint to oversaturated upstream lanes, thus limiting the flows entering downstream lanes. These two elements are highly interactive with opposing effects. A network-wide iterative process is used to find a solution that balances these opposing effects. Unlike traditional network models that use aggregate models of "links" or "lane groups", SIDRA Intersection uses a lane-based model to create second-by-second platoon arrival and departure patterns for signalized Sites (at-grade intersections, interchanges, pedestrian crossings) to calculate signal coordination effects as a function of signal offsets for internal approaches in network analysis.

The model takes into account midblock lane changes that apply to signal platoon patterns. This is particularly important in evaluating closely spaced (paired) intersections with high demand flows where vehicles have limited opportunities for lane changes between intersections. These lane-based modeling requirements are important in emulating the forward movements of platoons for estimating performance measures (delay, back of queue, stop rate) at an individual lane level. SIDRA Intersection provides various facilities for calibration of its traffic models for local conditions. The US HCM software setups (Customary and Metric units) of SIDRA INTERSECTION are based on the calibration of model parameters against the Highway Capacity Manual. In the USA, SIDRA intersection is recognized by the US Highway Capacity Manual, TRB Roundabout Guide (NCHRP Report 672) and various local roundabout guides. SIDRA Intersection is the most widely used software tool in the USA for roundabout capacity and performance analysis. In Australia and New Zealand, SIDRA Intersection is endorsed by AUSTROADS and various local guidelines (the Association of Australian State, Territory and Federal Road and Transport Authorities). Since its first release in 1984, the use of SIDRA Intersection has grown steadily over the years to make it a best-selling software package. In February 2017, the latest versions of the software were in use by about 1930 organizations with about 8200 licenses in 84 countries. The countries where

SIDRA Intersection was used most extensively were (with the approximate number of organizations shown) USA (650), Australia (440), Europe (190), New Zealand (70), South Africa (120), Canada (100), Malaysia & Singapore (110), Arabian Peninsula (90) and Latin America (60).

2.5.2. Calibration of SIDRA Intersection Software

Since the Sidra Intersection was developed for Australian conditions as default, it requires calibration for other countries. Calibration of the Sidra Intersection is performed by changing values of the parameters affecting capacity. This can be done in a few different ways, either by changing the value of the critical gap and the follow-up headway directly or by using the calibration parameters; environment factor and entry/circulating flow adjustment. The environment factor can be seen as a collection factor that includes everything at the Junction environment e.g. design type, visibility, grade, speed, driver response time and aggressiveness, amount of heavy vehicles and pedestrians and parking near the Junction. On the one hand, factors in the environment with positive effects on traffic are for example; good visibility, small volumes of pedestrians, short driver response times, and low levels of heavy vehicles and parking on the approaches. In cases like that, environment factor should be lower which leads to higher capacity. On the other hand, situations such as bad visibility, large volumes of pedestrians, long driver response times and large volumes of heavy vehicles have negative effects on capacity. Environment factor should therefore be higher which will lead to lower capacity. The default environment factor is set to 1, which is also the same in Australia. According to Myre (2010) studies in Norway have shown that 1.1 is a good value of environment factor for Norwegian conditions. Similarly, the Anna-Karin Ekman studies in Sweden have shown that 1.1 is also a good value of environmental factor for Swedish condition and he also suggested that the range of interesting values should be within 1.0 ± 0.2. The HCM version of the SIDRA Intersection model uses 1.2 as environment factor.

3. MATERIALS AND METHODS

3.1. Introduction

The methodology employed in the research work was the critical aspect for ensuring the proper result, which aligns with the objective. Hence, this part of the Thesis discusses the methodology applied to address the research problem and software programs that are available to analyze traffic operations at the roundabouts and signalized intersections.

3.2. Description of Study Area

Hosanna is found in southern Nation, Nationalities and peoples Region in Hadiya Zone, locally known as Wachemo, is located at 232km south from the capital Addis Ababa, 168kms away from Hawassa, and 89kms away from Butajira. It is the City of Hadiya zone. Hosanna town lies on an elevation ranges from 2130m-2417meters above mean sea level across the main high way leading from Addis Ababa via Butajira to Wolayita Sodo. It is found 7°30'30''N-7°35'30''N Latitude and 37°48'30''E-37°54'30''E longitude. It is surrounded by Lemo wereda, one of the weredas of Hadiya zone. The town has a total area of 37.13square kilometers. It serves as a major business center for inhabitants in the area. Hosanna is the administrative center of the Hadiya zone, with a population of 133,764. Out of which 65,132 are males and 68,632 are females (Hosanna Municipality, 2019).

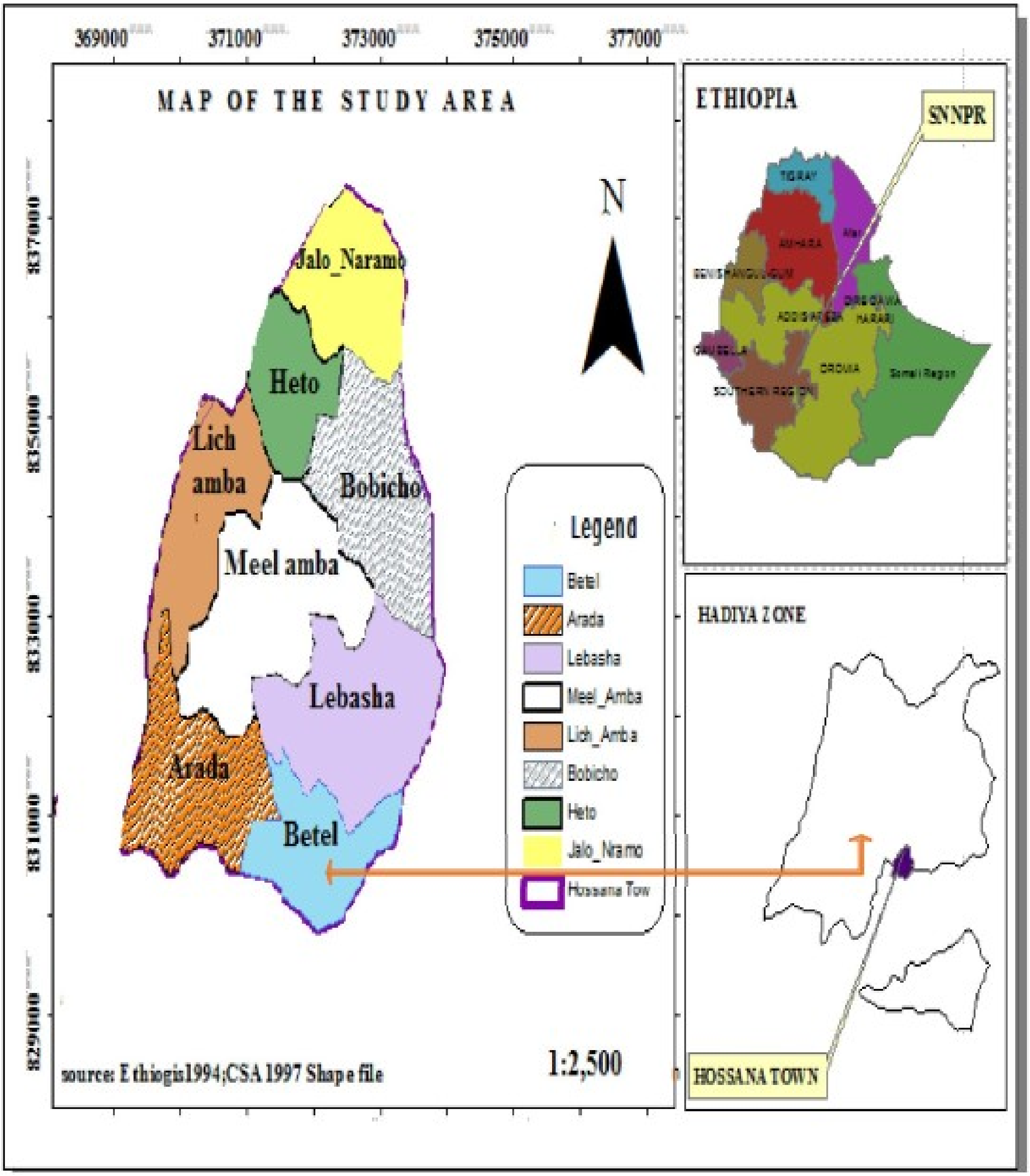


Figure 3.2 The study area, Hosanna City (Source: Ethiogis;CSA 1997 Shape file).

3.2.1 Road network

The road is a very important infrastructure and used as an indicator of the level of development of a particular country. A road network is the geographical expression of roads with line features. Hosanna Town has a network of 431.45kms of roads. Out of which 13.97kms were asphalt roads, 76.03kms were gravel roads, 53.57kms were cobblestone roads, and 287.88kms were earth roads (Hosanna Municipality, 2019). There are two signalized intersections and two main roundabouts currently in use in Hosanna City. This thesis was done on those two signalized intersections and two roundabouts in Hosanna City; those were areas where traffic congestions were frequently observed during peak hours. The names of intersections are Menharya signalized intersection and Mariyam signalized intersection. Roundabouts are also named as Bezabh Petros roundabout and Eyerusalem roundabout. Among the signalized intersections, both are four-legged, and Bezabh Petros roundabout has five approaches, and Eyerusalem roundabout has four approaches of different geometry with one another.

3.2.2 Traffic nature

The traffic movements in Hosanna are characterized by a lot of small vehicles like three wheelers, small taxis, passenger cars, buses and trucks. As shown below in table, the high recorded numbers of three wheelers exist in the city. So the transportation mode is highly occupied with three-wheelers.

Table 3.1 Types and number of vehicles recorded in Hosanna City. (Source: Transportation office of Hosanna City)

Types of vehicles	Number of vehicles
Three-wheelers	1358
Passenger Car	300
Public buses	595
Medium trucks	300
Large trucks	69

3.3 Study Period

The research was started at October 20, 2019 by site observation and identification of the problems. The geometric data was recorded from the road intersections, for a week from February 23 up to February 28, 2020 and the traffic data was conducted from March 5- March 9, 2020. Since the survey time this study was conducted up to October, 2020 by referring related materials and by analyzing the results of collected data.

3.4 Research Design

The research designs that are used by the researcher are quantitative and descriptive type of research. Quantitative data were used to determine all parameters which are related to performance characteristics of intersections like capacity, level of service, delay, queue length and degree of saturation. Descriptive type of research is chosen by the researcher to assess the performance evaluation of intersections. After the performances of the intersections were analyzed, the change of the parameters over the time period and the variables which has a significant effect on the change was analyzed.

3.5 Software and Instruments

The FHWA Guideline lists available computer Software programs that analyze traffic operations at roundabouts and signalized intersections. The Software can be divided into two types: macroscopic and microscopic models. The Macroscopic Models use traffic volume flows to model intersections as isolated locations. On the other hand, the Microscopic Models simulate individual vehicles' movement, thereby allowing a network-wide analysis. One of the macroscopic models (SIDRA intersection 5.1) software program was applied to analyze traffic operations at roundabouts and signalized intersections for this study. In fact, AACRA also recommends Sidra Intersection software for capacity analysis, which is developed using analytic methods with some geometric elements. The SIDRA Intersection 5.1 software is preferred for capacity analysis in this research due to the following reasons:

- ✓ It is a commercially available tool to offer full geometric and gap acceptance modeling capability within a single product;

- ✓ It has employed a combined (hybrid) geometry and gap-acceptance modeling approach in order to take into account the effect of roundabout geometry on driver behavior directly through gap-acceptance modeling; and
- ✓ It can be calibrated for local conditions, and it is highly flexible

Excel software was also used for the purpose of comparison of performance measurement parameters and Measuring tape was also used to measure geometric features. Detail explanation is found in analysis section.

3.6 Data Collection Process.

3.6.1 Traffic Volume Data

The traffic count surveys were carried out at all selected junctions for six hours; in the morning 7:00 am-10:00 am and in the afternoon 3:00 pm-6:00 pm at 15-minute intervals from March 5- March 9, 2020 by setting up video cameras. The peak hour was determined by finding the four consecutive 15-minute periods with the highest total volume. The highest traffic volume in each direction was recorded for use in the analysis of this research. Traffic volumes can vary greatly throughout the day, by day of the week, by the time of year, and even at 5-minute intervals during the peak hour. Traffic volumes can also experience additional fluctuations due to accidents, special incidents, or weather and will also change over time, depending on the City's growth dynamism. However, normally, traffic surveys are performed using the average weekday peak hour traffic counts. On normal commuter routes, there are morning and afternoon peak hours. The high pedestrian volume also has a significant effect on capacity. Because of this, numbers of pedestrians were recorded at peak hours along the direction of their movements. The number of counted vehicles and pedestrians are shown in the tables below.

3.6.1.1 Video with Manual Transcription Method

Video recording and manual transcription were used to collect traffic and pedestrian flow data. This data collection method relies on video cameras to collect or capture the traffic and pedestrian flows in the field and data recorders in others. According to the travel time collection handbook, though costly, video capturing techniques are preferred to the manual collection. This was because of the following reasons:

- ✓ It provides a permanent, easily-review record and shows traffic conditions at any time;
- ✓ It permits reading of required parameters in a controlled environment in which plate characters can be closely examined
- ✓ It provides additional information about traffic flow characteristics such as traffic volume and vehicle headways; and
- ✓ It provides time for accurate determination of arrival times and has better accuracy than manual counts.

Therefore, in order to utilize the above advantages and due to its convenience, the video camera was arranged at a convenient height where the maximum view could be captured, and visibility was also maximized. The locations of video capturing were on floors of high rising buildings in the area of the study locations.

3.6.1.2 Passenger Car Unit (PCU)

To conduct traffic volume, it is necessary to have a single unit counting the number of vehicles because different vehicles in a traffic stream have different effects. So, all vehicles which use the condor must be converted to a common unit called passenger car unit. In this research PCU were acquired from the High way Capacity Manual 2010 are depicted in the table shown below.

Table 3. 2. Passenger car units for vehicles

vehicle type	Passenger Car Equivalent (PCE)
Heavy vehicles	2.0
Passenger Car	1.0
*Three wheelers	0.4
*Motor cycle	0.25

*The PCU values of three wheelers and Motor cycle was taken from ERA Manual 2013.

3.6.2 Geometric Data

As per the requirement of the SIDRA Intersection Version 5.1, the collected geometric data include; island diameter, circulatory width, number of circulatory lanes, entry lane number and average lane width at the entry for roundabout junction; and number of lanes, lane width, grade, the width of the median for the signalized junction. These data were measured with a tape meter, and the collected geometric data are summarized as shown below.

Table 3.3 Existing roundabouts geometry data**.**

S.N.	Junction Name	Approach Leg	Entry Lane	Number of Circulatory Lane	Island Diameter (m)	Average lane width	Circulatory Road width (m)
1	Bezabh Petros roundabout	Mesalemya	2	2	24	3.3	10
		Menharya	2	2	25.4	3.3	10
		Hadiyya pharmacy	1	1	19	3.1	10
		Mobile	2	2	18	3.3	10
		Maremya	1	1	24	3.1	10
2	Eyerusalem round about	Gombera	2	2	19	3.3	9
		Mesalemiya	2	2	19	3.1	9
		Inatkalehiwet	1	1	16	3.2	9
		Maryam	2	2	15	3.3	9

Table 3.4 Signalized intersections geometric data

S.N.	Junction Name	Approach name	No. of Entry Lane	No. of Exit Lane	Lane width(m)	Median width(m)
1	Menharya signalized intersection	Hospital	1	1	3.5	No median
		Lucy	1	1	3.5	No median
		18 Mazorya	2	2	3.3	0.9
		Handa Mall	2	2	3.1	0.9
2	Maryam signalized intersection	Eyerusalem	1	1	3.5	No median
		Stadium	1	1	3.5	No median
		Mobile	2	2	3.3	0.9
		Ambicho	2	2	3.1	0.9

3.7 Data Processing and analysis

3.7.1 Evaluation of Performance Measurement parameters of signalized intersections and roundabouts.

There are two intersection analysis models which are Empirical models and Analytical p[models. The concern of Empirical models is on field data to build relationships between geometric design features and performance measures. As a substitute Analytical models are based on the concept of gap acceptance theory. The choice of an analysis approach depends on the calibration data available (HCM, 2010). The researcher used analytical model for this specific research intersection analysis. This is done through the use of SIDRA INTERSECTION version 5.1 software incorporated with Highway Capacity Manual (HCM 2010) which is the most widely adopted method for analysis of intersections. The HCM defines intersection performance in terms of average vehicle delay (seconds per vehicle) and then maps this delay against predefined boundaries to define intersection performance in terms of six levels of service (i.e. LOS A through LOS F).

To evaluate the performance of the signalized intersections and roundabouts, the traffic data was converted to Passenger Car Equivalents shown in the tables below.

Table 3.5 Peak hour traffic volumes (PCU) of signalized intersections.

Intersection	Approach	Direction	Traffic volume (PCU)	Traffic volume Of Three Wheeler (PCU)	%Three Wheeler	Traffic volume Of Heavy vehicles (PCU)	%Heavy vehicles
Menharya signalized intersection	Hospital	Left	125	110	88	8	6
		Through	40	33	83	3	8
		Right	160	145	91	10	6
		Total	325	288	89	21	6
	Lucy	Left	45	37	82	4	9
		Through	20	16	80	0	0
		Right	60	50	83	6	10
		Total	125	103	82	10	8
	18 Mazorya	Left	10	7	70	0	0
		Through	470	441	94	23	5
		Right	10	6	60	1	10
		Total	490	454	93	24	5
	Handa Mall	Left	35	27	77	0	0
		Through	574	523	91	34	6
		Right	18	17	94	0	0
		Total	627	567	90	34	5
Maryam signalized intersection	Eyerusalem	Left	58	43	74	9	16
		Through	21	17	81	3	14
		Right	33	24	73	5	15
		Total	112	84	75	17	15
	Stadium	Left	58	44	76	6	10
		Through	21	16	76	1	5
		Right	33	24	73	1	3
		Total	112	84	75	8	7
	Mobile	Left	6	3	50	0	0
		Through	343	310	90	21	6
		Right	21	13	62	2	10
		Total	370	326	88	23	6
	Ambicho	Left	32	27	84	0	0
		Through	543	503	93	31	6
		Right	15	14	93	0	0
		Total	590	544	92	31	5

Table 3.6 Peak hour traffic volumes (PCU) of roundabouts.

Intersection	Approach	Direction	Traffic volume (PCU)	Traffic volume Of Three Wheeler (PCU)	%Three Wheeler	Traffic volume Of Heavy vehicles (PCU)	%Heavy vehicles
Bezabh Petros roundabout	Mesalemya	Left	211	90	43	41	19
		Through	456	220	48	96	21
		Right	63	33	52	8	13
		U-turn	13	10	77	0	0
		Total	743	443	60	145	20
	Menharya	Left	15	12	80	0	0
		Through	529	318	60	132	25
		Right	450	225	50	68	15
		U-turn	25	13	52	0	0
		Total	1019	568	56	200	20
	Hadiyya pharmacy	Left	43	12	28	9	21
		Through	21	10	48	2	10
		Right	6	4	67	0	0
		U-turn	2	2	100	0	0
		Total	72	28	39	11	15
	Mobile	Left	466	155	33	98	21
		Through	32	19	59	2	6
		Right	312	184	59	37	12
		U-turn	3	3	100	0	0
		Total	813	361	44	137	17
	Maremya	Left	23	20	87	0	0
		Through	4	4	100	0	0
		Right	21	11	52	0	0
		U-turn	1	1	100	0	0
		Total	49	36	73	0	0
Eyerusalem roundabout	Gombera	Left	45	20	44	5	11
		Through	621	311	50	168	27
		Right	47	25	53	2	4
		Total	713	356	50	175	25
	Mesalemiya	Left	24	14	58	1	4
		Through	594	346	58	101	17
		Right	63	28	44	11	17
		Total	681	388	57	113	17
	Inat kalehiwet	Left	52	29	56	5	10
		Through	41	23	56	1	2
		Right	68	27	40	5	7
		Total	161	79	49	11	7
	Maryam	Left	103	64	62	13	13
		Through	11	6	55	1	9
		Right	76	44	58	14	18
		Total	190	114	60	28	15

Table 3. 7 Pedestrians volume of intersections at peak hour.

S.N	Junction Name	Approaches	Number of Pedestrians
1	Menharya signalized intersection	Hospital	396
		Lucy	435
		18 Mazorya	501
		Handa Mall	523
		Total	1855
2	Maryam signalized intersection	Eyerusalem	365
		Stadium	421
		Mobile	396
		Ambicho	323
		Total	1505
3	Bezabh petros roundabout	Mesalemya	365
		Menharya	345
		Hadiyya pharmacy	402
		Mobile	293
		Maremya	323
		Total	1728
4	Eyerusalem roundabout	Gombera	311
		Mesalemiya	274
		Inat kalehiwet	306
		Maryam	265
		Total	1156

Table 6.8 Default values used in this thesis

Parameters	Default Values
Basic Saturation Flow	1800 veh/hr
Follow up headway	2.6 sec
Critical Gap	4.5 sec
Lane utilization	100%

According to (Roper 1999, Akçelik and Besley 2002, TRB 2000), Two different basic saturation flows for two environment classes (area types) representing two different sets of road and traffic conditions. The definitions of the two environment classes (Ideal and Average to Poor) are based on past and recent research on queue discharge characteristics at signalized intersections. The Average to poor conditions indicated by adequate to poor intersection geometry, usually closely spaced intersection environment, possibly poor visibility, moderate to large numbers of pedestrians and interference from standing vehicles. In this case basic saturation flow of 1800 veh/h was recommended. Since all this are physical characteristics of intersections in Hosanna city 1800veh/h was taken as basic saturation flow.

The HCM, 2010 recommended to use critical gap between 4.1 and 4.6 and follow up time from 2.6 to 3.1. So because of this and from the literatures done in the same conditions as of Hosanna City, the critical value of 4.5 and follow up time of 2.6 used as default value in this condition.

3.7.2 Analysis of the effects of three wheelers on performance measurement parameters of intersections.

The effects of three wheelers on performance measurements parameters of intersections were evaluated by analyzing each intersection performances again excluding three wheelers by using SIDRA INTERSECTION as explained above and the performance measurement parameters of intersections after excluding three wheelers and the former are not the same. So by comparing the performance parameters, with and without three wheelers, the differences were clearly shown. Since other input parameters were the same as used to evaluate the first objective, the differences were considered as effects of three wheelers on performance measurement parameters of intersections.

Table 3. 9. Traffic volume (PCU) data of signalized intersections without three wheelers.

Intersection	Approach	Direction	Traffic volume (PCU)	Traffic volume O f Heavy vehicles (PCU)	%Heavy vehicle
Menharya signalized intersection	Hospital	Left	15	8	53
		Through	7	3	43
		Right	15	10	67
		Total	37	21	57
	Lucy	Left	8	4	50
		Through	4	0	0
		Right	10	6	60
		Total	22	10	45
	18 Mazorya	Left	3	0	0
		Through	29	23	79
		Right	4	1	25
		Total	36	24	67
	Handa Mall	Left	8	0	0
		Through	51	34	67
		Right	1	0	0
		Total	60	34	57
Maryam signalized intersection	Eyerusalem	Left	15	9	60
		Through	4	3	75
		Right	9	5	56
		Total	28	17	61
	Stadium	Left	14	6	43
		Through	5	1	20
		Right	9	1	11
		Total	28	8	29
	Mobile	Left	3	0	0
		Through	33	21	64
		Right	8	2	25
		Total	44	23	52
	Ambicho	Left	5	0	0
		Through	40	31	78
		Right	1	0	0
		Total	46	31	67

Table 3. 10. Traffic volume (PCU) data of roundabout without three wheelers.

Roundabout	Approach	Direction	Traffic volume (PCU)	Traffic volume O f Heavy vehicles (PCU)	%Heavy vehicle
Bezabh petros roundabout	Mesalemya	Left	121	41	34
		Through	236	96	41
		Right	30	8	27
		U turn	3	0	0
		Total	390	145	37
	Menharya	Left	3	0	0
		Through	211	132	63
		Right	225	68	30
		U turn	12	0	0
		Total	451	200	44
	Hadiyya pharmacy	Left	31	9	29
		Through	11	2	18
		Right	2	0	0
		U turn	0	0	0
		Total	44	11	25
	Mobile	Left	311	98	32
		Through	13	2	15
		Right	128	37	29
		U turn	0	0	0
		Total	452	137	30
	Maremya	Left	3	0	0
		Through	0	0	0
		Right	10	0	0
		U turn	0	0	0
		Total	13	0	0
Eyerusalem roundabout	Gombera	Left	25	5	20
		Through	310	168	54
		Right	22	2	9
		Total	357	175	49
	Mesalemiya	Left	10	1	10
		Through	248	101	41
		Right	35	11	31
		Total	293	113	39
	Inatkalehiwet	Left	23	5	22
		Through	18	1	6
		Right	41	5	12
		Total	82	11	13
	Maryam	Left	39	13	33
		Through	5	1	20
		Right	32	14	44
		Total	76	28	37

3.7.3 Comparison of the performance change of intersections by replacing three wheelers with mini bus.

From passenger carrying capacity point of view, one 12 seat minibus taxi can accommodate a passengers accommodated by four Three wheelers. This will definitely improve the performance of the traffic streams in many aspects. In this section the researcher tried to indicate the performance improvement that will be gained by replacing the Three wheelers vehicles with 12 seat taxis from the traffic engineering point of view. Cost benefit analysis between the two transport modes is out of the scope of this study.

The comparison was made for the peak hour traffic volumes of intersections under the following assumptions;

- ✓ All Three wheelers vehicles will be replaced by minibus taxis at the ratio of 1:4. When three wheelers are removed, traffic will be improved. These will improve the performance measurement parameters of intersections.
- ✓ The analysis is made with assumptions that the geometric conditions, the pedestrian characteristics and the roadway conditions will not be changed due to the replacement of three wheelers with minibus taxis.

Table 3. 11 Traffic volume (PCU) data of signalized intersections when three wheelers replaced by mini bus

Intersection	Approach	Direction	Traffic volume (PCU)	Traffic volume O f Heavy vehicles (PCU)	%Heav y vehicle
Menharya signalized intersection	Hospital	Left	84	8	10
		Through	28	3	11
		Right	106	10	9
		Total	217	21	10
	Lucy	Left	31	4	13
		Through	14	0	0
		Right	41	6	15
		Total	86	10	12
	18 Mazorya	Left	7	0	0
		Through	305	23	8
		Right	8	1	13
		Total	320	24	8
	Handa Mall	Left	25	0	0
		Through	378	34	9
		Right	12	0	0
		Total	414	34	8
Maryam signalized intersection	Eyerusalem	Left	42	9	21
		Through	15	3	21
		Right	24	5	21
		Total	81	17	21
	Stadium	Left	42	6	14
		Through	15	1	7
		Right	24	1	4
		Total	81	8	10
	Mobile	Left	5	0	0
		Through	227	21	9
		Right	16	2	12
		Total	248	23	9
	Ambicho	Left	22	0	0
		Through	354	31	9
		Right	10	0	0
		Total	386	31	8

Table 3.12 Traffic volume (PCU) data of roundabouts when three wheelers replaced by mini bus

Roundabout	Approach	Direction	Traffic volume (PCU)	Traffic volume O f Heavy vehicles (PCU)	%Heavy vehicles
Bezabh petros roundabout	Mesalemya	Left	177	41	23
		Through	374	96	26
		Right	51	8	16
		U turn	9	0	0
		Total	577	145	25
	Menharya	Left	11	0	0
		Through	410	132	32
		Right	366	68	19
		U turn	20	0	0
		Total	806	200	25
	Hadiyya pharmacy	Left	39	9	23
		Through	17	2	12
		Right	5	0	0
		U turn	1	0	0
		Total	62	11	18
	Mobile	Left	408	98	24
		Through	25	2	8
		Right	243	37	15
		U turn	2	0	0
		Total	678	137	20
	Maremya	Left	16	0	0
		Through	3	0	0
		Right	17	0	0
		U turn	1	0	0
		Total	36	0	0
Eyerusalem round about	Gombera	Left	38	5	13
		Through	504	168	33
		Right	38	2	5
		Total	580	175	30
	Mesalemiya	Left	19	1	5
		Through	464	101	22
		Right	53	11	21
		Total	536	113	21
	Inatkalehiwet	Left	41	5	12
		Through	32	1	3
		Right	58	5	9
		Total	131	11	8
	Maryam	Left	79	13	16
		Through	9	1	11
		Right	60	14	23
		Total	147	28	19

4. RESULTS AND DISCUSSION

4.1 Introduction

This chapter contains the results of analysis for each specific objective and discussions for the results. Since it is the main portion, the researcher, tried to elaborate the specific objectives step by step and clearly.

4.2. Performance evaluation of intersections.

4.2.1 Performance evaluation of Menharya signalized intersection.

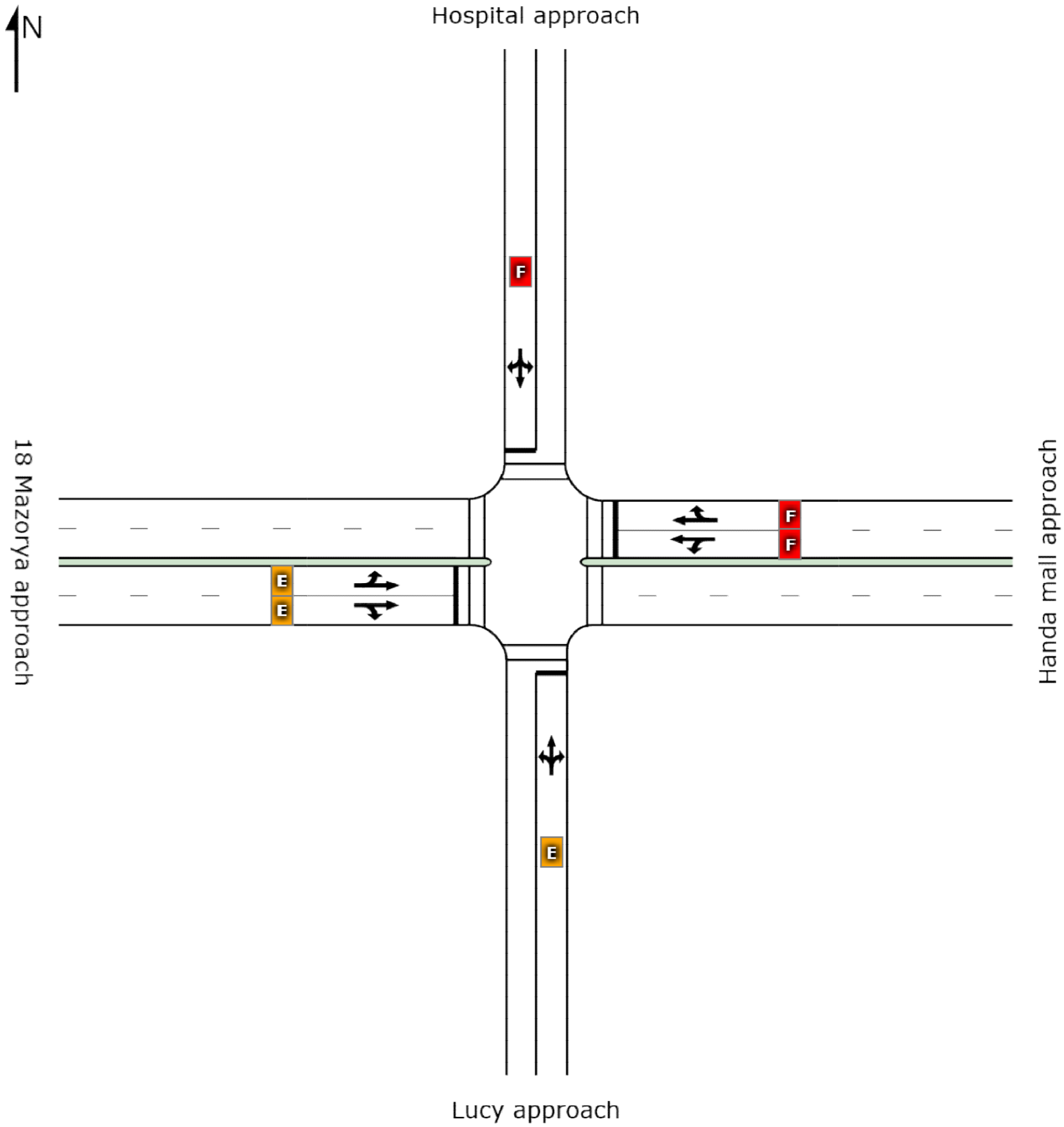
Menharya signalized intersection is one of the main intersections at Hosanna city. According to the output of SIDRA intersection, the summary of performance measurement parameters for each lane, approaches, and the intersection is summarized as follows.

Table 4.9 The lane use and performance output for Menharya signalized intersection for an existing condition

Approaches	Demand flows				H.V. %	Cap veh/h	Deg Satn	Lane Util	Average Delay Sec	Level of service	95% of Queue	
	L veh/h	T veh/h	R veh/h	Total veh/h							Vehicles Veh	Length M
South: Lucy approach												
Lane 1	49	22	65	136	8.0	231	0.587	100	65.7	LOS E	8	62.9
Approach	49	22	65	136	8.0		0.587		65.7	LOS E	8	62.9
East: Handa mall approach												
Lane 1	38	38	0	76	0.0	55	1.374	100	311.8	LOS F	10	68.4
Lane 2	0	536	19	555	0.0	404	1.374	100	234.6	LOS F	71	497.4
Approach	38	574	19	631	0.0		1.374		243.9	LOS F	71	497.4
North: Hospital approach												
Lane 1	132	44	168	344	6.3	257		100	234.3	LOS F	42	312.2
Approach	132	44	168	344	6.3		1.341		234.3	LOS F	42	312.2
West: 18 Mazorya approach												
Lane 1	11	191	0	202	4.7	264	0.766	100	71.7	LOS E	13	95.2
Lane 2	0	289	11	299	5.2	391	0.766	100	61.9	LOS E	19	136.4
Approach	11	480	11	501	5.0		0.766		65.8	LOS E	19	136.4
Intersection				1612	3.6		1.374		171.5	LOS F	71	497.4

In the software analysis, the lane LOS was done by using both average delay and volume to capacity ratio (degree of saturation) as it was stated in HCM 2010. Lane LOS values are based on average delay and v/c ratio (degree of saturation) per lane. LOS F will result if v/c > irrespective of lane delay value (does not apply for approaches and intersection). Intersection and Approach LOS values are based on average delay for all lanes (v/c not used as specified in HCM 2010). HCM Delay Model used.

As it is shown on the table above, Hospital and Handa mall approaches of this intersection are operating above their capacity because the volume to capacity ratio (degree of saturation) for both approaches is greater than one. Currently, the intersection is operating in congested condition with LOS F during the peak hour. Overall, the intersection is experiencing an average control delay of 171.5 seconds per vehicle with Degree of saturations as 1.374 and average queue length of 497.4 m. The Handa mall approach is experiencing major operational difficulties.



	South	East	North	West	Intersection
LOS	E	F	F	E	F

Figure 4.5 The layout and LOS values of Menharya Intersection for an existing condition.

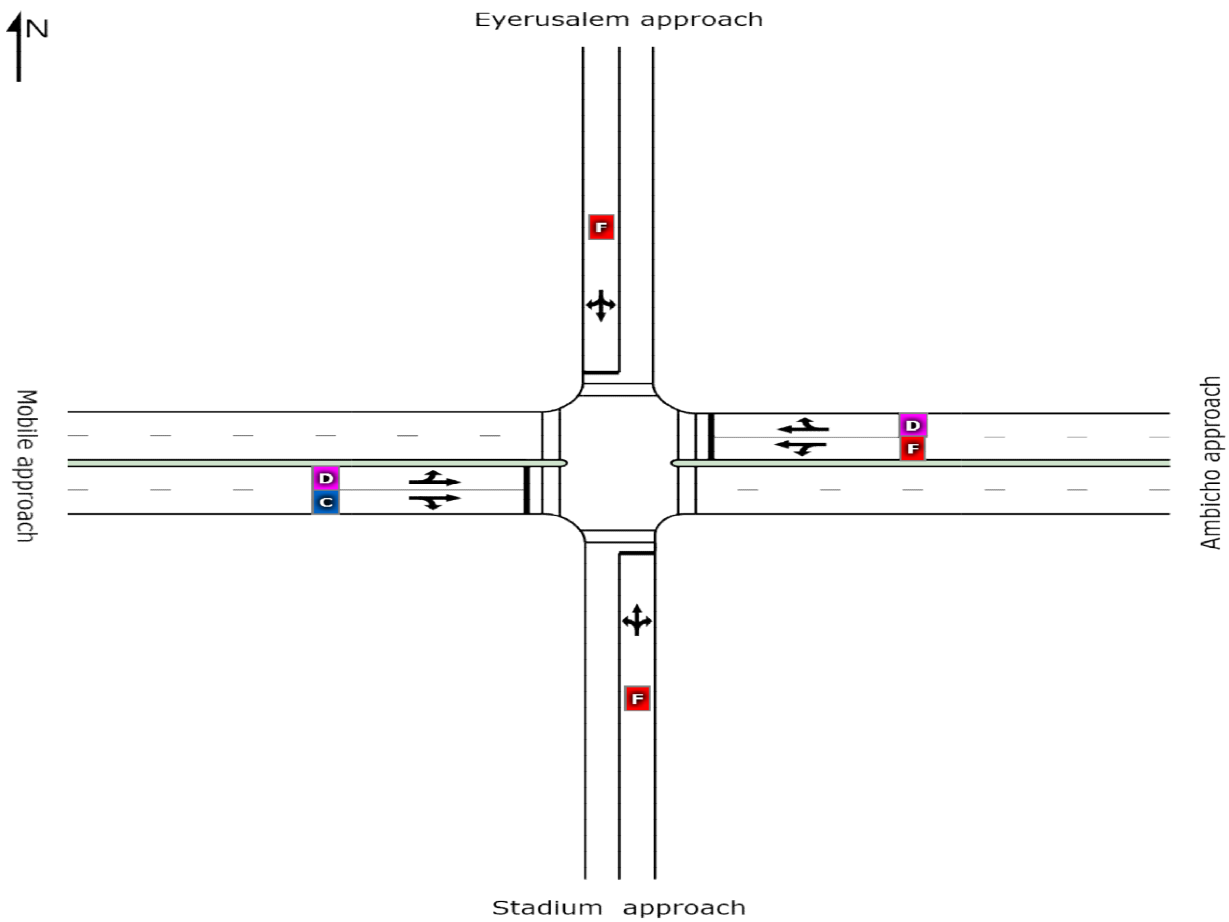
4.2.2 Performance evaluation of Maryam signalized intersection.

Table 4.10 The lane use and performance output for Maryam signalized intersection for an existing condition

Approaches	Demand flows				H.V %	Cap veh/h	Deg Satn	Lane util	Average Delay Sec	Level of services	95% of Queue	
	L veh/h	T veh/h	R veh/h	Total veh/h							Vehicles Veh	Length M
South: Stadium approach												
Lane 1	66	23	36	126	7.0	158	0.796	100	93.1	LOS F	8	62.6
Approach	66	23	36	126	7.0		0.796		93.1	LOS F	8	62.6
East: Ambicho approach												
Lane 1	34	29	0	63	2.8	74	0.852	100	130.6	LOS F	5	32.4
Lane 2	0	525	16	541	5.8	635	0.852	100	53.5	LOS D	35	253.3
Approach	34	554	16	604	5.5		0.852		61.5	LOS E	35	253.3
North: Eyerusalem approach												
Lane 1	61	24	35	119	15.3	153		100	91.4	LOS F	8.0	63.3
Approach	61	24	35	119	15.3		0.778		91.4	LOS F	8.0	63.3
West: Mobile approach												
Lane 1	6	134	0	140	5.7	383	0.367	100	46.1	LOS D	8	56.1
Lane 2	0	209	22	231	6.4	630	0.367	100	34.1	LOS C	11	81.1
Approach	6	343	22	371	6.1		0.367		38.7	LOS D	11	81.1
Intersection				1220	6.8		0.852		60.7	LOS E	35	253.3

In the software analysis, the lane LOS was done by using both average delay and volume to capacity ratio (degree of saturation) as it was stated in HCM 2010. Lane LOS values are based on average delay and v/c ratio (degree of saturation) per lane. LOS F will result if v/c > irrespective of lane delay value (does not apply for approaches and intersection). Intersection and Approach LOS values are based on average delay for all lanes (v/c not used as specified in HCM 2010). HCM Delay Model used.

As it is shown on the table above, all approaches of this intersection are operating below capacity because the volume to capacity ratio (degree of saturation) for all approaches is less than one. Since most approaches of the intersection have degree of saturation around 1, Currently, the intersection is operating in congested condition with LOS E during peak hour (at PM peak time). Overall, the intersection is experiencing an average control delay of 60.7 seconds per vehicle with Degree of Saturation as 0.852 and average queue length of 253.3 m. Ambicho approach is experiencing major operational difficulties.



	South	East	North	West	Intersection
LOS	F	E	F	D	F

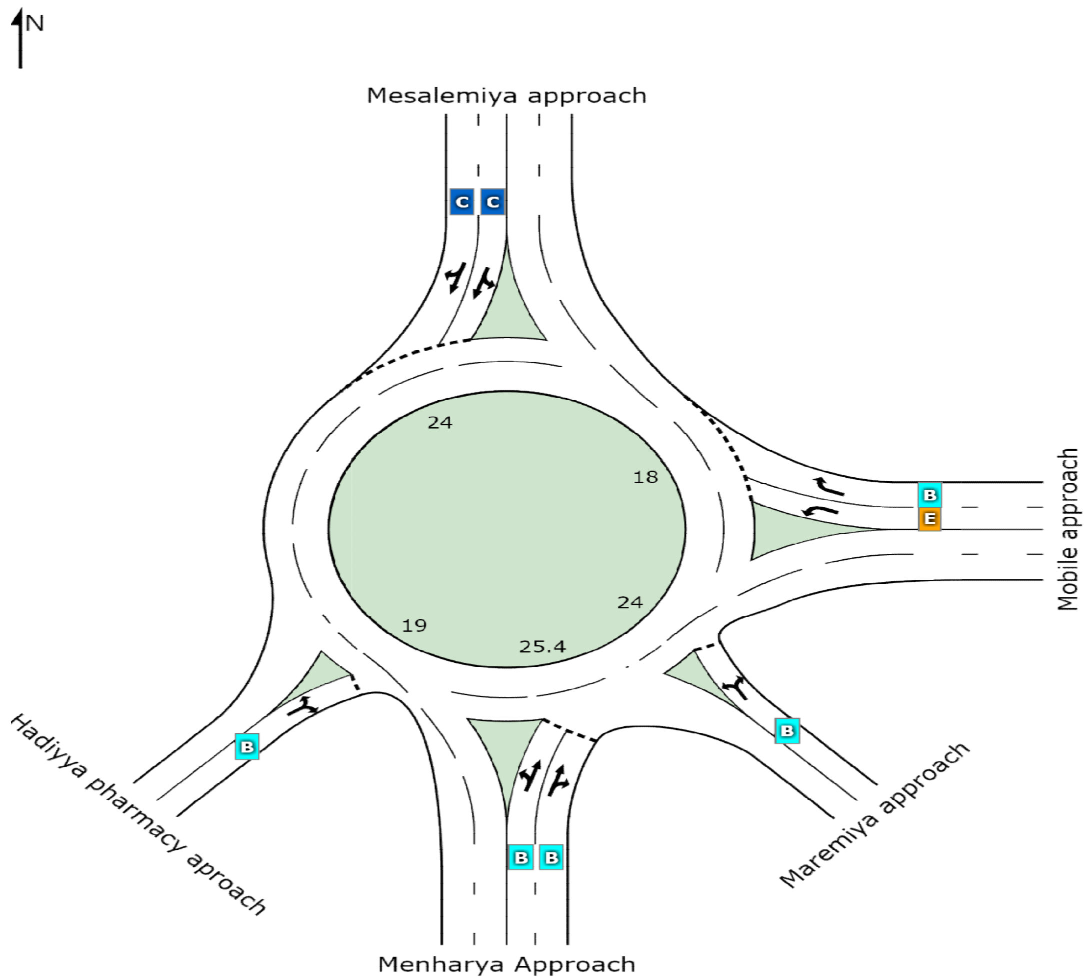
Figure 4.2 the layout and level of service values of Maryam Intersection for an existing condition

4.2.3 Performance evaluation of Bezabh Petros roundabout.

Table 4.11 The lane use and performance output for Bezabh Petros roundabout for an existing condition.

Approaches	Demand flows				H.V.	Cap	Deg	Lane	Average	Level of service	95% of Queue	
	L veh/h	T veh/h	R veh/h	Total veh/h	%	veh/h	satn	Util	Delay sec		Vehicles Veh	Length M
South: Menharya Approach												
Lane 1	16	499	0	515	24.2	781	0.660	100	16.4	LOS B	6	48.8
Lane 2	0	69	500	569	15.5	863	0.660	100	15.2	LOS B	6	46.3
Approach	16	569	500	1085	19.7		0.660		15.7	LOS B	6	48.8
South East: Maremiya approach												
Lane 1	28	0	28	56	0.0	342	0.164	100	13.4	LOS B	1	6.5
Approach	28	0	28	56	0.0		0.164		13.4	LOS B	1	6.5
East: Mobile approach												
Lane 1	529	0	0	529	19.9	540	0.980	100	17.2	LOS E	20	162.7
Lane 2	0	0	328	328	12.0	603	0.980	100	8.8	LOS B	4	31.8
Approach	529	0	328	858	16.9		0.980		14.8	LOS D	20	162.7
North: Mesalemiya approach												
Lane 1	237	157	0	217	19.1	539	0.731	100	26.3	LOS C	8	62.6
Lane 2	0	323	68	206	19.6	535	0.731	100	26.5	LOS C	8	62.6
Approach	237	480	68	422	19.4		0.731		26.4	LOS C	8	62.6
South West: Hadiyya pharmacy approach												
Lane 1	46	0	31	77	15.5	294	0.262	100	17.9	LOS B	2	12.3
Approach	46	0	31	77	15.5		0.262		17.9	LOS B	2	12.3
Intersection				2860	18.2		0.980		27.1	LOS C	20	162.7

The Bezabh Petros roundabout has five approach legs as shown in Figure below. The analysis is done by using Level of Service (LOS) Method: Delay& v/c (HCM 2010) and Roundabout LOS Method: Same as Signalized Intersections. In addition, lane LOS values are based on average delay and v/c ratio (degree of saturation) per lane. LOS F will result if v/c > irrespective of lane delay value (does not apply for approaches and intersection). Intersection and Approach LOS values are based on average delay for all lanes (v/c not used as specified in HCM 2010). Roundabout Capacity Model: SIDRA Standard. SIDRA Standard Delay Model used. From the table above, Bezabh Petros roundabout for existing situation, All approaches are operating in under saturated condition. Currently, the roundabout was observed to be operating better performance with LOS "B" for Menharya approach, Hadiyya Pharmacy and Maremya Approach. Mesalemiya approach has LOS of C and mobile approach has LOS of D. Generally the roundabout has LOS of C and Overall, the roundabout is experiencing an average control delay of 27.1 seconds per vehicle with Degree of saturation as 0.98 and average queue length of 162.7 m.



	South	Southeast	East	North	Southwest	Intersection
LOS	B	B	D	C	B	C

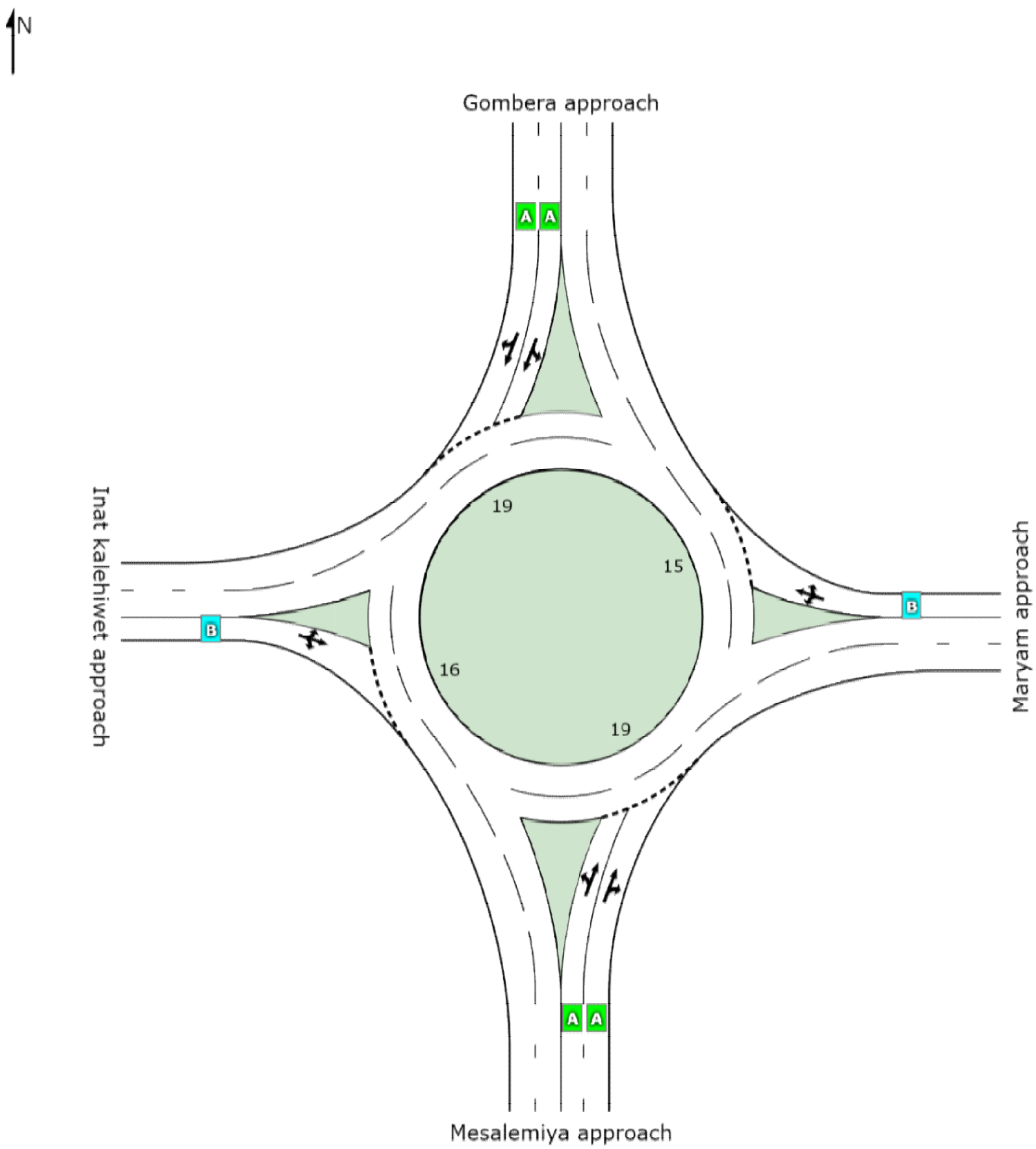
Figure 4. 3 The layout and level of service values of Bezbh Petros roundabout for an existing condition.

4.2.4 Performance evaluation of Eyerusalem roundabout.

Table 4.12 The lane use and performance output for Eyerusalem roundabout for an existing condition

Approaches	Demand flows				H.V.	Cap veh/h	Deg	Lane	Average	Level of service	95% of Queue	
	L veh/h	T veh/h	R veh/h	Total veh/h	%		satn	Util	Delay Sec		Vehicles Veh	Length M
South: Mesalemiya Approach												
Lane 1	25	341	0	367	16.1	947	0.387	100	8.1	LOS A	2	17.9
Lane 2	0	297	66	364	17.0	939	0.387	100	8.2	LOS A	2	18.0
Approach	25	639	66	730	16.6		0.387		8.1	LOS A	2	18.0
East: Maryam approach												
Lane 1	108	12	80	200	14.8	540	0.370	100	12.4	LOS B	2	16.1
Approach	108	12	80	200	14.8		0.370		12.4	LOS B	2	16.1
North: Gombera approach												
Lane 1	47	326	0	374	25.0	847	0.441	100	9.8	LOS A	3	22.5
Lane 2	0	327	49	377	24.0	854	0.441	100	9.7	LOS A	3	22.4
Approach	47	654	49	751	24.5		0.441		9.7	LOS A	3	22.5
West: Inat kalehiwet approach												
Lane 1	55	43	72	169	6.7	401	0.423	100	17.5	LOS B	2	16.3
Approach	55	43	72	169	6.7		0.423		17.5	LOS B	2	16.3
Intersection				1850	18.7		0.441		10.1	LOS B	3	22.5

The Eyerusalem roundabout has four approach legs as shown in Figure below. The analysis is done by using Level of Service (LOS) Method: Delay& v/c (HCM 2010) and Roundabout LOS Method: Same as Signalized Intersections. In addition, lane LOS values are based on average delay and v/c ratio (degree of saturation) per lane. LOS F will result if v/c > irrespective of lane delay value (does not apply for approaches and intersection). Intersection and Approach LOS values are based on average delay for all lanes (v/c not used as specified in HCM 2010). Roundabout Capacity Model: SIDRA Standard. SIDRA Standard Delay Model used. From the table above, Eyerusalem roundabout for existing situation, All approaches are operating in under saturated condition. Currently, the roundabout was observed to be operating better performance with LOS "A" for Mesalemya approach and Gombera Approach. Inat kalehiwet approach and Maryam approach has LOS of B. Generally the roundabout has LOS of B and overall, the roundabout is experiencing an average control delay of 10.1 seconds per vehicle with Degree of saturation as 0.441 and average queue length of 22.5m.



	South	East	North	West	Intersection
LOS	A	B	A	B	B

Figure 4. 4 The layout and Level of Service values of Eyerusalem roundabout for an existing condition

4.2.5 Summary on existing intersections performances.

The volume-to-capacity (v/c) ratio also referred to as degree of saturation, represents the sufficiency of an intersection to accommodate the vehicular demand for Menharya signalized intersection and Maryam signalized intersection is 1.374 and 0.852 respectively. As the v/c ratio approaches 1.0, traffic flow may become unstable, and delay and queuing conditions may occur. Once the demand exceeds the capacity (a v/c ration greater than 1.0), traffic flow is unstable and excessive delay and queuing is expected (FWHA, 2009). So in these both signalized intersections, traffic flow is unstable and excessive delay occurred.

Menharya signalized intersection has LOS of F and Maryam signalized intersection has LOS of E. HCM (2010) describes; LOS F indicates operations with control delay exceeding 80 s/veh or a volume-to-capacity ratio greater than 1.0. This level is typically assigned when the volume-to-capacity is very high, progression is very poor, and the cycle length is long. So both signalized intersections have poor progression and long queue length of 497.4m for Menharya and 253.3m for Maryam signalized intersections.

Performance measures of Bezabh Petros roundabout and Eyerusalem roundabout show that Eyerusalem roundabout is performing relatively in a good operating condition than Bezabh Petros round about because both have LOS of B and C respectively. Bezabh Petros roundabout is experiencing an average control delay of 27.1 seconds per vehicle with Degree of saturation as 0.98 and average queue length of 162.7 m and Eyerusalem roundabout is experiencing an average control delay of 10.1 seconds per vehicle with Degree of saturation as 0.441 and average queue length of 22.5m.

4.3. The consequences of three wheelers with performance parameters.

To know the effects of three wheelers on performance measurement parameters of Intersections, it is very important to evaluate intersection performances excluding three wheelers again and comparing the differences between performance measurement parameters with and without three wheelers.

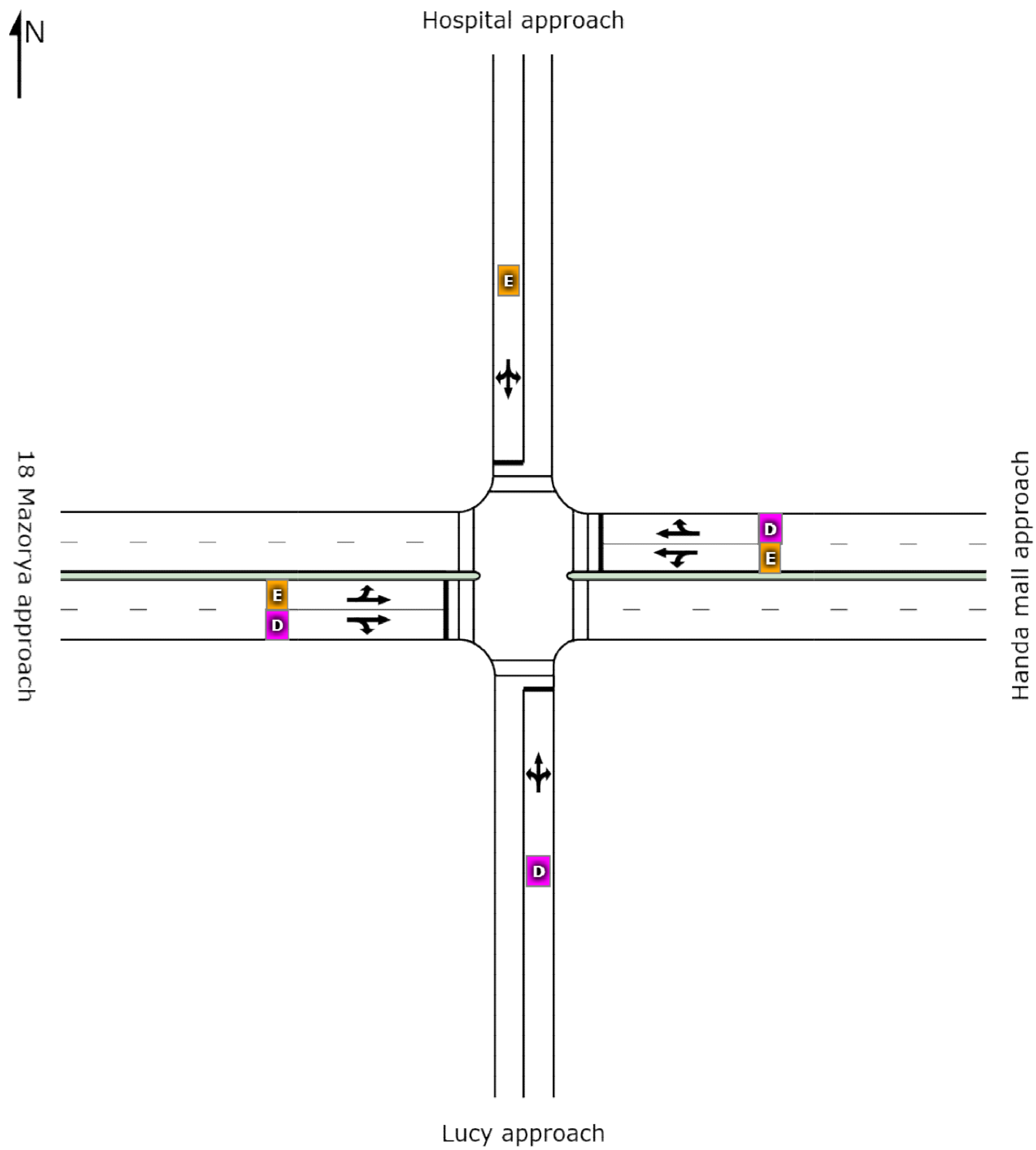
4.3.1 Performance evaluation of Menharya signalized intersections without three wheelers.

Table 4.13 the lane use and performance output for Menharya signalized intersection without three wheelers.

Approaches	Demand flows				H.V.	Cap	Deg	Lane	Average	Level of services	95% of Queue	
	L veh/h	T veh/h	R veh/h	Total veh/h	%	veh/h	Satn	Util	Delay Sec		Vehicles Veh	Length M
South: Lucy approach												
Lane 1	9	4	11	25	45.4	212	0.116	100	52.7	LOS D	1.4	13.8
Approach	9	4	11	25	45.4		0.116		52.7	LOS D	1.4	13.8
East: Handa mall approach												
Lane 1	8	7	0	16	28.4	81	0.196	100	64.2	LOS E	1.0	8.9
Lane 2	0	51	4	55	58.2	282	0.196	100	44.8	LOS D	2.9	30.9
Approach	8	58	4	71	51.6		0.196		49.1	LOS D	2.9	30.9
North: Hospital approach												
Lane 1	16	8	16	39	56.6	198	0.199	100	55.1	LOS E	2.3	24.3
Approach	16	8	16	39	56.6		0.199		55.1	LOS E	2.3	24.3
West: 18 Mazorya approach												
Lane 1	3	3	0	6	39.4	55	0.114	100	64.5	LOS E	0.4	3.9
Lane 2	0	26	4	30	71.4	264	0.114	100	43.4	LOS D	1.6	17.8
Approach	3	29	4	36	65.9		0.114		47.1	LOS D	1.6	17.8
Intersection				171	54.9		0.199		50.6	LOS D	2.9	30.9

In the software analysis, the lane LOS was done by using both average delay and volume to capacity ratio (degree of saturation) as it was stated in HCM 2010. Lane LOS values are based on average delay and v/c ratio (degree of saturation) per lane. LOS F will result if v/c > irrespective of lane delay value (does not apply for approaches and intersection). Intersection and Approach LOS values are based on average delay for all lanes (v/c not used as specified in HCM 2010). HCM Delay Model used.

As it is shown on the table above, all the approaches of this intersection are operating below their capacity because the volume to capacity ratio (degree of saturation) for all approaches is less than one. In this case, the intersection is operating in congested condition with LOS E for Hospital approach and Lucy approach, 18 Mazorya approach and Handa Mall approaches have LOS of D. Overall, when Three wheelers removed from analysis, the intersection is experiencing an average control delay of 50.6 seconds per vehicle with Degree of saturations as 0.199 and average queue length of 30.9m.



	South	East	North	West	Intersection
LOS	D	D	E	D	D

Figure 4.5 the layout and Level of Service values of Menharya intersection without Three wheelers.

4.3.1.1. Comparison of Menharya signalized intersection performance measurement parameters with and without three wheelers.

It is essential to compare the performance measurement parameters of intersections with and without three wheelers to understand the effect of three wheelers on performance measurement parameters easily. The performance evaluation in both cases is already analyzed, as shown above. On the analysis without three wheelers, three wheelers were totally removed from analysis by considering other parameters the same. So based on those results, the difference in previous (including three wheelers) and current (excluding three wheelers) is shown below clearly.

Table 4.14 Comparison of the difference between previous and current level of services (with and without three wheelers) of Menharya signalized intersection.

Approach name	Previous Level of Service (LOS)	Current Level of Service (LOS)	Remark
Hospital	F	E	Improved
Lucy	E	D	Improved
18 mazorya	E	E	Same
Handa Mall	F	D	Improved
Intersection	F	D	Improved

All approaches have a big difference in LOS because it shows LOS difference from F to D except 18 Mazorya approach. When three wheelers is excluded, the intersection LOS improved from F to D.

Table 4.15 Comparison of the difference between previous and current signal delay time (sec) (with and without three wheelers).

Approach name	Previous Signal Delay time in sec	Current Signal Delay time in sec	Difference
Hospital	234.3	55.1	179.2
Lucy	65.7	52.7	13
18 Mazorya	65.8	47.1	18.7
Handa Mall	243.9	49.1	194.8
Intersection	171.5	50.6	120.9

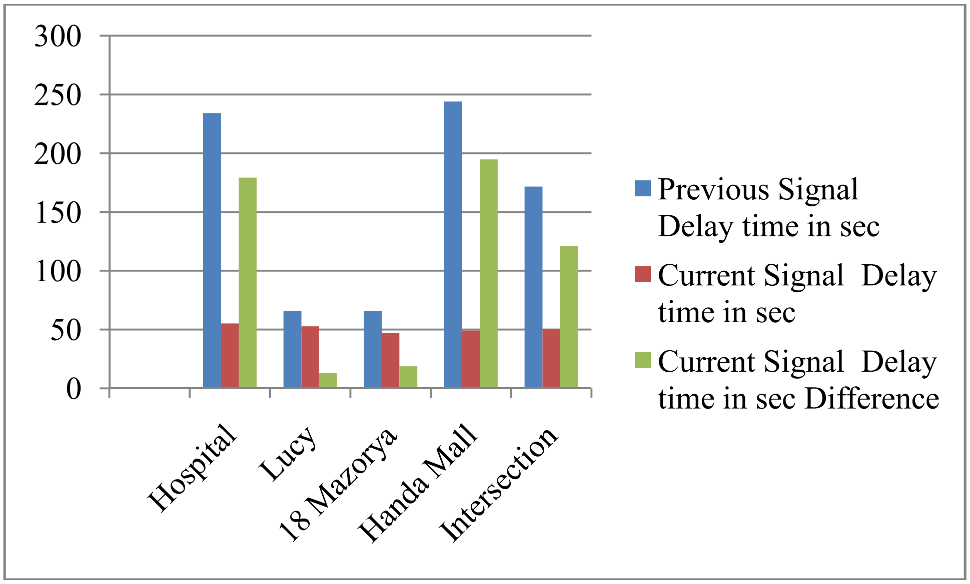


Figure 4.6 Comparison of the difference between Previous and Current signal delay time (sec) (with and without three wheelers).

From the above output, 76.5% cause for delay of the Hospital approach, 19.8% cause for delay of Lucy approach, 28.4% cause for delay of 18 mazorya approaches, and 79.9% cause for delay of Handa mall approach is the presence of three wheelers.

Generally, Menharya signalized intersection delay is 70.5% caused due to the presence of three wheelers.

Table 4. 8 Comparison of the difference between previous and current degree of saturation (with and without three wheelers)

Approach	Previous Degree of saturation	The current Degree of saturation	difference
Hospital	1.341	0.199	1.142
Lucy	0.587	0.116	0.471
18 Mazorya	0.766	0.114	0.652
Handa Mall	1.374	0.196	1.178
Intersection	1.374	0.199	1.175

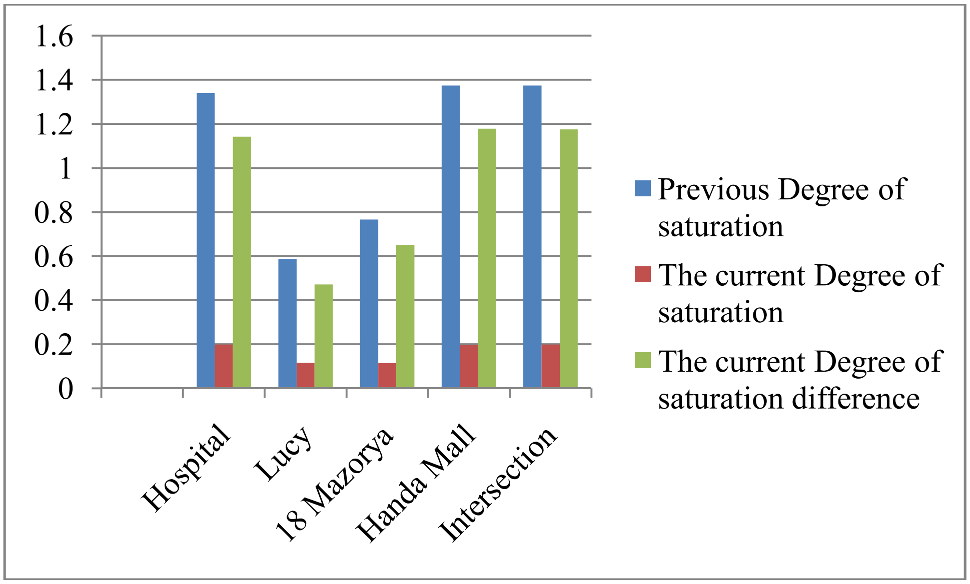


Figure 4. 7 Comparison of the difference between previous and current degree of saturation (with and without three wheelers) of Menharya intersection

From the above output, 85.2% degree of saturation of the Hospital approach, 80.2 % degree of saturation of Lucy approach, 85.1% degree of saturation of 18 mazorya approach, and 85.7% degree of saturation of Handa mall approach is due to the presence of Three wheelers.

Generally, Menharya signalized intersection degree of saturation is 85.5% caused due to the presence of three wheelers.

Table 4.16 Comparison of the difference between previous and current 95% back of queue length (m) (with and without three wheelers) of Menharya intersection.

Approach	Previous 95% back of Queue length (m)	Current 95% back of Queue length (m)	Difference
Hospital	312.2	24.3	287.9
Lucy	62.9	13.8	49.1
18 Mazorya	136.4	17.8	118.6
Handa Mall	497.4	30.9	466.5
Intersection	497.4	30.9	466.5

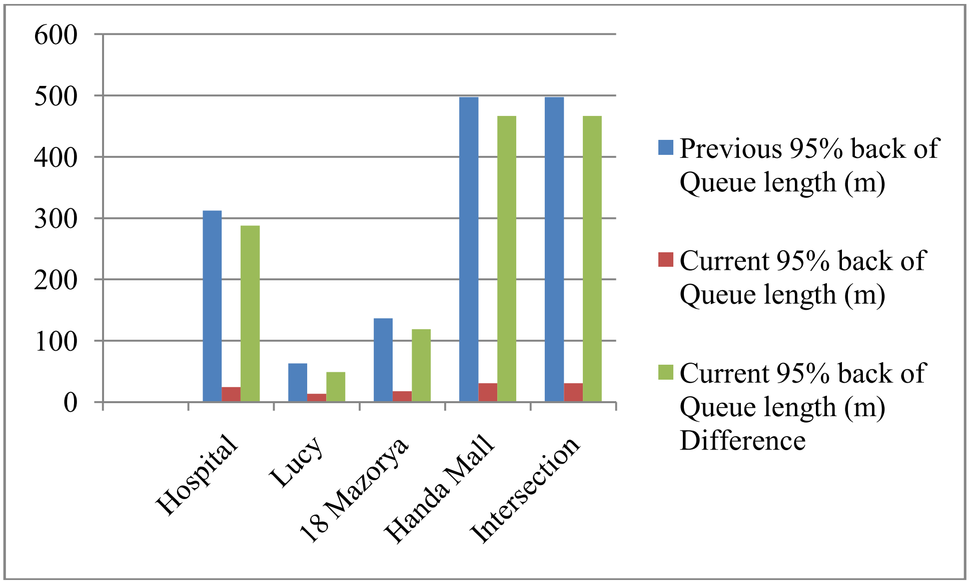


Figure 4.7 Comparison of the difference between previous and current 95% back of queue length (m) (with and without three wheelers)

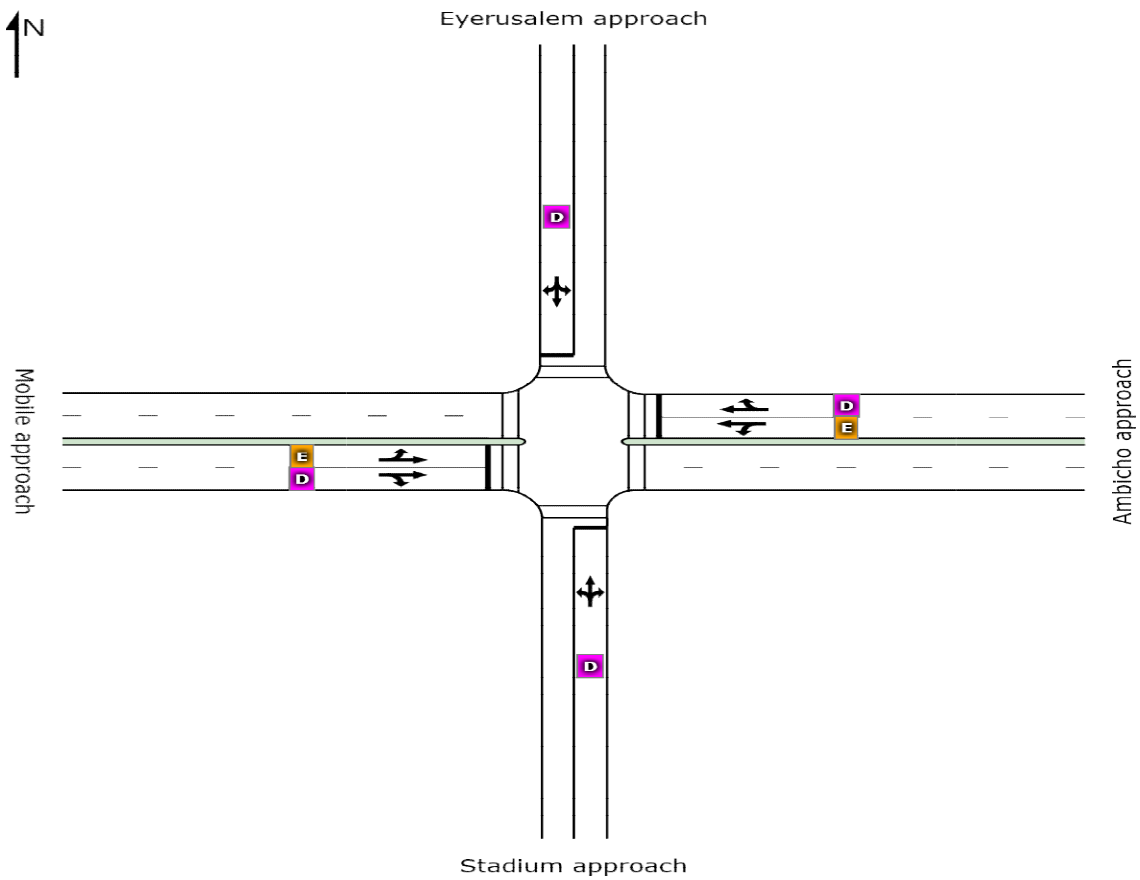
From the above output 92.2 % Queue length of the Hospital approach, 78.1% Queue distance of Lucy approach, 87.0% Queue distance of 18 mazorya approach, and 93.8% Queue distance of Handa mall approach is due to the presence of Three wheelers.

Generally, Menharya signalized intersection Queue distance of 93.8 % is caused due to the presence of three wheelers.

Based on the above results, it can be concluded easily that, three wheelers is affecting the performance measurement parameters of Menharya signalized intersection highly than other vehicle types.

4.3.2. Performance evaluation of Maryam signalized intersections without three wheelers.

As discussed above, by analyzing the performance measurement parameters of Maryam intersection without three wheelers, it has a delay of 54.7cm, degree of saturation of 0.366, 95% queue length of 54cm and LOS of D. the parameters in detail for each approach is shown in tabular form at appendixes.



	South	East	North	West	Intersection
LOS	D	D	D	D	D

Figure 4.8 The layout and level of service values of Maryam intersection without three wheelers

4.3.2.1 Comparison of Maryam signalized intersection performance measurement parameters with and without three wheelers.

It is essential to compare the performance measurement parameters of intersections with and without three wheelers to understand the effect of three wheelers on performance measurement parameters easily. The performance evaluation in both cases is already analyzed, as shown above. So based on those results, the differences in previous (including three wheelers) and current (excluding three wheelers) are shown below clearly.

Table 4.10 Comparison of the difference between Previous and Current level of services (with and without three wheelers) of Maryam intersection.

Approach name	Previous Level of Service (LOS)	Current Level of Service (LOS)	Remark
Eyeruslem	F	D	Improved
Stadium	F	D	Improved
Mobile	D	D	Same
Ambicho	F	D	Improved
Intersection	E	D	Improved

There is a difference of LOS on each approach, including the whole intersection. The Eyerusalem approach and Stadium approach shows the difference of LOS from F to D. And Ambicho approach is improved from F to D. When three wheelers is excluded, the LOS of Maryam Signalized intersection shows the improvement from E to D.

Table 4.11 Comparison of the difference between Previous and Current signal delay time (sec) (with and without three wheelers) of Maryam intersection.

Approach	Previous Signal Delay time in sec	Current Signal Delay time in sec	Difference
Eyeruslem	91.4	52.2	39.2
Stadium	93.1	54.2	38.9
Mobile	47.9	38.7	9.2
Ambicho	61.5	48.9	12.6
Intersection	60.7	50.3	10.4

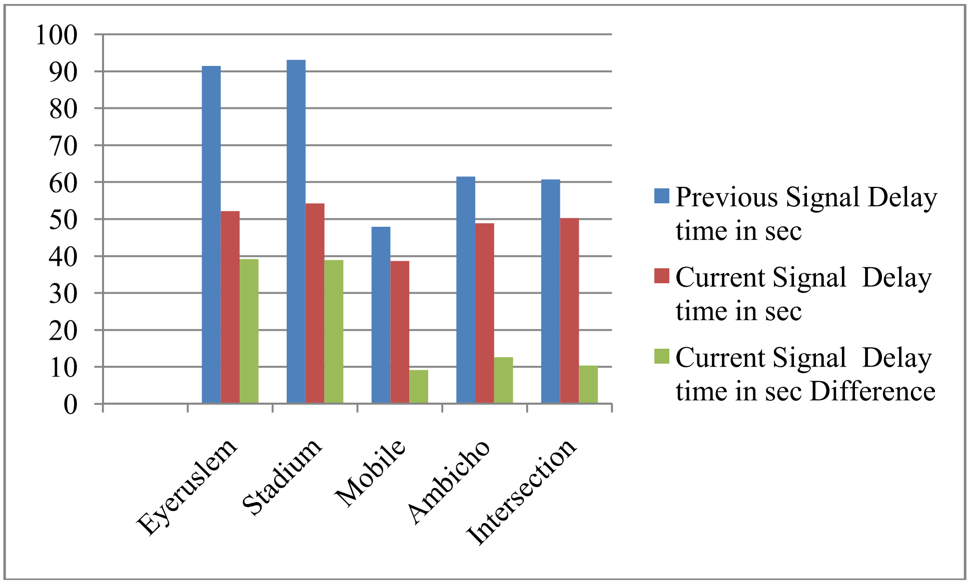


Figure 4. 10 Comparison of the difference between Previous and Current signal delay time (sec) (with and without three wheelers) of Maryam intersection.

From the above output, 42.9 % cause for delay of the Eyeruslem approach, 41.8% cause for delay of Stadium approach, 19.2 % cause for delay of Mobile approach, and 20.5% cause for delay of Ambicho approach is the presence of three wheelers.

Generally, Maryam signalized intersection delay is 17.1% caused due to the presence of three wheelers.

Table 4.12 Comparison of the difference between previous and current degree of saturation (with and without three wheelers) of Maryam intersection.

Approach	Previous Degree of saturation	Current Degree of saturation	difference
Eyeruslem	0.778	0.138	0.64
Stadium	0.796	0.152	0.644
Mobile	0.367	0.134	0.233
Ambicho	0.852	0.152	0.7
Intersection	0.852	0.152	0.7

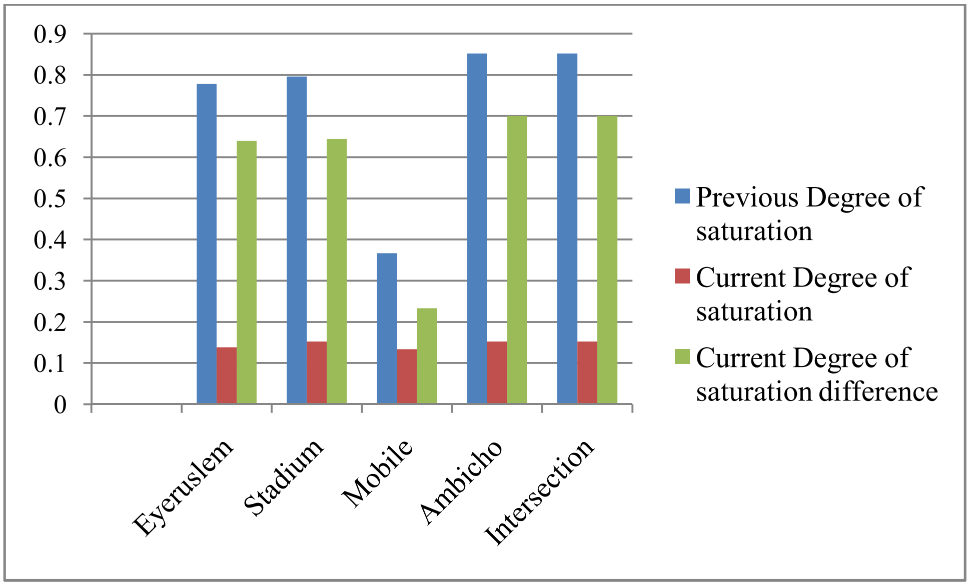


Figure 4. 11 Comparison of the difference between previous and current degree of saturation (with and without three wheelers) of Maryam intersection.

From the above output 82.3 % degree of saturation of Eyeruslem approach, 80.9% degree of saturation of Stadium approach, 63.5% degree of saturation of Mobile approach, and 82.2% degree of saturation of the Ambicho approach is due to the presence of three wheelers.

Generally, 82.2 % degree of saturation of Maryam signalized intersection is caused due to the presence of three wheelers.

Table 4.13 Comparison of the difference between Previous and Current 95% back of queue distance (m) (with and without three wheelers) of Maryam intersection.

Approach	Previous 95% back of Queue length(m)	Current 95% back of Queue length (m)	Difference
Eyeruslem	63.3	18.3	45
Stadium	62.6	16.1	46.5
Mobile	81.1	20.0	61.1
Ambicho	253.3	23.6	229.7
Intersection	253.3	23.6	229.7

From the above output 71.1% Queue distance of the Eyerusalem approach, 74.3% Queue distance of Stadium approach, 75.3% Queue distance of Mobile approach, and 90.7% Queue distance of the Ambicho approach is due to the presence of three wheelers.

Generally, Maryam signalized intersection Queue distance of 90.7% is caused due to the presence of three wheelers.

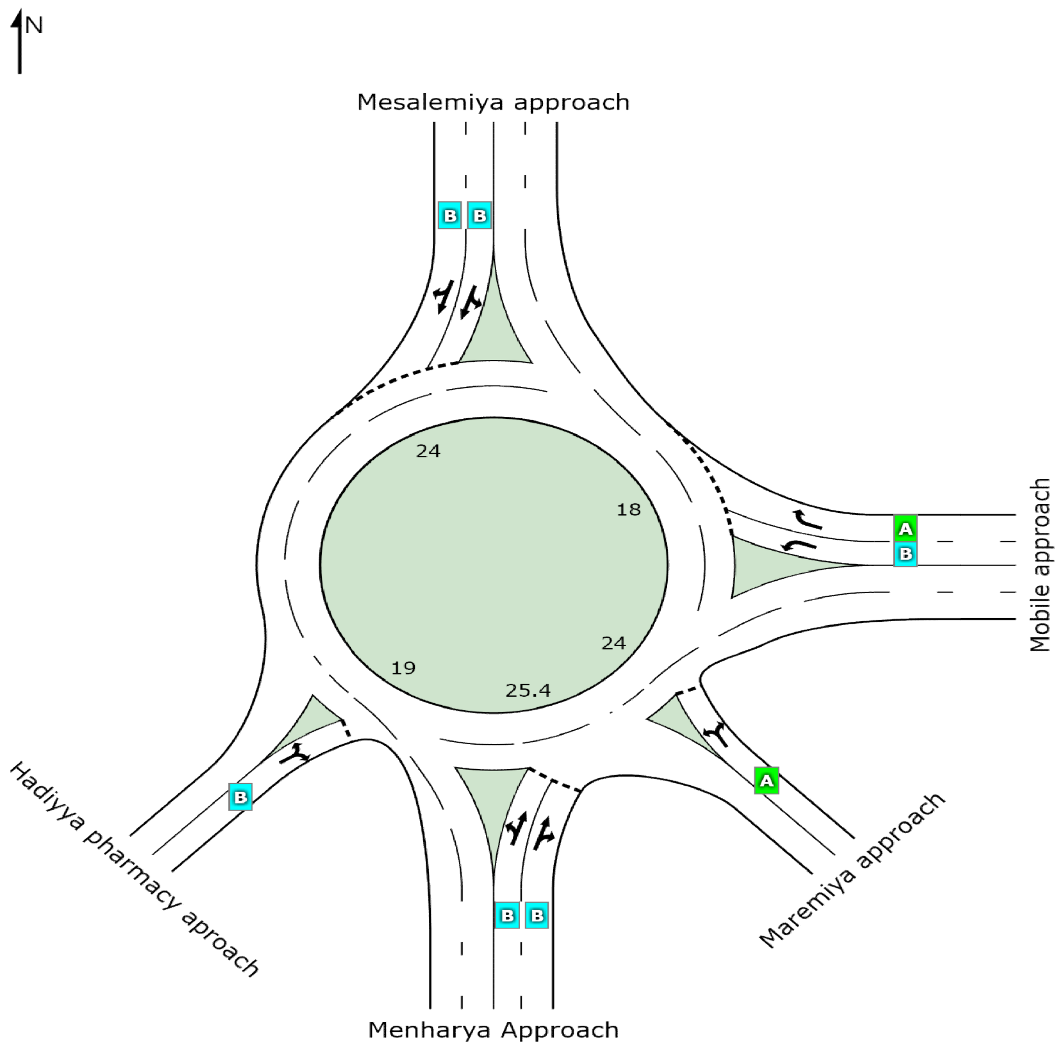
Based on the above results, it can be concluded easily that three wheelers is affecting the performance measurement parameters of Maryam's signalized intersection more than other vehicle types.

4.3.3. Performance evaluation of Bezabh Petros roundabout without three wheelers.

Table 4.14 the lane use and performance output for Bezabh Petros roundabout without three wheelers.

Approaches	Demand flows				HV %	Cap veh/h	Deg satn	Lane util	Average Delay sec	Level of services	95% of Queue	
	L veh/h	T veh/h	R veh/h	Total veh/h							Vehicles Veh	Length M
South: Menharya Approach												
Lane 1	3	203	0	206	62.0	538	0.384	100	12.7	LOS B	2.0	21.1
Lane 2	0	24	249	273	31.5	711	0.384	100	10.1	LOS B	2.1	18.5
Approach	3	227	249	480	44.6		0.384		11.2	LOS B	2.1	21.1
South East: Maremiya approach												
Lane 1	17	0	11	29	0.0	595	0.048	100	6.6	LOS A	0.2	1.7
Approach	17	0	11	29	0.0		0.048		6.6	LOS A	0.2	1.7
East: Mobile approach												
Lane 1	342	0	0	342	31.3	588	0.582	100	17.2	LOS B	4.1	36.6
Lane 2	0	0	135	135	29.0	603	0.582	100	8.8	LOS A	1.1	9.4
Approach	342	0	135	477	30.6		0.582		14.8	LOS B	4.1	36.6
North: Mesalemiya approach												
Lane 1	142	75	0	217	34.2	510	0.425	100	14.3	LOS B	2.4	21.6
Lane 2	0	173	32	206	38.8	484	0.425	100	14.9	LOS B	2.4	22.1
Approach	142	248	32	422	36.4		0.425		14.6	LOS B	2.4	22.1
South West: Hadiyya pharmacy approach												
Lane 1	33	0	14	47	25.0	390	0.121	100	11.1	LOS B	0.6	5.3
Approach	33	0	14	47	25.0		0.121		11.1	LOS B	0.6	5.3
Intersection				1454	36.1		0.582		13.3	LOS B	4.1	36.6

Level of Service (LOS) Method: Delay & v/c (HCM 2010). Roundabout LOS Method: Same as Signalised Intersections. Lane LOS values are based on average delay and v/c ratio (degree of saturation) per lane. LOS F will result if v/c > irrespective of lane delay value (does not apply for approaches and intersection). Intersection and Approach LOS values are based on average delay for all lanes (v/c not used as specified in HCM 2010). Roundabout Capacity Model: SIDRA Standard. HCM Delay Model used.



	South	Southeast	East	North	Southwest	Intersection
LOS	B	A	B	B	B	B

Figure 4.12 The layout and level of service values of Bezabh Petros roundabout without three wheelers.

4.3.3.1 Comparison of Bezabh petros roundabout performance measurement parameters with and without three wheelers.

Table 4.15 Comparison of the difference of level of services with and without three wheelers of Bezabh Petros roundabout

Approach name	Previous Level of Service (LOS)	Current Level of Service (LOS)	Remark
Menharya	B	B	Same
Mesalemiya	B	B	Same
Mobile	D	B	Improved
Hadiyya pharmacy	B	B	Same
Maremiya	B	A	Improved
Intersection	C	B	Improved

There is a visible difference of LOS on some approaches, including the whole intersection. The mobile approach shows the difference of LOS from D to B and the Maremiya approach from B to A.

When three wheelers are excluded, the LOS of Bezabh Petros roundabout shows the improvement from C to B.

Table 4.16 Comparison of the difference of delay time (sec) with and without three wheelers at Bezabh Petros roundabout

Approach name	Previous delay time in sec	Current delay time in sec	Difference
Menharya	15.7	11.2	4.5
Mesalemiya	26.4	14.6	11.8
Mobile	43.9	14.8	29.1
Hadiyya pharmacy	17.9	11.1	6.8
Maremiya	13.4	6.6	6.8
Intersection	27.1	13.3	13.8

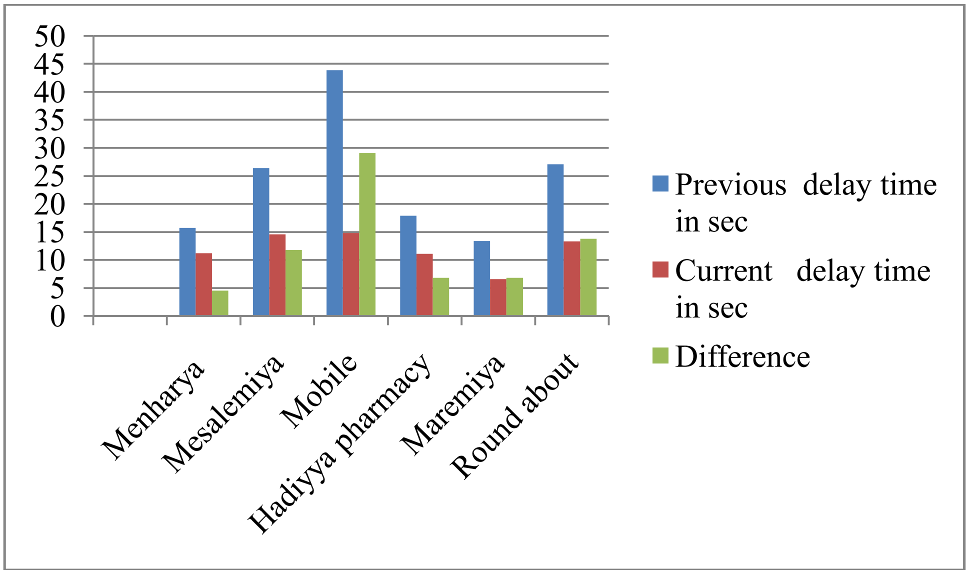


Figure 4.13 Comparison of the difference of delay time (sec) with and without three wheelers at Bezabh Petros roundabout.

From the above output, 29.0% cause for delay of Menharya approach, 44.7% cause for delay of Mesalemiya approach, 66.3% cause for delay of Mobile approach, 38.0% cause for delay of Hadiyya pharmacy approach and 50.1% cause for delay of Maremiya approach is the presence of three wheelers.

Generally, the Bezabh Petros roundabout delay is 51% caused due to the presence of three wheelers.

Table 4.17 Comparison of Degree of saturation with and without three wheelers at Bezabh Petros roundabout.

Approach name	Previous Degree of saturation	Current Degree of saturation	difference
Menharya	0.66	0.384	0.276
Mesalemiya	0.731	0.425	0.306
Mobile	0.98	0.582	0.398
Hadiyya pharmacy	0.262	0.121	0.141
Maremiya	0.164	0.048	0.116
Intersection	0.980	0.582	0.398

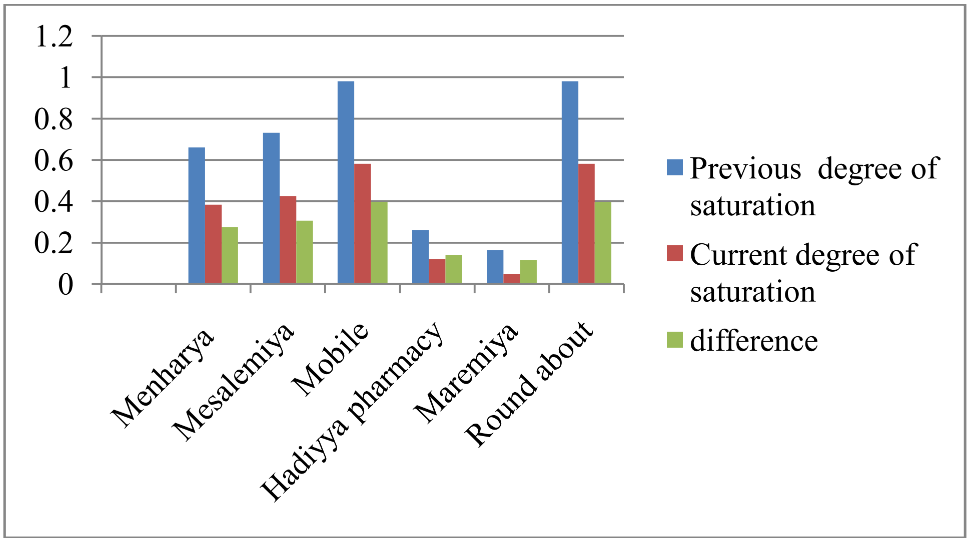


Figure 4.14 Comparison of degree of saturation with and without three wheelers at Bezabh Petros roundabout.

From the above output 42.0% degree of saturation of Menharya approach, 42.0% degree of saturation of Mesalemiya approach, 41.0% degree of saturation of Mobile approach, 54.0% degree of saturation of Hadiyya pharmacy approach and 71.0 % degree of saturation of Maremiya approach is due to the presence of Three wheelers.

Generally, Bezabh Petros degree of saturation is 41.0 % caused due to the presence of three wheelers.

Table 4.18 Comparison of the difference between previous (with three wheelers) and current (without three wheelers) 95% back of queue length (m) of Bezabh Petros roundabout.

Approach name	Previous 95% back of queue length (m)	Current 95% back of queue length (m)	Difference
Menharya	48.8	21.1	27.7
Mesalemiya	62.6	22.1	40.5
Mobile	162.7	36.6	126.1
Hadiyya pharmacy	12.3	5.3	7
Maremiya	6.5	1.7	4.8
Intersection	162.7	36.6	126.1

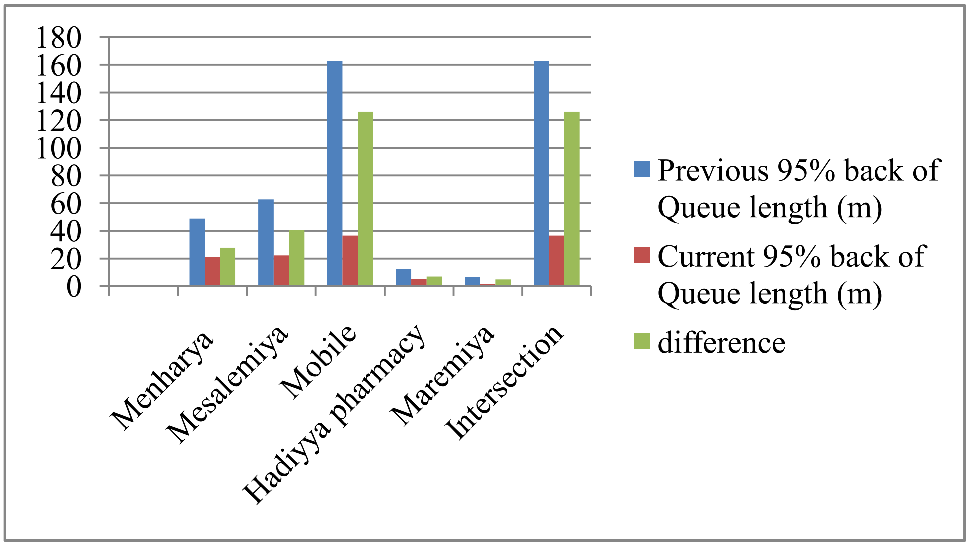


Figure 4. 15 Comparison of the difference between previous (with three wheelers) and current (without three wheelers) 95% back of queue length (m) of Bezabh Petros roundabout.

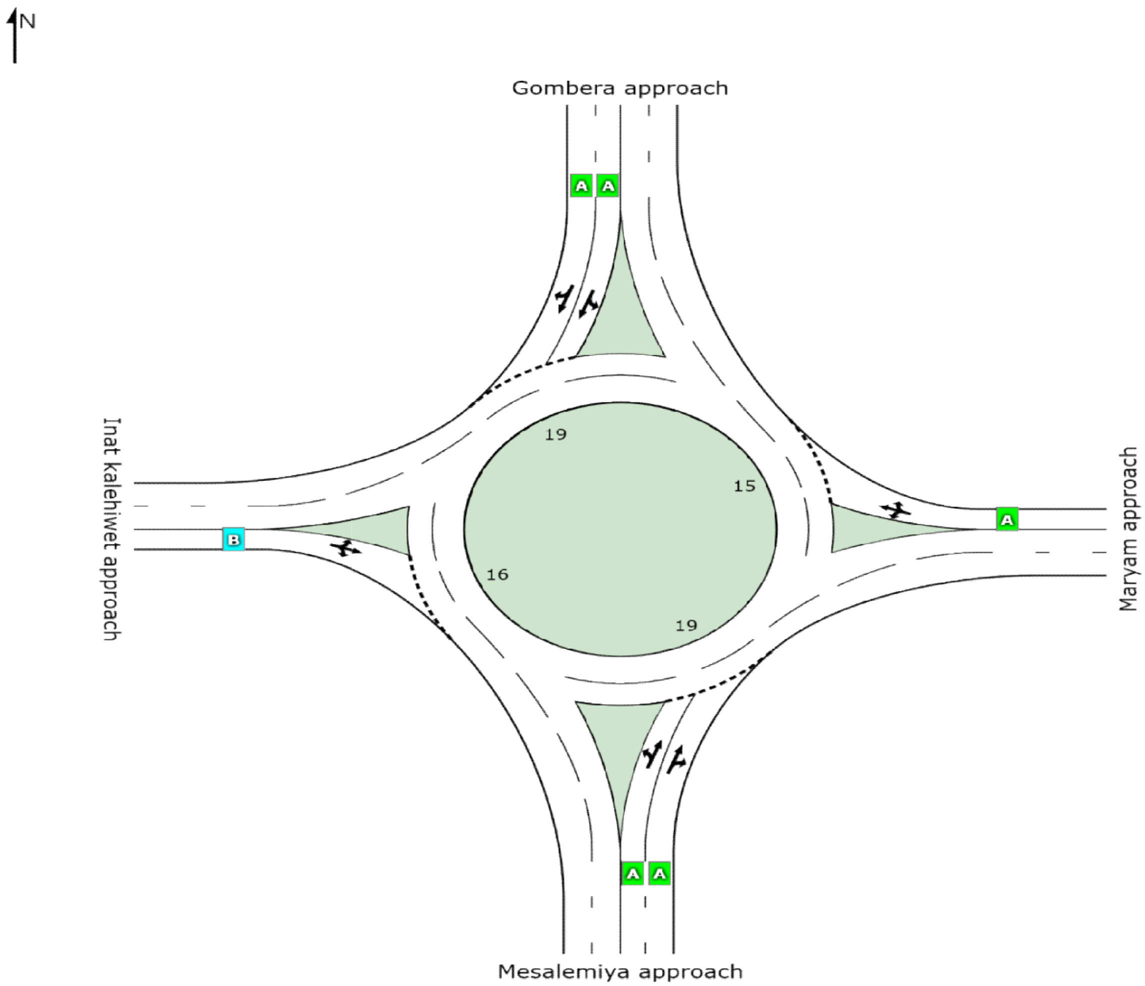
From the above output 56.7% queue length of the Menharya approach, 64.7% queue length of Mesalemiya approach, 77.5% queue length of Mobile approach, 57.0% queue length of Hadiyya pharmacy approach and 73.8% queue length of Maremiya approach is due to the presence of three wheelers.

Generally, the Bezabh Petros roundabout queue length of 77.5% is caused due to the presence of three wheelers.

Based on the above results, it can be concluded easily that, three wheeler is affecting the performance measurement parameters of Bezabh Petros roundabout highly than other vehicle types.

4.3.4. Performance evaluation of Eyerusalem roundabout without three wheelers.

The performance measurement parameters output of Eyerusalem roundabout from SIDRA intersection excluding three wheelers indicates that, the roundabout has average delay of 7.3 sec, degree of saturation of 0.247, 95% queue length of 12.1m and LOS of A. So it indicates that the roundabout has free traffic stream.



	South	East	North	West	Intersection
LOS	A	A	A	B	A

Figure 4. 16 The layout and level of service values of Eyerusalem roundabout without three wheelers.

4.3.3.1 Comparison of Eyerusalem roundabout performance measurement parameters with and without three wheelers.

Table 4.19 Comparison of the difference between Previous (with three wheelers) and current (without three wheelers) level of services of Eyerusalem roundabout.

Approach name	Previous Level of Service (LOS)	Current Level of Service (LOS)	Remark
Mesalemiya	A	A	Same
Maryam	B	A	Improved
Gombera	A	A	Same
Inatkalehiwet	B	B	Same
Intersection	B	A	Improved

LOS of Maryam approach is improved from B to A, and Eyerusalem roundabout shows the improvement of LOS from B to A.

Table 4.20 Comparison of the difference between previous and current delay time (sec) (with and without three wheelers of Eyerusalem roundabout).

Approach name	Previous delay time in sec	Current delay time in sec	Difference
Mesalemiya	8.1	6.3	1.8
Maryam	12.4	7.6	4.8
Gombera	9.7	7.4	2.3
Inatkalehiwet	17.5	10.6	6.9
Intersection	10.1	7.3	2.8

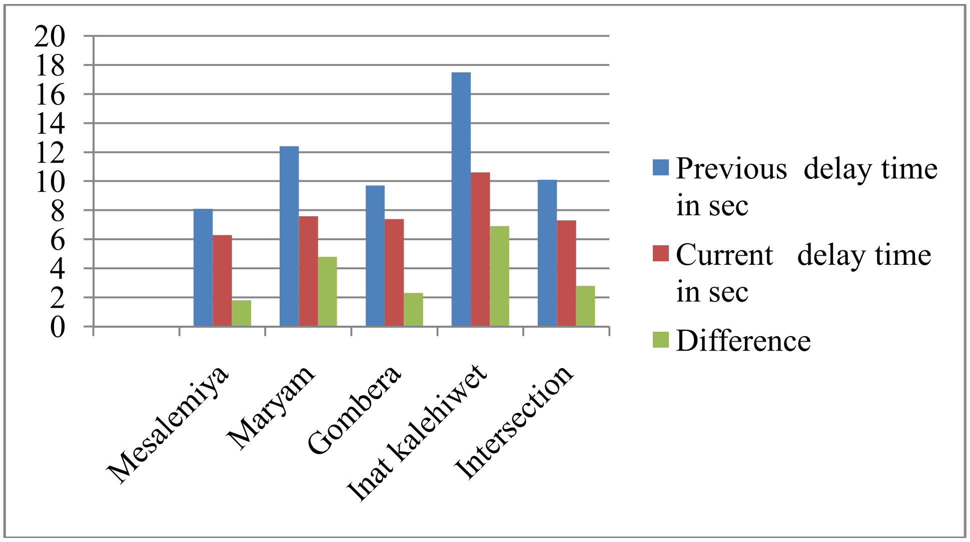


Figure 4.17 Comparison of the difference between previous and current delay time (sec) (with and without three wheelers of Eyerusalem roundabout).

From the above output, 22.2% cause for delays of Mesalemiya approach, 38.7% cause for the Maryam approach, 23.7% cause for delay of Gombera approach, and 39.4% cause for delay of Inat kalehiwet approach is the presence of three wheelers.

Generally, the Eyerusalem roundabout delay is 28 % caused due to the presence of three wheelers.

Table 4.21 Comparison of the difference between previous and current (with and without three wheelers) degree of saturation of Eyerusalem roundabout.

Approach name	Previous Degree of saturation	Current Degree of saturation	difference
Mesalemiya	0.387	0.189	0.198
Maryam	0.37	0.134	0.236
Gombera	0.441	0.247	0.194
Inatkalehiwet	0.423	0.189	0.234
Intersection	0.441	0.247	0.194

From the above table, 51.2% degree of saturation of Mesalemiya approach, 64.0% degree of saturation of Maryam approach, 44.0% degree of saturation of Gombera approach, and 55.4 % degree of saturation of Inat kalehiwet approach is due to the presence of three wheelers.

Generally, Eyerusalem roundabout degree of saturation is 44.0 % caused due to the presence of three wheelers.

Table 4.22 Comparison of the difference between previous (with three wheelers) and current (without three wheelers) 95% back of queue length (m)

Approach name	Previous 95% back of queue length (m)	Current 95% back of queue length (m)	Difference
Mesalemiya	18	8.2	9.8
Maryam	16.1	5.5	10.6
Gombera	22.5	12.1	10.4
Inat kalehiwet	16.3	5.8	10.5
Intersection	22.5	12.1	10.4

From the above output, 54.4% queue length of Mesalemiya approach, 65.8% queue length of Maryam approach, 46.2% queue length of Gombera approach, and 64.4% queue length of Inat kalehiwet approach is due to the presence of three wheelers.

Generally, the Bezabh Petros roundabout Queue length of 77.5% is caused due to the presence of three wheelers.

Based on the above results, it can be concluded easily that three wheeler is affecting the performance measurement parameters of Eyerusalem roundabout highly than other vehicle types.

4.3.5 Summary on the effects of three wheelers on intersection performances.

From the result of analysis, three wheeler is highly affecting Menharya and Maryam signalized intersections. For Menharya signalized intersection When Three wheelers removed from analysis, average delay reduced from 171.5 sec to 50.6 sec, degree of saturation reduced from 1.374 to 0.199, queue length reduced from 497.4m to 30.9m and LOS improved from F to D. For Maryam signalized intersection, When Three wheelers removed from analysis, average delay reduced from 60.7 sec to 50.3 sec, degree of saturation reduced from 0.852 to 0.152, queue length reduced from 253.3m to 23.6m and LOS improved from E to D. So according to the output of analysis, three wheeler is highly affecting the performance measurement parameters of signalized intersections in Hosanna City.

In Bezabh Petros roundabout and in Eyerusalem roundabout, the effects of three wheeler on performance parameters are also high. For Bezabh Petros roundabout When Three wheelers removed from analysis, average delay reduced from 27.1 sec to 13.3 sec, degree of saturation reduced from 0.980 to 0.582, queue length reduced from 162.7m to 36.6m and LOS improved from C to B. For Eyerusalem roundabout, When Three wheelers removed from analysis, average delay reduced from 10.1 sec to 7.3 sec, degree of saturation reduced from 0.441 to 0.247, queue length reduced from 22.5m to 12.1m and LOS improved from B to A.

4.4. Comparing the performance change of intersections when Three wheelers replaced by minibus.

This portion explained one of the solutions for reducing the effects of three wheelers on performance measurement parameters of intersections at Hosanna city. The comparison was made for the peak hour traffic volumes of intersections under the following assumptions;

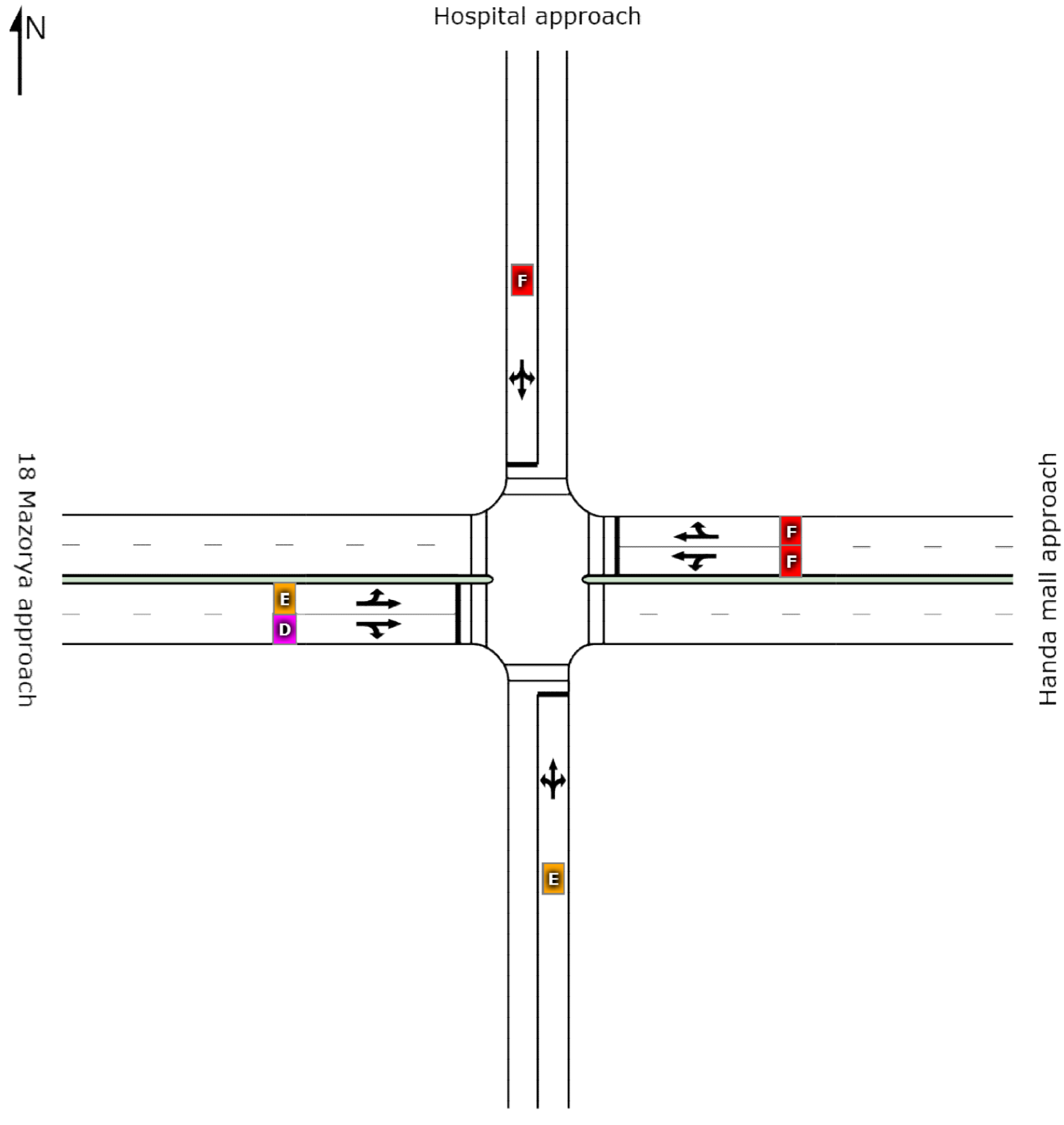
- ✓ All Three wheelers vehicles will be replaced by minibus taxis at the ratio of 1:4. When three wheelers are removed, the traffic of the road will be improved. These will improve the LOS.
- ✓ The analysis is made with assumptions that the geometric conditions, the pedestrian characteristics, and the roadway conditions will not be changed due to the replacement of three wheelers with minibus taxis.

To compare the changes in performance measurement parameters of intersections when three wheelers are replaced by minibus, new intersection performances must be evaluated with a minibus. After that, the difference in performance measurement parameters of intersections was analyzed.

4.4.1. Performance evaluation of Menharya signalized intersection when three wheelers replaced by minibus.

Table 4.23 The lane use and performance output for Menharya signalized intersection when three wheelers replaced by minibus.

Approaches	Demand flows				HV	Cap	Deg	Lane	Average Delay	Level of service	95% of Queue	
	L veh/h	T veh/h	R veh/h	Tot veh/h	%	veh/h	satn	util	Sec		Vehicles Veh	Length M
South: Lucy approach												
Lane 1	34	16	44	93	8.0	229	0.408	100	59.4	LOS E	6	42.3
Approach	34	16	44	93	8.0		0.408		59.4	LOS E	6	42.3
East: Handa mall approach												
Lane 1	27	25	0	52	2.9	56	0.939	100	166.4	LOS F	4.0	28.8
Lane 2	0	353	13	366	5.8	390	0.939	100	83.2	LOS F	27.0	201.5
Approach	27	378	13	418	5.4		0.939		93.6	LOS F	27.0	201.5
North: Hospital approach												
Lane 1	88	31	112	231	6.3	251	0.918	100	95.3	LOS F	17	123.4
Approach	88	31	112	231	6.3		0.918		95.3	LOS F	17	123.4
West: 18 Mazorya approach												
Lane 1	8	122	0	129	4.7	255	0.508	100	58.2	LOS E	8	56.4
Lane 2	0	190	9	198	5.2	391	0.508	100	50.3	LOS D	11	82.1
Approach	8	311	9	328	5.0		0.508		53.4	LOS D	11	82.1
Intersection				1070	5.7		0.939		78.7	LOS E	28	201.5



	South	East	North	West	Intersection
LOS	E	F	F	D	E

Figure 4.18 the layout and level of service values of Menharya signalized intersection when three wheelers replaced by minibus.

4.4.1.1 Comparing the performance change of Menharya signalized intersections when three wheelers replaced by mini bus.

Table 4.24 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) level of services for Menharya intersection.

Approach name	Previous Level of Service (LOS)	Current Level of Service (LOS)	Remark
Hospital	F	E	Improved
Lucy	E	E	Same
18 mazorya	E	E	Same
Handa Mall	F	F	Same
Intersection	F	E	Improved

When three wheelers replaced by minibus at Menharya signalized intersection, the intersection was improved by LOS from F to E.

Table 4.25 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) signal delay time (sec) of Menharya intersection.

Approach	Previous Signal Delay time in sec	Current Signal Delay time in sec	Difference
Hospital	234.3	95.5	138.8
Lucy	65.7	59.4	6.3
18 Mazorya	65.8	53.4	12.4
Handa Mall	243.9	93.6	150.3
Intersection	171.5	78.7	92.8

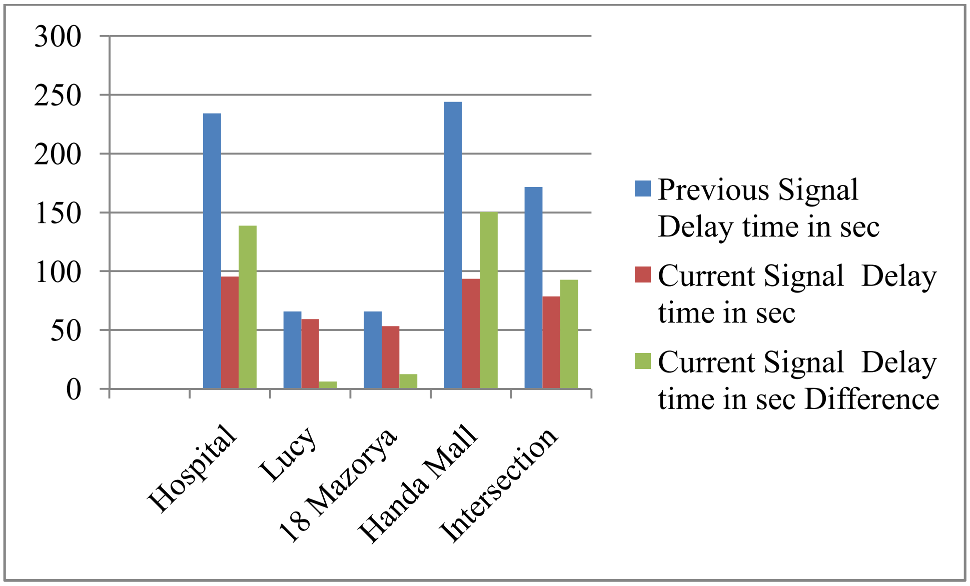


Figure 4.19 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) signal delay time (sec) of Menharya intersection.

As a result, shows above, there was a clear improvement in delay when Three wheelers replaced by minibus as an approach and as an intersection. 59.2% delay of Hospital approach, 9.6 % delay of Lucy approach, 18.8% delay of 18 mazoriya approaches, and 61.6% delay of Handa mall approach is improved when Three wheelers replaced by minibus.

Generally, 54.1% delay of Menharya signalized intersection is improved when Three wheelers replaced by minibus.

Table 4.26 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) degree of saturation of Menharya intersection.

Approach	Previous degree of saturation	The current degree of saturation	difference
Hospital	1.341	0.918	0.423
Lucy	0.587	0.408	0.179
18 Mazorya	0.766	0.508	0.258
Handa Mall	1.374	0.939	0.435
Intersection	1.374	0.939	0.435

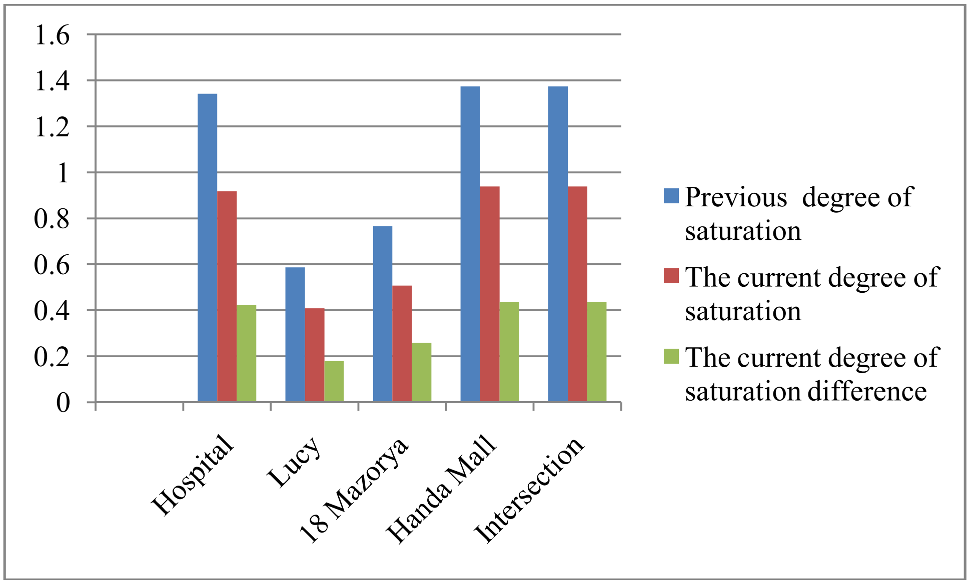


Figure 4.20 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) degree of saturation of Menharya intersection.

From the above output 31.5% degree of saturation of the Hospital approach, 30. 5% degree of saturation of Lucy approach, 33.7% degree of saturation of 18 mazoriya approaches, and 31.7% degree of saturation of Handa mall approach is improved when Three wheelers replaced by minibus. Generally, a 31.7% degree of saturation of Menharya signalized intersection is improved when Three wheelers replaced by minibus.

Table 4.27 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) queue length of Menharya intersection.

Approach	Previous 95% back of queue length (m)	Current 95% back of queue length (m)	Difference
Hospital	312.2	123.4	188.8
Lucy	62.9	42.3	20.6
18 Mazorya	136.4	82.1	54.3
Handa Mall	497.4	201.5	295.9
Intersection	497.4	201.5	295.9

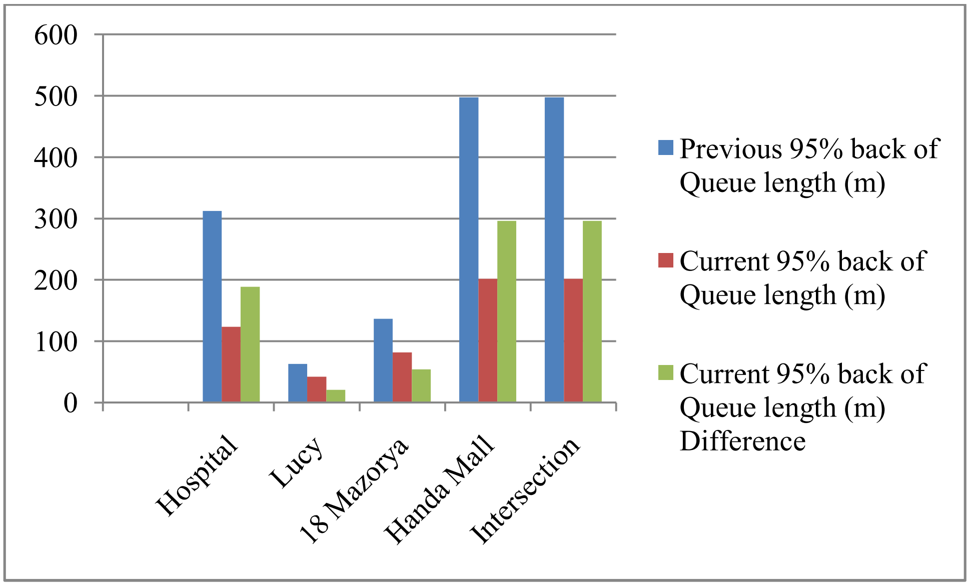


Figure 4.21 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) queue distance of Menharya intersection.

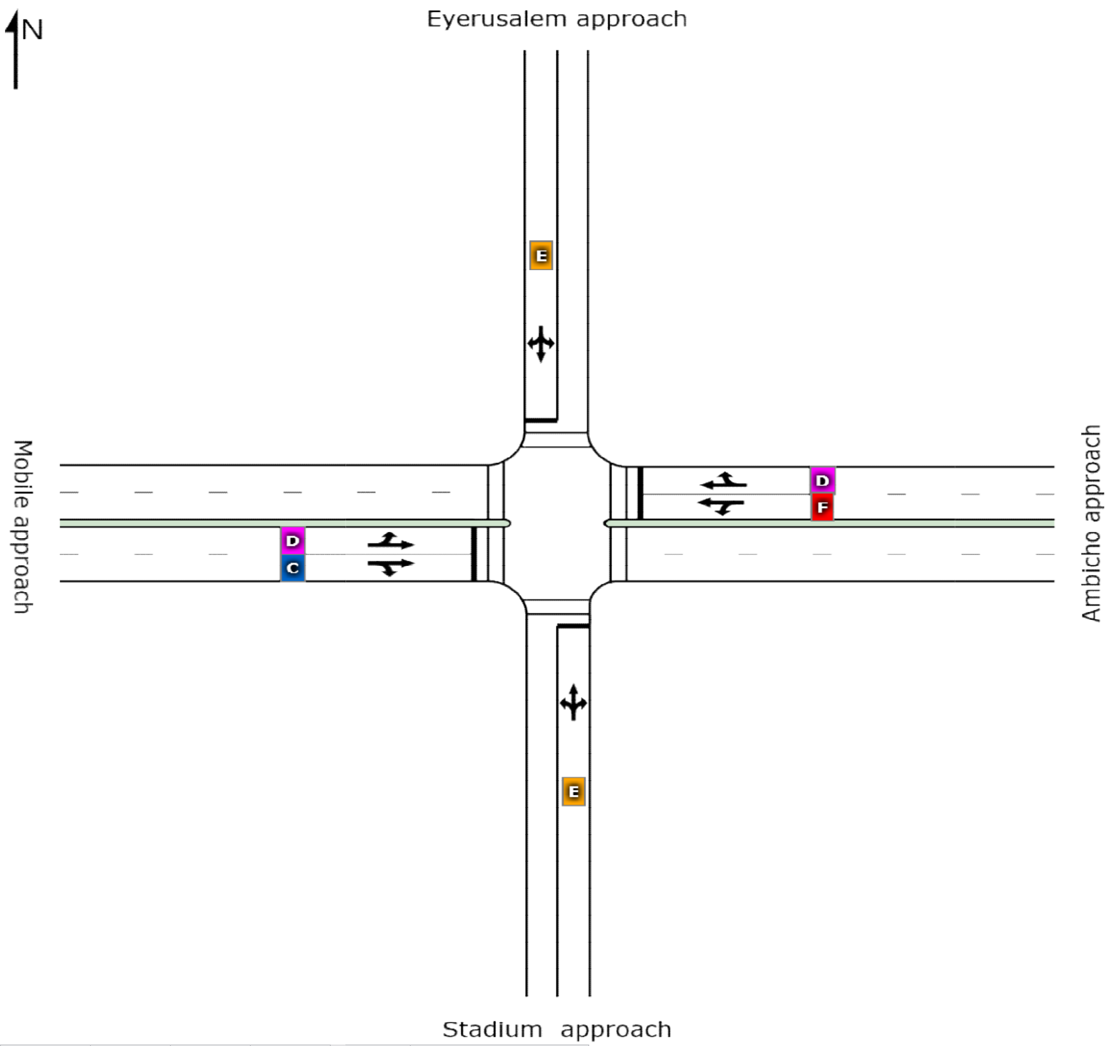
As a result, shows above, there was a clear improvement in queue distance when three wheelers replaced by minibus as an approach and as an intersection. 60.5% queue distance of the Hospital approach, 32.8% Queue distance of Lucy approach, 39.8% queue distance of 18 mazoriya approaches, and 59.5% queue distance of Handa mall approach is improved when three wheelers replaced by minibus.

Generally, 59.5% queue length of Menharya signalized intersection is improved when three wheelers replaced by minibus.

As a summary, performance measurement parameters of the Menharya signalized intersection improved when three wheelers replaced by minibus.

4.4.2. Performance evaluation of Maryam signalized intersection when three wheelers replaced by minibus.

When three wheelers replaced by minibus, Maryam signalized intersection has a summarized performance measurement parameters of 58.9sec delay, 0.499 degree of saturation, 95% queue length of 127m and LOS of D.



	South	East	North	West	Intersection
LOS	E	D	E	D	D

Figure 4. 22 The layout and level of service values of Maryam signalized intersection when three wheelers replaced by minibus.

4.4.2.1 Comparing the performance change of Maryam signalized intersections when three wheelers replaced by mini bus.

Table 4.28 Comparison of the difference between Previous (with three wheelers) and Current (when three wheelers replaced by minibus) level of services for Maryam intersection.

Approach name	Previous Level of Service (LOS)	Current Level of Service (LOS)	Remark
Eyeruslem	F	E	Improved
Stadium	F	E	Improved
Mobile	D	D	Same
Ambicho	F	D	Improved
Intersection	E	D	Improved

There is a LOS improvement for all approaches except Mobile approach.

Table 4.29 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) signal delay time (sec) of Maryam intersection.

Approach	Previous Signal Delay time in sec	Current Signal Delay time in sec	Difference
Eyeruslem	91.4	72.6	18.8
Stadium	93.1	72.8	20.3
Mobile	47.9	38.3	9.6
Ambicho	61.5	45.3	16.2
Intersection	60.7	49	11.7

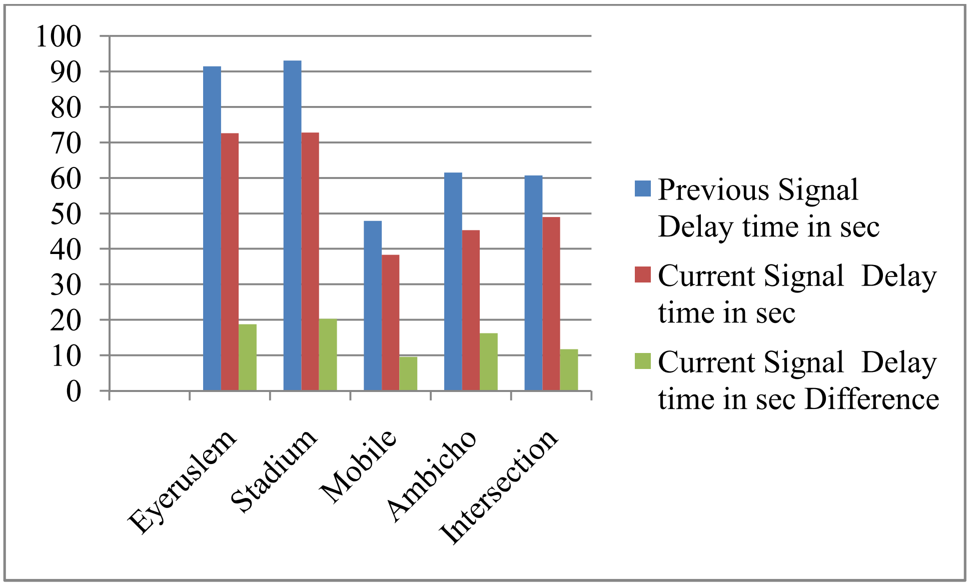


Figure 4.23 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) signal delay time (sec) of Maryam intersection.

As a result, shows above, there was a clear improvement in delay when Three wheelers replaced by minibus as an approach and as an intersection. 20.6% delay of Eyeruslem approach, 21.8 % delay of Stadium approach, 20.0% delay of Mobile approach, and 26.3% delay of Ambicho approach is improved when Three wheelers replaced by minibus.

Generally, a 19.3% delay of Maryam signalized intersection is improved when three wheelers replaced by minibus.

Table 4.30 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) degree of saturation of Maryam intersection.

Approach	Previous degree of saturation	The current degree of saturation	difference
Eyeruslem	0.778	0. 553	0.225
Stadium	0.796	0. 563	0.233
Mobile	0.367	0.269	0.098
Ambicho	0.852	0.576	0.276
Intersection	0.852	0.576	0.276

From the above output, 28.9% degree of saturation of the Eyeruslem approach, 29.3% degree of saturation of Stadium approach, 26.7% degree of saturation of Mobile approach, and 32.4% degree of saturation of the Ambicho approach is improved when three wheelers replaced by minibus.

Generally, a 32.4 % degree of saturation of Maryam signalized intersection is improved when three wheelers replaced by minibus.

Table 4.31 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) queue length of Maryam intersection.

Approach	Previous 95% back of queue length (m)	Current 95% back of queue length (m)	Difference
Eyeruslem	63.3	45.7	17.6
Stadium	62.6	44.1	18.5
Mobile	81.1	56.9	24.2
Ambicho	253.3	137.9	115.4
Intersection	253.3	137.9	115.4

As a result, summarized above, there was a clear improvement in queue length when three wheelers replaced by minibus as an approach and as an intersection. 27.8% queue length of the Eyeruslem approach, 29.6% queue length of Stadium approach, 29.8% queue length of Mobile approach and 45.6% queue length of the Ambicho approach is improved when Three wheelers replaced by minibus.

Generally, 45.6% queue distance of Maryam signalized intersection is improved when three wheelers replaced by minibus.

As a summary, performance measurement parameters of Maryam signalized intersection improved when three wheelers replaced by minibus.

4.4.3. Performance evaluation of Bezabh Petros roundabout when three wheelers replaced by minibus.

Table 4.32 the lane use and performance output for Bezabh Petros roundabout when three wheelers replaced by minibus.

Approaches	Demand flows				HV	Cap	Deg	Lane	Average	Level of service	95% of Queue	
	L veh/h	T veh/h	R veh/h	Total veh/h	%	veh/h	satn	util	Delay Sec		Vehicles Veh	Length M
South: Menharya Approach												
Lane 1	9	363	0	373	34.1	640	0.583	100	16.1	LOS B	4.1	37.1
Lane 2	0	46	384	431	20.7	739	0.583	100	14.3	LOS B	4.1	34.0
Approach	9	410	384	803	26.9		0.583		15.2	LOS B	4.1	37.1
South East: Maremiya approach												
Lane 1	16	0	20	36	0.0	388	0.094	100	10.7	LOS B	0.5	3.5
Approach	16	0	20	36	0.0		0.094		10.7	LOS B	0.5	3.5
East: Mobile approach												
Lane 1	442	0	0	442	24.0	511	0.866	100	41.7	LOS D	11.1	94.0
Lane 2	0	0	239	239	16.0	569	0.866	100	12.9	LOS B	2.4	19.5
Approach	442	0	239	681	21.2		0.866		31.6	LOS C	11.1	94.0
North: Mesalemiya approach												
Lane 1	187	120	0	307	24.5	481	0.639	100	23.0	LOS C	5.2	44.3
Lane 2	0	252	52	304	25.3	476	0.639	100	23.2	LOS C	5.2	44.4
Approach	187	373	52	611	24.9		0.639		23.1	LOS C	5.2	44.4
South West: Hadiyya pharmacy approach												
Lane 1	40	0	22	62	18.7	302	0.205	100	16.0	LOS B	1.1	9.0
Approach	40	0	22	62	18.7		0.205		16.0	LOS B	1.1	9.0
Intersection				2194	23.9		0.866		22.4	LOS C	11.1	94.0

As shown above table, when Three wheelers replaced by mini bus, Bezabh petros roundabout has average delay of 22.4sec, degree of saturation of 0.866, 95% queue length of 94m and LOS of C. So there is an improvement of performances in this condition and detail comparisons are discussed below.

4.4.3.1 Comparing the performance change of Bezabhpetros roundabout when three wheelers replaced by mini bus.

Table 4.33 Comparison of the difference between Previous (with three wheelers) and Current (when three wheelers replaced by minibus) level of services for Bezabh Petros roundabout.

Approach name	Previous Level of Service (LOS)	Current Level of Service (LOS)	Remark
Menharya	B	B	Same
Mesalemiya	B	B	Same
Mobile	D	C	Improved
Hadiyya pharmacy	B	B	Same
Maremiya	B	B	Same
Intersection	C	C	Same

There is a LOS improvement of only the mobile approach from D to C., But as a roundabout, there is no improvement of LOS when Three wheelers replaced by minibus.

Table 4.34 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) signal delay time (sec) of Bezabh Petros roundabout.

Approach name	Previous delay time in sec	Current delay time in sec	Difference
Menharya	15.7	15.2	0.5
Mesalemiya	26.4	23.1	3.3
Mobile	43.9	31.6	12.3
Hadiyya pharmacy	17.9	16	1.9
Maremiya	13.4	10.7	2.7
Intersection	27.1	22.4	4.7

As a result, shows above, there was a clear improvement in delay when Three wheelers replaced by minibus as an approach and as a roundabout. 3.2% delay of the Menharya approach, 12.5% delay of Mesalemiya approach, 28.0 % delay of Mobile approach, 10.6% delay of Hadiyya pharmacy approach, and 20.1% delay of Maremiya approach is improved when Three wheelers replaced by minibus.

Generally, a 17.3% delay of Bezabh Petros roundabout is improved when Three wheelers replaced by minibus.

Table 4.35 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) degree of saturation of Bezabh Petros roundabout.

Approach name	Previous degree of saturation	The current degree of saturation	Difference
Menharya	0.66	0.583	0.077
Mesalemiya	0.731	0.639	0.092
Mobile	0.98	0.866	0.114
Hadiyya pharmacy	0.262	0.205	0.057
Maremiya	0.164	0.094	0.07
Intersection	0.980	0.866	0.114

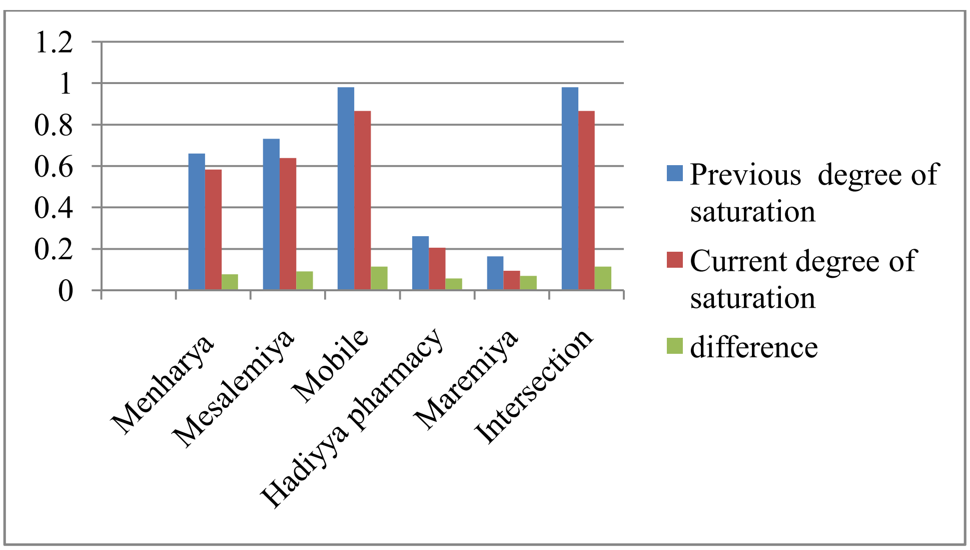


Figure 4.24 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) degree of saturation of Bezabh Petros roundabout.

From the above output 11.7% degree of saturation of Menharya approach, 12.6% degree of saturation of Mesalemiya approach, 11.6% degree of saturation of Mobile approach, 21.8% degree of saturation of Hadiyya pharmacy approach and 42.7% degree of saturation of Maremiya approach is improved when three wheelers replaced by minibus.

Generally, an 11.6% degree of saturation of Bezabh Petros roundabout is improved when three wheelers replaced by minibus.

Table 4.36 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) queue length (m) of Bezabh Petros roundabout.

Approach name	Previous 95% back of queue length (m)	Current 95% back of queue length (m)	Difference
Menharya	48.8	37.1	11.7
Mesalemiya	62.6	44.1	18.5
Mobile	162.7	94.0	68.7
Hadiyya pharmacy	12.3	9.0	3.3
Maremiya	6.5	3.5	3
Intersection	162.7	94.0	68.7

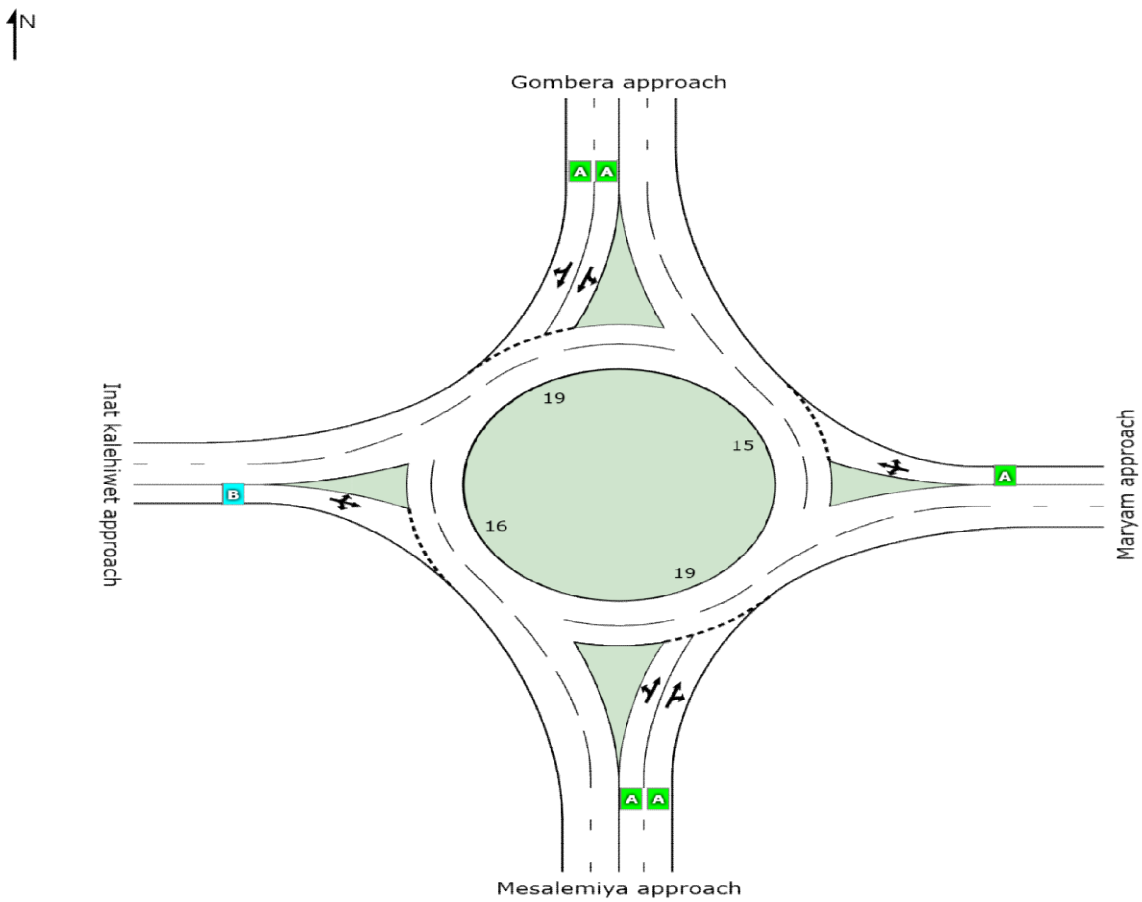
As a result, shows above, there was a clear improvement in queue length when Three wheelers replaced by minibus as an approach and as an intersection. 24.0% queue length of the Menharya approach, 29.6% queue length of Mesalemiya approach, 42.3% queue length of Mobile approach, 26.9% queue length of Hadiyya pharmacy approach and 46.2% queue length of Maremiya approach is improved when Three wheelers replaced by minibus.

Generally, 42.3% queue distance of Bezabh Petros roundabout is improved when Three wheelers replaced by minibus.

As a summary, there is an improvement in performance measurement parameters of Bezabh Petros roundabout when three wheelers replaced by minibus.

4.4.4. Performance evaluation of Eyerusalem roundabout when three wheelers replaced by minibus.

When Three wheelers replaced by minibus, Eyerusalem roundabout has an average delay of 8.2 sec, degree of saturation of 0.345, 95% queue length of 16.8m and LOS of A. there is improvement on performance of the roundabout and the detail comparison was shown clearly at next portion.



	South	East	North	West	Intersection
LOS	A	A	A	B	A

Figure 4.25 The layout and level of service values of Eyerusalem roundabout when three wheelers replaced by minibus

4.4.4.1. Comparing the performance change of Eyerusalem roundabout when three wheelers replaced by mini bus.

Table 4.37 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) level of services for Eyerusalem roundabout.

Approach name	Previous Level of Service (LOS)	Current Level of Service (LOS)	Remark
Mesalemiya	A	A	Same
Maryam	B	A	Improved
Gombera	A	A	Same
Inatkalehiwet	B	B	Same
Intersection	B	A	Improved

There is LOS improvement at Maryam approach from B to A, and as a roundabout, LOS is improved from B to A when three wheelers replaced by minibus.

Table 4.38 Comparison of the difference between Previous (with three wheelers) and Current (when three wheelers replaced by minibus) signal delay time (sec) of Eyerusalem roundabout.

Approach name	Previous delay time in sec	Current delay time in sec	Difference
Mesalemiya	8.1	4.5	3.6
Maryam	12.4	5.5	6.9
Gombera	9.7	8.7	1
Inat kalehiwet	17.5	13.7	3.8
Intersection	10.1	8.5	1.6

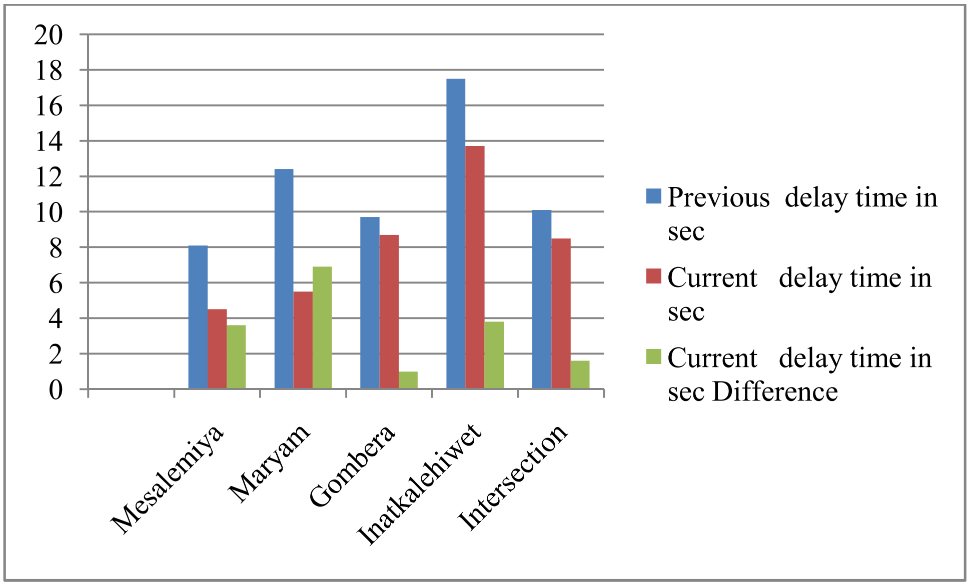


Figure 4.26 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) signal delay time (sec) of Eyerusalem roundabout.

As a result, shows above, there was a clear improvement in delay when three wheelers replaced by minibus as an approach and as a roundabout. 44.4% delay of Mesalemiya approach, 55.6% delay of Maryam approach, 10.3% delay of Gombera approach, and 21.7% delay of Inat kalehiwet approach is improved when three wheelers replaced by minibus.

Generally, an 15.8% delay of Eyerusalem roundabout is improved when three wheelers replaced by minibus.

Table 4.39 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) degree of saturation of Eyerusalem roundabout.

Approach name	Previous degree of saturation	The current degree of saturation	difference
Mesalemiya	0.387	0.085	0.302
Maryam	0.37	0.1	0.27
Gombera	0.441	0.37	0.071
Inatkalehiwet	0.423	0.318	0.105
Intersection	0.441	0.37	0.071

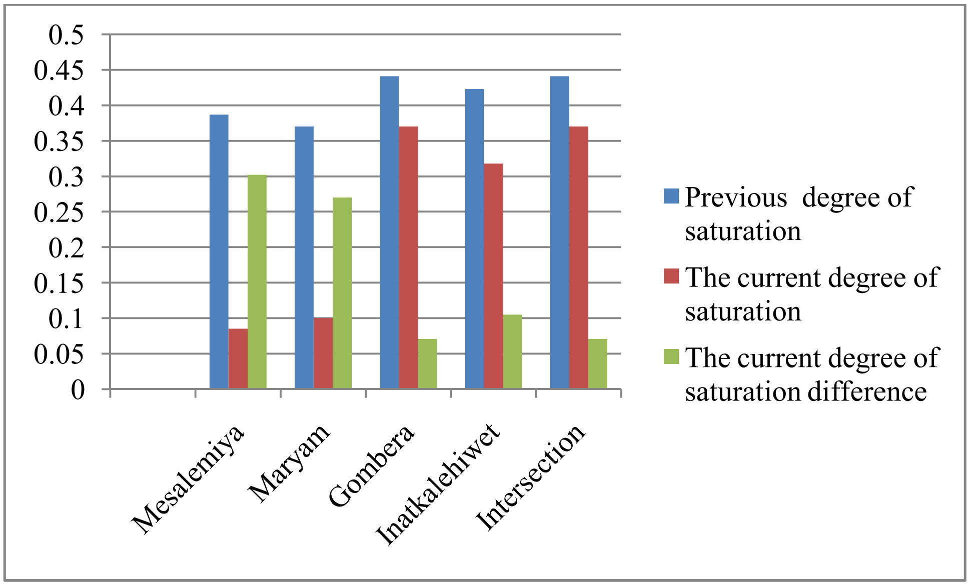


Figure 4.27 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) degree of saturation of Eyerusalem roundabout.

From the above output, 78.0% of the Mesalemiya approach, 73.0% degree of saturation of Maryam approach, 16.1% degree of saturation of Gombera approach, and 24.8% degree of saturation of Inat kalehiwet approach is improved when three wheelers replaced by minibus. Generally, a 16.1% degree of saturation of Eyerusalem roundabout is improved when three wheelers replaced by minibus.

Table 4.40 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) queue length (m) of Eyerusalem roundabout.

Approach name	Previous 95% back of queue length (m)	Current 95% back of queue length (m)	Difference
Mesalemiya	18	3.1	14.9
Maryam	16.1	4.1	12
Gombera	22.5	17	5.5
Inat kalehiwet	16.3	10.6	5.7
Intersection	22.5	17	5.5

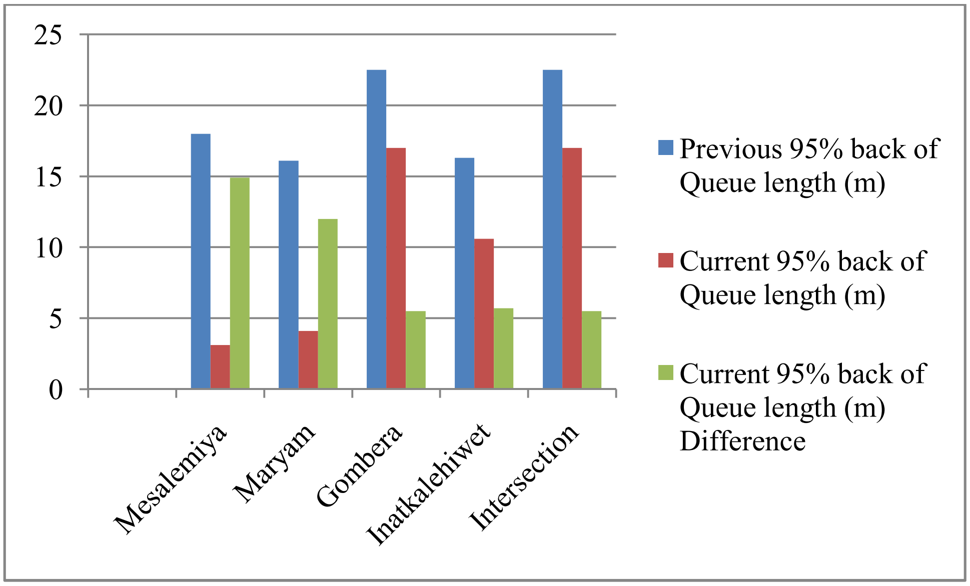


Figure 4.28 Comparison of the difference between previous (with three wheelers) and current (when three wheelers replaced by minibus) queue length (m) of Eyerusalem roundabout.

As a result, shows above, there was a clear improvement in Queue length when three wheelers replaced by minibus as an approach and as an intersection. 82.8% queue length of Mesalemiya approach, 74.5% queue length of Maryam approach, 24.4% Queue length of Gombera approach, and 35.0% queue length of Inat kalehiwet approach is improved when three wheelers replaced by minibus.

Generally, 24.4% Queue distance of Eyerusalem roundabout is improved when three wheelers replaced by minibus.

As a summary, there is an improvement in performance measurement parameters of Bezabh Petros roundabout when three wheelers replaced by minibus.

4.4.5 Summary on intersection performances when three wheelers replaced by mini bus.

When three wheelers replaced by minibus, there was improvement on performance of intersections. For Menharya signalized intersection When Three wheelers replaced by mini bus, average delay changed from 171.5 sec to 78.7sec, degree of saturation reduced from 1.374 to 0.939, queue length reduced from 497.4m to 201.5m and LOS improved from F to E. For Maryam signalized intersection, When three wheelers replaced by mini bus, average delay reduced from 60.7 sec to 49sec, degree of saturation reduced from 0.852 to 0.576, queue length reduced from 253.3m to 137.9m and LOS improved from E to D.

In Bezabh Petros roundabout and in Eyerusalem roundabout, there is also clear improvement of intersection performances when three wheelers replaced by mini bus. For Bezabh Petros roundabout When three wheelers replaced by mini bus, average delay reduced from 27.1 sec to 22.4 sec, degree of saturation reduced from 0.980 to 0.866 and queue length reduced from 162.7m to 94.0m.For Eyerusalem roundabout, When three wheelers replaced by mini bus, average delay reduced from 10.1 sec to 8.5 sec, degree of saturation reduced from 0.441 to 0.37, queue length reduced from 22.5m to 17m and LOS improved from B to A.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Based on the findings of the analysis in this study, the result of analysis for Menharya signalized intersection of the Hosanna City indicated that the intersection is in serious condition and Maryam signalized intersection is also in congested condition.

- ✓ During the peak periods, Menharya signalized intersection has the average delay of 171.5sec, queue length of 497.4m, degree of saturation of 1.374 and the level of service was "F."
- ✓ Maryam signalized intersection also has a high average delay of 60.7sec, the queue length of 253.3m, degree of saturation of 0.852, and level of service of "E."
- ✓ Both Bezabh Petros roundabout and Eyerusalem roundabouts have relatively good LOS of C and B, respectively.

Three wheelers are highly affecting the performance measurement parameters of intersections. For Menharya signalized intersection when three wheelers removed,

- ✓ The Average delay decreases from 171.5sec to 50.6 sec, degree of saturation decreases from 1.374 to 0.199, LOS improved from F to D and queue length decreases from 497.4m to 30.9m. That means 70.5% cause for delay, 85.5% cause for a degree of saturation, and 93.8% cause for the queue distance of Menharya signalized intersection is three wheeler's presence.
- ✓ In the same manner for Maryam signalized intersection, 17.1% cause of delay. 82.2% cause of degree of saturation, and 90.7% cause of queue length is three wheeler's presence.
- ✓ As explained in the last chapter, Bezabh Petros roundabout and Eyerusalem roundabout's performance measurement parameters are also affected highly due to the presence of three wheelers.

By replacing three wheeler vehicles by minibus taxis as a means of public transport in Hosanna city, performance improvement will be gained under the prevailing conditions. The improvement is significant for all intersections.

- ✓ For Menharya signalized intersection, 54.1% Average delay, 31.7% degree of saturation and 59.5% queue distance improved when three wheelers replaced by minibus. LOS also improved from F to E.
- ✓ For Maryam signalized intersection, 19.3% Average delay, 32.4% degree of saturation and 45.6% queue distance improved when three wheelers replaced by minibus. LOS also improved from E to D.
- ✓ For Bezabh Petros roundabout, 17.3% Average delay, 11.7% degree of saturation and 42.25% queue distance improved when three wheelers replaced by minibus and
- ✓ For Eyerusalem roundabout, 15.8% Average delay, 16.1% degree of saturation and 24.4% queue distance is improved when three wheelers replaced by minibus. LOS also improved from B to A.

5.2. Recommendations

- ✓ One way to improve intersection performances is to replace the three wheelers with minibus as a public transport option. So the concerned body should apply this recommendation.
- ✓ The assumptions made in replacing three wheelers vehicles by minibus taxis shall be studied thoroughly, and the cost-benefit analysis shall be done in replacing the two-vehicle classes.
- ✓ The effect of heavy vehicles on performance measurement parameters of intersection should also be done.
- ✓ The passenger car unit used in this research is from manuals so it is necessary to assess passenger car unit of vehicles in Hosanna city.
- ✓ Since this research assessed only the effect of three wheelers on performance measurement parameters of signalized intersections and roundabouts, it should be analyzed for unsignalized intersections also.

REFERENCES

Abojaradeh M, 2013 “Travel Time and Delay Study to Improve Public Transit Systems in Jordan” Journal of Environment and Earth Science issued from IISTE USA Volume 3, No. 4, pp 85-97.

AACRA (Addis Ababa City Roads Authority), 2004 “Geometric Design Manual".

Ahmed, 2018 “Analysis of traffic congestion and remedial measures at traffic mor in pabna city” Bangladesh.

Akcelik R, 2002 “Evaluating Roundabout Capacity, Level of Service and Performance” Paper presented at the ITE 2009 Annual Meeting. Texas, USA.

Akcelik, R, 2017 “Roundabout model comparison table”.Akcelik and Associates Pty Ltd, Melbourne, Australia.

Akcelik & Associates Pty Ltd, 2011.“SIDRA INTERSECTION user guide part 4” output Guide, Australia.

Borkloe J K, Nyantakyi E K and Mohammed G, 2013“Capacity Analysis of Selected Intersections on Mampong Road, Kumasighana Using Micro Simulation Model”. International Journal of Structural and Civil Engineering Research.

FHWA (Federal Highway Administration), 2009. ROUNDABOUTS: An Informational Guide U.S Department of Transportation (USDOT), Washington, DC.

FHWA (Federal Highway Administration), 2009 ROUNDABOUTS: An Informational Guide U.S Department of Transportation (USDOT), Washington, DC.

Fisk, C.S, 1991 “Traffic Performance Analysis at Roundabouts” Transportation Research, Vol. 25B, Bi 2/3. pp. 89-102.

Garber, 2010.Traffic and Highway Engineering 4th SI Edition, USA.

HCM (Highway Capacity Manual) 2010 Transportation Research Board's (TRB) fifth edition of the Highway Capacity Manual HCM, Washington D.C USA.

Henry X. Liu, Wenteng Ma, Xinkai Wu, and HengHu ,2009 "Development of a Real Time Arterial Performance Monitoring System Using Traffic Data Available from Existing Signal System" Department of Civil Engineering University of Minnesota 500 Pillsbury Dr. SE Minneapolis, Minnesota 55455-0220, 2009.

Hossana Municipality, 2019.

Kumar N and Nagakumar M S, 2014 "Performance Evaluation of At-Grade Intersections and Improvement Using Signal Coordination".

Mallikarjuna R, 2014 "Operational Analysis of Roundabouts under Mixed Traffic Flow Condition" M. Tech Thesis National Institute of Technology, Rourkela, India.

MASS HIGHWAY, 2006, Chapter 6 intersection January 2006.

McShane W, and Roess R, 1990 Traffic Engineering, New Jersey, Prentice Hall, Inc, pp 509 548 Papacostas C., Prevedonros P, 2008, Transportation Engineering and Planning, Fourth Edition, USA.

Mordidpour, S, 2014 "Impact of heavy vehicles on surrounding traffic characteristics" September 12, 2014.

Nurhussien Belay,2015 "Performance Evaluation of Selected Intersections in Bahirdar City" Msc Thesis.Department of Civil Engineering, Addis Ababa University,Addis Ababa.

Papacostas C, Prevedonros P, 2008 Transportation Engineering and Planning, Fourth Edition, USA.

RaoSh , 2015. "Performance Analysis of Roundabouts Using Empirical Method for Indian Scenario" National Institute of Technology, Rourkela, India.

Roess, 2004 "Traffic engineering 3rd edition ".

Saha.K, 2013 "Analysis of traffic congestion and remedial measures at traffic mor in pabna City, Bangladesh".

Syoum.B, 2018 "The Effects of Traffic Mixes with 3-Wheelers on Performance of Unsignalized Intersections in Harar City" MSc Thesis, Department of Civil Engineering, Addis Ababa University, Addis Ababa.

Tewodros G,2017 "Capacity Evaluation of Roundabout Junctions in Addis Ababa" MSc Thesis, MSc Thesis.Department of Civil Engineering, Addis Ababa University, Addis Ababa.

Tom V. Mathew and K V Krishna Rao, 2006 "Introduction to Transportation Engineering" NPTEL, May 24, 2006.

Transportation office of Hosanna City, 2019.

Transportation Research Board, 2000 Highway Capacity Manual,National Research Council, Washington D.C, chapter 19.

APPENDICES

Appendix I

Signalization data existing in signalized intersection

For Menharya Signalized Intersection

Phase	**A**	**B**	**C**	**D**
Green Time (sec)	29	24	24	29
Yellow Time (sec)	4	4	4	4
All-Red Time (sec)	2	2	2	2

For Maryam Signalized Intersection

Phase	**A**	**B**	**C**	**D**
Green Time (sec)	25	28	28	25
Yellow Time (sec)	4	4	4	4
All-Red Time (sec)	2	2	2	2

Appendix II

Layouts and performance outputs of intersections.

Table 1.The lane use and performance output for Maryam signalized intersection without three wheelers.

Approaches	Demand flows				HV	Cap	Deg	Lane	Average	Level of services	95% of Queue	
	L veh/h	T veh/h	R veh/h	Total veh/h	%	veh/h	satn	Util	Delay Sec		Vehicles Veh	Distance M
South: Stadium approach												
Lane 1	16	6	10	31	28.8	207	0.152	100	54.2	LOS D	1.8	16.1
Approach	16	6	10	31	28.8		0.152		54.2	LOS D	1.8	16.1
East: Ambicho approach												
Lane 1	5	4	0	9	32.1	59	0.152	100	65.9	LOS E	0.6	5.3
Lane 2	0	37	1	38	75.8	251	0.152	100	45.0	LOS D	2.0	23.6
Approach	5	41	1	47	67.5		0.152		48.9	LOS D	2.0	23.6
North: Eyerusalem approach												
Lane 1	16	4	9	30	61.0	216	0.138	100	52.2	LOS D	1.7	18.3
Approach	16	4	9	30	61.0		0.138		52.2	LOS D	1.7	18.3
West: Mobile approach												
Lane 1	3	5	0	8	39.1	61	0.134	100	63.1	LOS E	0.5	5.0
Lane 2	0	28	8	36	55.0	273	0.134	100	44.5	LOS D	1.9	20.0
Approach	3	33	8	45	52.1		0.134		47.9	LOS D	1.9	20.0
Intersection				153	53.8		0.152		50.3	LOS D	2.0	23.6

Table 2 .The lane use and performance output for Eyerusalem roundabout without three wheelers.

Approaches	Demand flows				HV	Cap	Deg	Lane	Average	Level of services	95% of Queue	
	L veh/h	T veh/h	R veh/h	Total veh/h	%	veh/h	satn	util	Delay Sec		Vehicles Veh	Length M
South: Mesalemiya Approach												
Lane 1	11	146	0	157	38.9	841	0.186	100	6.2	LOS A	0.9	8.2
Lane 2	0	120	37	157	38.7	843	0.186	100	6.2	LOS A	0.9	8.2
Approach	11	267	37	314	38.8		0.186		6.2	LOS A	0.9	8.2
East: Maryam approach												
Lane 1	41	5	34	80	36.8	597	0.134	100	7.6	LOS A	0.6	5.4
Approach	41	5	34	80	36.8		0.134		7.6	LOS A	0.6	5.4
North: Gombera approach												
Lane 1	26	161	0	187	49.2	772	0.243	100	7.4	LOS A	1.2	11.8
Lane 2	0	165	23	188	48.5	776	0.243	100	7.3	LOS A	1.2	11.8
Approach	26	326	23	376	48.8		0.243		7.4	LOS A	1.2	11.8
West: Inat kalehiwet approach												
Lane 1	24	19	43	86	13.5	460	0.187	100	10.5	LOS B	0.7	5.8
Approach	24	19	43	86	13.5		0.187		10.5	LOS B	0.7	5.8
Intersection				856	40.5		0.243		7.3	LOS A	1.2	11.8

Table 3. The lane use and performance output for Eyerusalem roundabout when three wheelers replaced by minibus.

Approaches	Demand flows				HV	Cap	Deg	Lane	Average Delay	Level of services	95% of Queue	
	L veh/h	T veh/h	R veh/h	Total veh/h	%	veh/h	satn	util	sec		Vehicles Veh	Distance M
South: Mesalemiya Approach												
Lane 1	83	0	0	83	16.0	980	0.085	100	4.4	LOS A	0.4	3.1
Lane 2	0	10	63	73	21.4	929	0.085	100	4.6	LOS A	0.4	2.9
Approach	83	10	63	156	18.5		0.085		4.5	LOS A	0.4	3.1
East: Maryam approach												
Lane 1	41	5	34	80	36.8	804	0.100	100	5.5	LOS A	0.4	4.1
Approach	41	5	34	80	36.8		0.100		5.5	LOS A	0.4	4.1
North: Gombera approach												
Lane 1	40	264	0	304	30.4	822	0.370	100	8.8	LOS A	1.9	17.0
Lane 2	0	267	40	307	29.3	829	0.370	100	8.7	LOS A	1.9	16.9
Approach	40	531	40	611	29.9		0.370		8.7	LOS A	1.9	17.0
West: Inat kalehiwet approach												
Lane 1	43	34	61	138	8.5	434	0.318	100	13.7	LOS B	1.4	10.6
Approach	43	34	61	138	8.5		0.318		13.7	LOS B	1.4	10.6
Intersection				984	25.6		0.370		8.5	LOS A	1.9	17.0