



**MULTIVARIATE COMPARATIVE ANALYSIS FOR SELECTION OF  
INTERSECTION CONTROL  
(CASE STUDY FOR SELECTED UNCONTROLLED INTERSECTIONS IN  
HAWASSA CITY)**

**MSc THESIS**

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**HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA**

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INTERSECTION CONTROL**

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**A THESIS SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING**

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## ADVISORS' APPROVAL SHEET

This is to certify that the thesis entitled “**Multivariate Comparative Analysis for Selection of Roundabout or Signal Intersection Control (Case Study for Existing Shell And Addisu Menhariya Uncontrolled Intersections in Hawassa City)**” submitted in partial fulfillment of the requirements for the degree of **Master’s** with specialization in **Road and Transport Engineering**, the Graduate Program of the **Department of Civil Engineering**, and has been carried out by **Zemenayhu Borena (ID. No. PGRO/047/09)**, under us supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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## **ACRONYMS / ABBREVIATIONS**

AACRA: Addis Ababa city construction road authority

DOS: degree of saturation

ERA: Ethiopian Road Authority

LOS: level of service

SIDRA: signalized and un signalized intersection design research aid

SNNPRG: southern nation nationality people regional government

## ABSTRACT

Uncontrolled intersections that are found on major road carrying a higher traffic volume generally have traffic safety and operational problems. This is due to the crossing and turning movements at this intersection cannot be satisfactorily managed with existing uncontrolled intersection. At major arterial road intersection with medium and high volume roads where grade separation can't be justified traffic would generally be controlled by either signal or roundabouts. The main objective of this thesis is to assess and find out optimum intersection control mechanism from roundabout or signalized intersection for existing uncontrolled intersection of shell and Addisu Menhariya in Hawassa city. These intersections are selected because both are found on major road carrying high traffic volumes (AADT) that justify the introduction of roundabout or signalized intersection based on ERA intersection selection criteria. The methodology that is used for selection is multivariate comparative analysis that uses cost, operational performance and safety performance as evaluation criteria. The traffic, geometric, cost, signal and crash data's are collected to make Comparison. Operational performance analyses are made using HCM 2010 methodologies incorporated in SIDRA Intersection software 5.1. The safety performances are measured using mean crash rates and causalities for similar intersection types for years from 2014 to 2018 G.C for millions of entering vehicles to intersections. The costs that are used for comparison are estimated initial costs for alternatives based on current market prices of the city and operational costs that are found using SIDRA Intersection software 5.1. The result show that proposed roundabout and signal intersections will serve LOS C and LOC F with existing traffic condition in both intersections respectively. The summary data indicates that the casualty crash exposure rate at roundabouts in Hawassa city is approximately 19% less than the casualty crash exposure rate of signalized intersections, when averaged across all crash types. The fuel costs and operational cost for roundabout intersection are also lesser than alternative signalized intersection. But the initial cost for roundabout is higher than proposed signalized intersection. Roundabout options are finally recommended for existing uncontrolled intersections of shell and Addisu Menhariya in Hawassa city.

**Keywords:** cost, roundabout, safety performance, SIDRA intersection software 5.1, signalized intersection, operational performance.

# 1. INTRODUCTION

## 1.1 Background

Intersections play a significant role in the operation of the road network. Generally, appropriate intersection control depends on traffic and site needs (main roads,2015). A properly selected intersection type could improve the safety performance for intersections, assure acceptable operational performance and finally selected intersection type should be economically feasible compared with alternative proposed intersections (Mainroads, 2015).

In order to select appropriate intersection control from alternatives the above consideration should be taken in to account. However, different researches that are made so far on selection of control are not self-sufficient to consider factors that affect selection fully. These researches can be mentioned with their title comparative assessment of the performance of two intersection controls types (Regab, 2006), comparative analysis of roundabout and traffic signal through corridors (Lebas, 2015) and modern roundabouts intersection when to use them? Comparison with signalized intersection (Mark and William, 2009).With their evaluation criteria safety, environmental space utilization and performance aspect, travel time and average delay and operational characteristics respectively (Vic roads, 2005).

In Hawassa city, way of intersection selection is traditional with no systematic and credible method of evaluation. The City does not have a formal process for reviewing traffic control options for intersections prior to detailed design. The purpose of this thesis is to become pioneer for other practitioners to make an objective comparison between roundabouts and traffic signals for the purpose of intersection control-type selection for Hawassa city and for other cities of the country. This research will use multivariate factors in detail to assess and compare their effect on selection of optimum intersection from proposals.

## 1.2 Problem statement

Uncontrolled intersections that are found on major road carrying a higher traffic volume generally have poor safety and operational performances (Mainroads, 2015). (Mainroads, 2015) conclude that this is due to the crossing and turning movements at this intersection cannot be satisfactorily managed with existing uncontrolled intersection.

In Hawassa city uncontrolled intersections that are found along a major trunk road from Addis Ababa to Moyale these problems are common to observe. Prior to problem identification traffic counts and visual observation were made on the selected uncontrolled intersection of Shell and Addisu Menhariya in Hawassa city. The observation to this two intersection reveal that a higher number of conflicting points due to no management to crossing and turning movements and a higher exposure to conflicts, with no priority to through traffic is given, no yield and stop sign, no priority given to pedestrian, with no speed limit posted, unsafe for cyclist and generally a higher accident casualty .The traffic counts that is made on uncontrolled intersection of shell show AADT values 13842 veh/day for major and 8352 veh/day for minor intersecting roads as shown on Table 3.15. Likewise the uncontrolled intersections of Addisu Menhariya have AADT Values 12950 veh/hr and 3590 veh/hr for major and minor intersecting roads respectively as shown on Table 3.16.

According to ERA selection criteria based on traffic flow on major and minor intersecting roads with above AADT values it's not possible to manage traffic with existing uncontrolled intersection satisfactorily. These problems necessitate proper traffic intersection control that will ensure optimum safety and operational efficiency. The recommended intersection on ERA 2013 geometric design manual Figure.2.2 junction selection based on traffic flows indicate that appropriate intersection for existing intersection of Shell and Addisu Menhariya in Hawassa city are roundabout or signal.

In order to select appropriate intersection ERA 2013 geometric design manual suggest a multivariate comparative analysis that involve safety, operational performance and cost as evaluation criteria. This multivariate analysis will bring objective based comparison between proposals and select optimum intersection control that is cost effective which balances the safety, operational and amenity needs of road users.

Comparative ratings will be used to compare advantage and disadvantage of alternative proposals with regard of factors that affect the selection. The factors that are identified for evaluation are operational performance, safety performance, initial cost, operational costs and Environmental impact. Comparative ratings + (for advantage),-(for disadvantage) and= (for equal or no significance) are used. Finally alternative proposal with more summed rating of advantages will be selected. Without consideration of the

above factors on intersection selection it's impossible to choose optimum intersection controls that perform better and cost effective. Due to this fact, it was clear that this thesis should be needed.

### **1.3 objectives**

#### **1.3.1 General Objective**

The general objective of this thesis is to assess and find out optimum traffic intersection control mechanism that balance initial and operational cost, operational and safety performance. (Based on a case study for existing uncontrolled intersections of shell and Addisu Menhariya in Hawassa city)

#### **1.3.2 Specific Objectives**

- ✓ To analyze operational performance of alternative intersection of roundabout and signalized intersections.
- ✓ To analyze suitability of alternative intersection of roundabout and signalized intersections
- ✓ To assess initial and operational cost of control proposals: roundabout and signalized intersections

### **Significance of the study**

Research finding assist the Hawassa city municipality in order to select appropriate intersection control from roundabout and signalized intersections for existing uncontrolled intersection .This help municipality to adopt objective comparison between roundabout and signal intersections to upgrade existing uncontrolled intersection prior to introduction. If objective of this study was achieved the following advantages can be attained : intersection with better operational and safety performance will be identified, less costly intersection from proposals will be known, intersection with reduced fuel consumption and greenhouse effect will be identified.

### **Research questions**

In order to seek a solution of the problem, a question were formulated as follows

- a) Which traffic intersection control mechanism from proposed is cost effective for existing uncontrolled intersection
- b) Which traffic intersection control mechanism from proposed is more efficient for safety operation of traffic for existing uncontrolled intersection

c) Which traffic intersection control mechanism from proposed gives a better operational efficiency for traffic of existing uncontrolled intersection

**Scope and limitation**

This study is limited to multivariate comparative analysis for proposed traffic intersection controls for existing uncontrolled intersection of Shell and Addisu Menhariya. The multivariate comparative analysis uses cost, safety and operational performances as evaluation criteria.

## **2. LITERATURE REVIEW**

### **2.1. General Overview**

It is presumed that the traffic volumes would be too high for un signalized intersections to be an appropriate form of intersection treatment for major roads carrying higher traffic volumes. Basically information related with objective comparison for selection of roundabout and signalized intersections are assessed. Comparison variables that are reviewed with this chapter are safety performances, operational performance and cost for alternative roundabout and signalized intersection.

Intersections play a significant role in the operation of the road network. Where two or more roads meet or cross, the intersection controls the amount of traffic able to use the intersecting roads and together with the capacity of the road links themselves, provides a significant contributing factor in determining the capacity of the road network as a whole. The crossing and turning movements at intersections need to be appropriately managed to ensure that safety and operational efficiency are optimized. Generally, appropriate intersection control depends on traffic and site needs that may rely on giving way at a T-intersection, regulatory signs (Stop or Give Way), roundabouts, traffic signals or grade separations. These forms of control may also be provided with appropriate layout design and channelization to control vehicle movements and points of conflict.

At major arterial road intersections with medium and high volumes (Primary Distributor and Distributor A roads) and where grade separation cannot be justified, traffic would generally be controlled by either traffic signals or roundabouts (Mainroads, 2015).

### **2.2 Safety Performance of Roundabouts and Traffic Signals**

#### **2.2.1 Crash Frequencies**

Typical crash rates for similar types of intersections can provide a basis for assessing safety performance in the following ways: A comparison of performance for intersections of differing types or traffic control and putting a benchmark against which a specific intersection can be compared.

Summary statistical data of crashes for the five year period or more on road location provides averaged safety performance data for road intersections controlled by roundabouts and traffic signals. These average rates may be used to compare a specific intersection with the network wide averages appropriate to the road environment.

Different researches show intersections controlled by roundabouts have a significantly lower crash rate than intersections controlled by traffic signals (Mainroad, 2015). Even where traffic volumes are higher, roundabouts have less than half the crash rate of intersections controlled by traffic signals (Mainroad, 2015).

### 2.2.2 Crash Rates – Exposure Relative to Traffic Volumes

When crash frequencies are related to traffic volumes using the intersections, they provide a measure related to exposure and traffic use. The mean safety performance rates at roundabout or signalized intersection types for casualty crashes expressed with crash rates are per million entering vehicles are compared

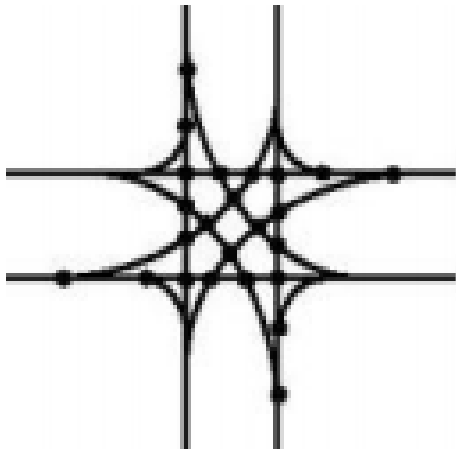
### 2.2.3 Why is Roundabouts Safer for Vehicles?

When designed correctly, the roundabout is probably the safest type of intersection for motor vehicles (Mainroad, 2015) conclude the following features generally contribute to the high standard of safety of roundabouts:

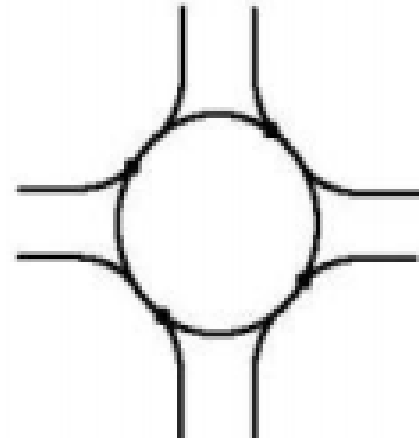
Roundabouts have Low operating speed. Slow moving traffic means low energy / low severity crashes and can also enable a driver to avoid a collision. Traffic at a roundabout is initially slowed down by the curved approach and the provision of the splitter island. The location of the central island then physically deflects the traffic through the intersection and controls the speed of traffic.

Roundabouts eliminate high angles of conflict thereby ensuring low relative speeds between conflicting vehicles. The roundabout layout limits the types of crashes and angle of impact. This results in low severity crashes in the event of a collision because traffic is moving in the same general direction at a low relative angle i.e. Significantly reducing the incidence of head-on or right angle crashes.

Roundabouts have fewer and further separated conflict points. A conflict point occurs where two travel paths merge or cross. Roundabout layouts satisfy safe intersection design principles in relation to conflict points as they minimize the number of conflict points and separate the areas of conflict as demonstrated in the following diagram.



24 Conflict points



4 Conflict points

Figure2. 1 Conflict points in signal and roundabout

Traffic signal phasing separates major conflicting movements in time, so this reduces some conflict situations. However, this is less effective in preventing crashes than physically restricting vehicle conflicts. At signals, crashes may also occur at controlled conflict situations when a vehicle travels through a red light.

A large area of conflict can occur where wide roads or offset crossroads intersect or when roads intersect at an acute angle. Roundabout layouts minimize conflict areas and have simple channelized approaches to separate points of conflict.

Roundabouts are relatively simple for decision making by drivers ..Drivers only look for traffic on the right, making it easier to judge an entry into the intersection.

on undivided roads in high speed areas, long curvilinear splitter islands on roundabout can provide good “advance warning” of the presence of the intersection and type of intersection.

These factors not only reduce the number of crashes but ensure that crashes are less severe than those that occur at other types of intersections. In this regard roundabouts fit well within the “Safe System” approach to road safety. The Safe System approach takes human errors and frailty into account, acknowledging that crashes will continue to occur but seeking to avoid death and serious injury as outcomes. Speed is a critical element in this approach. Speeds must be contained so that in the event of a crash the impact forces remain below human injury tolerance. Studies have consistently shown that the

installation of roundabouts results in crash reductions of up to 75% in overall crashes and injury crashes (Austroads, 2013)

#### 2.2.4 Pedestrian Safety at Roundabouts

Evidence suggests that roundabouts are at least as safe for pedestrians as other forms of intersection control possibly because pedestrians are able to cross one direction of traffic at a time by staging on the splitter islands. A Review of Pedestrian Safety at Roundabouts (Charmaine Tumber, 1997) was carried out by Vic Roads in 1997. The review considered available investigations and literature from Australia and overseas as well as an evaluation of data for roundabouts constructed on arterial roads in the Melbourne metropolitan area over the period 1987 – 1994.

The review concluded that there is not a demonstrated safety problem for pedestrians at roundabouts. The Melbourne data indicated that there is an average of 0.02 pedestrian crashes per roundabout per year at roundabouts. The findings also indicated that the severity of crashes involving pedestrians is lower than for other forms of control at intersections. Although available information indicates that roundabouts are relatively safe for pedestrians, there appears to be a perception that they are unsafe. It is acknowledged that some pedestrians are concerned about their safety because roundabouts do not give positive priority to pedestrians over through and turning movements. Exits are problematic, particularly for elderly pedestrians and children who may consider that traffic signals provide greater security for them to cross the road. In addition, pedestrians who are sight impaired have greater difficulty assessing traffic movements at roundabouts. Because pedestrians can have difficulty using roundabouts, this may also cause confusion between perceptions of safety and level of service.

#### 2.2.3 Cyclist Safety at Roundabouts

Evidence exists to show that roundabouts are not as safe for cyclists as for other road users, and that traffic signals are generally safer for cyclists. The size and layout of roundabouts is a factor in safety for cyclists. In general, small roundabouts with relatively low traffic speeds and with a circulating roadway narrow enough to prevent motor vehicles overtaking cyclists, present no special risks for cyclists (The Plan for Cycling is to Encourage it, 1992) (Bruede U. & Larsson J., 1996) (Van Minnen, 1996). Studies have shown that a large proportion of cyclist crashes (about 50%) involve an entering motor

vehicle colliding with a cyclist on the circulating roadway. This suggests that entering drivers have difficulty in detecting the presence of cyclists as they scan for larger vehicles that are approaching from their right. Specific provision for cyclists is not generally required at single lane roundabouts on local streets where vehicle speeds are low (i.e.  $\leq 50$  km/h) and traffic volumes are low (i.e.  $\leq 3000$  vpd). For larger roundabouts a key factor is the speed at which vehicles can enter and pass through the roundabout. Where cyclists and pedestrians are expected to use a roundabout, the design speed should be minimized, within the limitations necessary to provide adequate service to other road users. Where a significant number of cyclists and pedestrians use or are expected to use a site, the alternative of providing a signalized intersection should be considered.

### **2.3 Operational Performance of Signals and Roundabouts**

#### **2.3.1 Capacity Analysis**

The process of selecting an appropriate intersection control assumes that the preferred control is acceptable from a capacity point of view. If an acceptable operational efficiency cannot be practically achieved for a particular type of intersection control, this would constitute a “fatal flaw”. Operational performance is typically measured in terms of “Level of Service” and “Degree of Saturation”.

The capacity of a form of control to operate satisfactorily is dependent on the traffic volumes during periods of peak flow, including the volumes of turning traffic and the distribution of traffic on the various approach legs at the intersection. Therefore, it is important to determine appropriate design volumes as outlined above. Analyses are best undertaken using software which provide the key output measures relating to operational performance for a proposed intersection layout of Level of Service (LOS), Degree of Saturation (DOS) and (in some situations) Length of Queues for evaluating or comparing performance of individual lanes, approaches or the intersection as a whole.

The Level of Service (LOS) measure for intersections is “control delay” (measured in seconds) and is a measure of the driver discomfort, frustration, fuel consumption and increased travel time. As control delay increases, LOS worsens. LOS for intersections, based on the Highway Capacity Manual 2010 is given in Table 2.1 below

It should be noted that the delay for a particular level of service at signalized intersections is higher than the delay for the corresponding level of service at a priority controlled

intersection or roundabout. This is because drivers tend to expect (and tolerate) higher delays at signalized intersections compared with non-signalized intersections. Analysts need to be aware of this when comparing results using packages that only report the intersection delay, and not the level of service as defined in Table 2.1.

Table 2.1 level of service definition based on delay (HCM method)

Level of service	Control delay per vehicle in seconds (d) (including geometric delay )	
	Signalized intersection	Priority controlled intersections And roundabouts
A	$d \leq 10$	$d \leq 10$
B	$10 < d < 20$	$10 < d < 15$
C	$20 < d < 35$	$15 < d < 25$
D	$35 < d < 55$	$25 < d < 35$
E	$55 < d \leq 80$	$35 < d \leq 50$
F	$D > 80$	$D > 50$

(Source: transportation research board, 2010)

The Degree of Saturation (DOS) is defined as the ratio of demand flow to capacity (also known as the volume to capacity ratio – v/c ratio) for any particular lane. The movement DOS is the largest DOS for any lane of the movement. The approach DOS is the largest v/c value for any movement (or lane) in the approach and the intersection DOS is the largest v/c value for any approach.

Lengths of Queues have particular importance in assessing requirements for the length of auxiliary through lanes or storage in turn lanes. The 95% queue length is generally adopted as the minimum storage for turn lanes, however longer lane lengths may be required for deceleration of vehicles.

Performance Criteria -The overall LOS during peak periods must be the maximum achievable using the lane configuration provided by the Project Manager in conjunction with the Asset Owner and no individual movement should have a DOS greater than the following: for Signalized intersections 0.90 and for Roundabouts 0.85

A sensitivity analysis to consider the implications of higher volumes may need to be considered where there is uncertainty regarding design volumes or future traffic growth.

### 2.3.2 Comparison Of Operational Performance Of Roundabout And Signals

A roundabout operating within design volumes will manage peak traffic flows in a self-regulating manner and provide acceptable delays under usual roundabout priority control. Even with relatively high traffic flows on each approach, traffic is generally broken up to create gaps in the circulating flow for entering traffic. For multilane roundabouts, the provision of exclusive lanes for turning traffic is generally unnecessary unless a turning movement requires more than one lane. The shared lanes then provide more flexibility for off peak periods or times when flows vary from the design volumes used.

At intersections where there are high proportions of right turning traffic, roundabouts may be an appropriate form of intersection control. Unlike most other intersection treatments, roundabouts can operate efficiently with high volumes of right turning vehicles. However, satisfactory operation is dependent on the entering flows being balanced so that a heavy right turn does not cause excessive delays on subsequent entries. Right turning vehicles contribute to good roundabout operation because they create opportunities for vehicles on other approaches to enter the roundabout

Where the entering traffic from a dominant leg prevents traffic from another approach from entering the roundabout (generally the adjacent approach to the left of the dominant flow), this deficiency can usually be addressed by the provision of part time metering signals that regulate the dominant flow and provide gaps in the circulating traffic. Metering signals are activated by queue loops in the approach that is being delayed. Roundabouts generally provide significant advantages over traffic signals in minimizing delays during off peak periods. An economic evaluation may be based on calculated delays for the peak periods, but may also consider the operation during off peak operation. A 'whole of day' analysis provides a more precise assessment of benefits / disadvantages. Lower off peak delay during the day is particularly beneficial for business travel and freight.

At traffic signals, the number and layout of lanes and phasing are determined to suit peak demands. The phase times and operation for the varying periods through the day are then managed by the vehicle actuated controller and signal linking settings.

## **2.4 Analysis Software**

### **2.4.1 Software Calibration**

The calibration of the software for the capacity analysis is desirable when modeling congested intersections or comparing improvement options with an existing situation. The most critical ‘default’ values and parameters that can be modified when calibrating the software are: Lane saturation flows. Gap acceptance and follow-up headway parameters (these are particularly critical when assessing roundabouts with high percentages of multi-combinational vehicles: it is important that the analysis realistically reflects their reduced ability to “pick a gap”). Phase and cycle times if signals are in a linked system (consultation with the Traffic Operations Centre is important to establish appropriate phasing and cycle times) and Lane utilization factor, where applicable.

### **2.4.2 Accuracy of Current Analytical Tools**

The computer software SIDRA INTERSECTION has traditionally been used as the primary tool to analyse the capacity and operating performance of traffic signals, roundabouts and other non-signalized intersections. More recently, researchers has started using LINSIG as an analysis and optimization tool, particularly for signalized intersections, arterial routes and networks. The strength of LINSIG is as an optimization tool for signalized intersections, so at this stage it is unsure whether it would be a preferred tool for roundabout analysis. Although early manual analysis methods based on ARRB Research reports or Austroads guides are available, the SIDRA INTERSECTION software has refined these methods and theory over the years. While the roundabout analysis method used in SIDRA INTERSECTION was originally based on the Austroads Roundabout Guide, significant enhancements have been introduced in various versions of the program including the ability to analyze roundabout metering applications.

The current version of the software, SIDRA INTERSECTION 6, has the capability of analyzing a road network comprising up to 20 intersections, whereas previous versions were only able to analyse individual intersections. This has enabled the analysis of linked intersections, such as a freeway diamond interchange, to be modeled more accurately.

Case studies relating to the validation of the SIDRA modeling are referred to in the SIDRAINTERSECTION User Guide. For signalized intersections, one case study

indicates that performance measures for actuated signals were found to be highly accurate based on the results of real life surveys. In a roundabout case study, the analyses showed that the roundabout operated in excess of expectations in spite of increased levels of demand. Micro-simulation software such as VISSIM and PARAMICS are also used to analyses roundabouts and traffic signals. The strength of these tools lies in their ability model networks taking into consideration the interaction between intersections as well as using an input flow profile over a period of time, rather than just for a peak hour. The graphic output is also very useful for demonstrating to stakeholders the impact of various options, in particular the impact on congestion and queue lengths. However, it should be borne in mind that these micro-simulation tools are a lot more time consuming and costly and should generally only be used if a demonstration is needed for community consultation or other stakeholder purposes at the end of the project.

#### 2.4.3 Reliability of Capacity Analyses

The modeling of intersection capacity needs to consider a number of parameters including traffic volumes for the various movements, number of lanes and lane configuration, type of control, signal phasing, etc. The studies and other anecdotal experience indicate that generally there can be confidence in the capacity analysis tools available. However, the results obtained from analysis may sometimes be questionable due to the following factors: Knowledge and expertise relating to the use of the software. Although the SIDRA INTERSECTION and LINSIG software's are relatively user friendly, there are a number of variables to be entered and default values may need to be adjusted to accurately calibrate the program. All models of existing intersections should be calibrated based on field observations such as queue lengths, lane usage, saturation flow rates, gap acceptance and follow-up headways. Training and knowledge in the use of SIDRA INTERSECTION and LINSIG is essential.

Knowledge and experience of the person undertaking the analysis relating to geometric Intersection layout and parameters affecting capacity. The capacity analysis is closely related to the geometry of an intersection, the number of lanes, need for exclusive lanes and, if a signalized intersection, the type of signal phasing to be provided. Knowledge of these factors, as well as a sound knowledge of the SCATS operating system, is essential to the effective use of the capacity analysis computer software.

Severely congested intersections may result in inconsistent performance outputs. In some situations the computer programs may also indicate uncertainty due to the analysis having 'unsettled results.' It is important that the designs have sufficient residual capacity to avoid these effects

The traffic volumes used in a capacity analysis are often the 'weak link' in the overall process of determining performance. This may be due to:

Using existing traffic counts where demand is much higher than the volumes able to clear the intersection. In this case existing throughput is counted rather than the volumes actually needing to use the intersection;

Adopting existing traffic volumes rather than future volumes based on an assessment of traffic growth. The determination of realistic design volumes is one of the keys to accurate modeling of intersection performance. The actual performance of an intersection some years after construction may also lead to certain conclusions relating to the adequacy of the initial analysis or the form of control choice. For example, with traffic signals, the signal timings are only effective as long as the traffic patterns that were used to generate the initial signal timings or lane configurations remain reasonably similar. Over time traffic patterns change, so initial signal timings, phasing, linking plans or lane allocations should be reviewed to ensure effective operation. Similarly, traffic patterns may change at a roundabout and a review of exclusive lane allocation or need for change (additional lanes or metering signals) may be required.

Ideally, flexibility should be built into an initial design, particularly in a developing area, to accommodate future changes.

## **2.5 Costs for roundabout and signals**

The initial cost of a control proposal may include: Land acquisition, Relocation of utilities, Construction costs. The cost may also be influenced by the degree to which a proposal is to be compatible with staging of longer term works. Recurrent costs may also need to be considered, particularly in relation to an economic evaluation. A form of control involving traffic signals would generally have higher recurrent costs than a roundabout. The costs include maintenance, linking and operation of the signals.

The economic evaluation relating to a decision on control options under consideration needs to quantify and compare the anticipated benefits for each option (positive and negative) and costs discounted over the life of the control.

The factors to be considered generally include: Safety performance - anticipated crashes that may occur (cost) or be saved relative to an alternative option (benefit). Capacity performance – delay costs or calculated delays relative to alternative options (cost /benefit).Initial and Recurrent costs.

The project life in the economic evaluation needs to consider a realistic timeframe relating to the nature of the works before the control may need to be replaced or upgraded (Mainroads, 2015). Common practice for assessment of ‘accident black-spot’ projects is to adopt a standard project life of 10 years for both signal projects and roundabouts. While the objective of the program is to address current crash problems, invariably the longer term capacity needs are not evaluated.

The project life can be an important issue in relation to capacity, particularly in a developing area where there is the potential for high traffic growth (Mainroads, 2015). Where forms of control are designed as a staging of medium or longer term works, a 20 year project life may be more appropriate. However, if a control is not compatible with upgrading to accommodate traffic increases, a shorter project life is appropriate (Mainroads, 2015).

The travel time costs relating to operation would usually be based on calculated delays obtained from capacity analyses using design volumes for the peak periods (Mainroads, 2015). However, also considering the operation for control options during off peak operation provides a more precise assessment of ‘whole of day’ community benefits or disadvantages. The off peak operational periods during the day are particularly relevant for business and freight.

## **2.6 Similar Case Studies on Selection of Traffic Intersection Control Roundabout or Signal**

### **2.6.1 A Comparative Assessment of the Performance of Two Intersection Control Types**

A paper presents a comparative analysis of the performance of roundabouts and signalized intersections in terms of delay and capacity. Two scenarios are considered with signalized intersections to indicate whether a left turn storage lane can be

accommodated on the signalized intersection approach, representing the flare used at roundabouts. Results of all cases and scenarios were consistent and indicated that, at traffic demand below 50% of intersection capacity, both roundabout and signalized intersection (with or without a left turn lane) can be used for controlling the intersection traffic. As the traffic demand increases, the roundabout offers better performance than the signalized intersection when no left turn storage lane is considered (Regab, 2006).

#### 2.6.2 Performance analysis of roundabouts as an alternative for intersection control in japan

This study aims at analyzing performance of roundabout as an effective option to other conventional intersections in terms of safety, environmental, space utilization and operational aspects. Consequently, comparison of delays computed at four-leg intersection assuming a signal control and a presence of a roundabout is made. Then, the effective ranges of traffic volume for roundabouts in Japan are identified. As a result, roundabouts are found to offer a good alternative to other intersections under low traffic conditions. (Shyamalee et al, 2003)

#### 2.6.3 A comparative analysis of roundabouts and traffic signals through a corridor

The research evaluates alternative roundabout designs in order to improve traffic flow through a currently congested corridor. The three alternatives that were considered as part of this study were the existing signalized corridor, a partial two-lane roundabout corridor, and a partial three-lane roundabout corridor.. The performance measures used to compare the alternatives were average vehicle travel time, average delay per vehicle for each corridor, and average delay per vehicle at each intersection. The results showed that the overall alternative roundabout corridors provided a benefit over the existing signalized corridor for the existing traffic volumes tested. The partial three-lane roundabout provided the lowest vehicle travel times and lowest average delay due to the added capacity. For the higher traffic volumes at the interchange, the partial two-lane roundabout had a higher average vehicle travel time exiting the exit ramp than the existing corridor. The statistical analysis of the average vehicle delay at each intersection indicated that there were no significant differences between the alternatives at a five percent level of significance at the interchange. (lebas ,2015)

#### 2.6.4 Modern Roundabout Intersections: When to Use Them? A Comparison with Signalized Intersections.

The differing operational characteristics of roundabouts and traffic signals are compared (Mark and William, 2009).

#### 2.6.5 Summary of Similar Case Studies and Compression of their Result

These five case studies provide examples where roundabouts provide distinct benefits over the signal alternative

The roundabouts provided improved traffic operations, safety and fit into the context of the project sites very well.

The roundabouts mitigated, the negative attributes often associated with our roadway and highway projects. Such as: impacts to business access, residential impacts, costly roadway and structure widening.

Like all transportation projects roundabouts also require trade-offs and of course there are many situations when signals will simply outperform roundabouts.

However, roundabouts and signals are not mutually exclusive. In fact, they are compatible and can be used in a 'systems approach' to achieve optimal operations.

Roundabouts are suitable for low, medium, and high volume situations

Roundabouts are not a panacea; require the application of thorough traffic engineering principles and sound design techniques to achieve proper operations

### **2.7 Selection of junction on ERA 2013 Geometric design manual**

The choice of a junction type requires knowledge of traffic demand, intersection performance accident prediction. It's often difficult to determine the best intersection type for any particular situation, taking in to account capacity, delay, safety and physical layout factors. Several alternatives may be possible at a junction (ERA geometric design manual, 2013). A guide for selection of junction type based on different combination of traffic flows is shown in figure 2.2

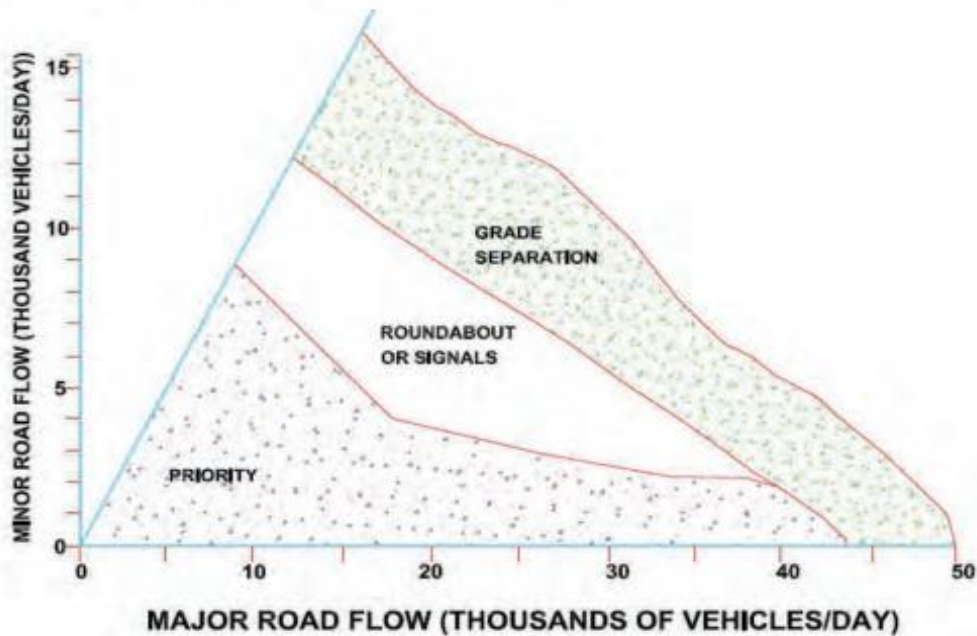


Figure 2.2 Junction selection based on traffic flow. (Source: ERA geometric design manual, 2013)

## 2.8 Summary of Literature Review

Different literatures that are related with selection of roundabout and signalized intersection are reviewed. The safety performance of alternative roundabout and signalized intersection with different users of road vehicles, pedestrian and cyclist are showed. Generally evidences on similar study show practically roundabout are more safer than signalized intersection.

roundabout are safer for motorized to Low operating speed., Elimination of high angles of conflict thereby ensuring low relative speeds between conflicting vehicles and Fewer and further separated conflict points.

Evidence suggests that roundabouts are at least as safe for pedestrians as other forms of intersection control possibly because pedestrians are able to cross one direction of traffic at a time by staging on the splitter islands.

Evidence exists to show that roundabouts are not as safe for cyclists as for other road users, and that traffic signals are generally safer for cyclist. This is because entering motor vehicle colliding with a cyclist on the circulating roadway since entering drivers

has difficulty in detecting the presence of cyclists as they scan for larger vehicles that are approaching from their right.

These five case studies provide examples where roundabouts provide distinct benefits over the signal alternative. The roundabouts provided improved traffic operations, safety and fit into the context of the project sites very well. The roundabouts mitigated, the negative attributes often associated with our roadway and highway projects. Such as: impacts to business access, residential impacts, costly roadway and structure widening. Like all transportation projects roundabouts also require trade-offs and of course there are many situations when signals will simply outperform roundabouts. However, roundabouts and signals are not mutually exclusive. In fact, they are compatible and can be used in a 'systems approach' to achieve optimal operations. Roundabouts are suitable for low, medium, and high volume situations. Roundabouts are not a panacea; require the application of thorough traffic engineering principles and sound design techniques to achieve proper operations.

There are different computer software's to 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 the movement of individual vehicles, thereby allowing a network-wide analysis (Bewket A, Emir Q & Tarkagn K, 2017). For research, one of the macroscopic models (SIDRA) software program is applied to analyze traffic operations at roundabout. In fact, AACRA also recommends SIDRA Intersection software for capacity analysis, which was developed by using analytic methods with some geometric elements.

For this research, the Signalized & Un-signalized Intersection Design and Research Aid (SIDRA) software is preferred for capacity analysis for the following reasons:

- It is commercially available tool to offer geometric and gap acceptance capability Within a single product.
- It has employed a combination of geometric and gap acceptance modeling approach in Order to take into account the effect of roundabout geometry on driver directly through gap-acceptance modeling; and
- It can be calibrated for local conditions and it is highly flexible

### 3. MATERIALS AND METHODS

#### 3.1 Description of the Study Area

Hawassa is a city in Ethiopia, on the shores of Lake Hawassa in the Great Rift Valley. The city is located in the Sidama Zone 273 km South of Addis Ababa via Debre Zeit, 130 km East of Sodo, 75km North of Dilla and 1125 km North of Nairobi. It is the capital of the Southern Nations Nationalities and Peoples Region. The city lies on the Trans-African Highway 4 Cairo-Cape Town, with a latitude and longitude of 7°03' 43.38"N coordinates: 38°28' 34.86"E and an elevation of 1708 meter. The city is bounded by Lake Hawassa in the West, Oromia Region in the North, Wondo- genet woreda in the East and Shebedino woreda in the South (Figure 3.1)

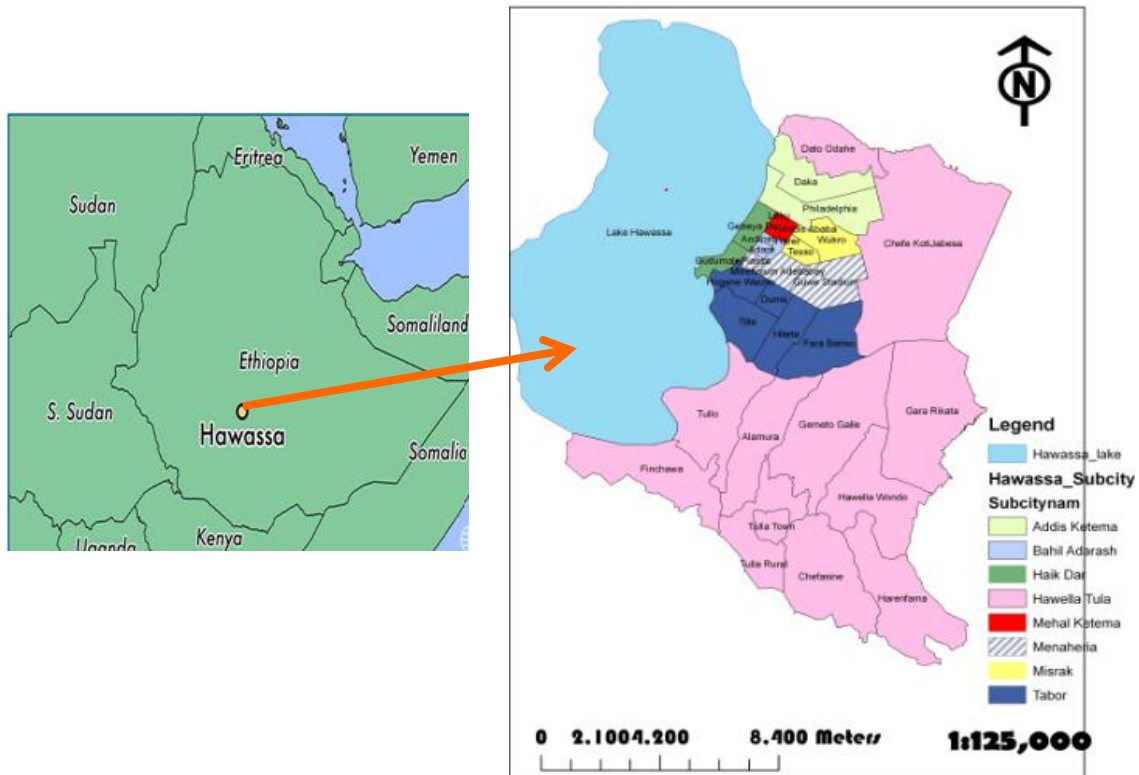


Figure3. 1 Map of Ethiopia showing the location of Hawassa and Hawassa City Administration Map (Source: City Administration of Hawassa, 2019)

Hawassa City had a transportation service since 1952, which run by Ministry of works. At the beginning the gravel roads were constructed, and upgraded to asphalt roads after the Municipality was established. Road infrastructure of the city has made a radical change since 2004. The city infrastructural asset inventory summary show that In year

2019 G.C, the city had 95.31 km of asphalt, 144.79 km of cobble stone, 226.25 Km of Red Ash road, 139.75 Km of Earth Pressed road and a total of 606.10 km (Hawassa city administration, 2019 G.C).In Hawassa City there are seventeen signalized intersections and nine roundabouts currently in use .The remaining intersection are uncontrolled, stop and yield controlled.

Hawassa has been one of the fast growing cities in the country .A large part of this rapid growth is due to the high level of migration. Based on 2007 G.C National Population and Housing Census, the projected population of Hawassa city for year 2019 is 302,000 inhabitants .The annual average population growth rate of the city is 4.02%. This rapid increase in population of Hawassa city become the main cause for the increased demand of transportation and mobility .In near future there are projects that may also increase the mobility and bring congestion in a city such as continuous increase in migration to the city from neighboring Weredas, recent inauguration of Hawassa Industry Park with expected 50,000 employees, construction of part of Trans-African Highway (Mojo-Hawassa expressway and Hawassa-Moyale highway projects), proposed construction of Mojo-Hawassa railway project, currently inaugurated Hawassa Airport, and increasing capacity of students in Hawassa University( Daniel C,2018).This create major performance problems, especially during the peak periods on existing intersections. These problems necessitate selecting appropriate intersection control for satisfactory management of traffic flow to upgrade performance of existing intersection type.

### **3.2. Study Subject**

In Hawassa city uncontrolled intersections that are found along a major trunk road from Addis Ababa to Moyale problems of crossing and turning movements are common to observe. In order to select appropriate intersection in Hawassa city, the researcher selected two uncontrolled intersection control as illustrated in Table 3.1 from the major road corridors along the major trunk road which represents significant traffic activities and for amore adverse intersection condition that is observed in Hawassa city. The traffic intersections are named Shell and Addisu Menhariya. Both intersections are four legged with through traffic passing through the major trunk road linking Addis Ababa to Nairobi. They are shown in the following figures below based the pictures taken from Google earth

Prior to problem identification traffic counts and visual observation were made on the selected uncontrolled intersection of Shell and Addisu Menhariya in Hawassa city. The observation to this two intersection reveal that a higher number of conflicting points due to no management to crossing and turning movements and a higher exposure to conflicts, with no priority to through traffic is given, no yield and stop sign, no priority given to pedestrian, with no speed limit posted, unsafe for cyclist and generally a higher accident casualty .The traffic counts that is made on uncontrolled intersection of shell show AADT values 13842 veh/day for major and 8352 veh/day for minor intersecting roads as shown on Table 3.15. Likewise the uncontrolled intersections of Addisu Menhariya have AADT Values 12950 veh/hr and 3590 veh/hr for major and minor intersecting roads respectively as shown on Table 3.16.

According to ERA selection criteria based on traffic flow on major and minor intersecting roads with above AADT values it's not possible to manage traffic with existing uncontrolled intersection satisfactorily. These problems necessitate proper traffic intersection control that will ensure optimum safety and operational efficiency. The recommended intersection on ERA 2013 geometric design manual Figure.2.2 junction selection based on traffic flows indicate that appropriate intersection for existing intersection of Shell and Addisu Menhariya in Hawassa city are roundabout or signaal

Table3.1 Selected intersections for study

Intersection type	Intersection name	Number of approach	Major Intersecting road	Minor intersecting road
Uncontrolled	Shell intersection	4	Industrial park to cherkacherke	Arogawe menhariya to IOT-HU
Uncontrolled	Addisu Menhariya	4	Cherkacherke to monopole	Addisu gabiya to cheff

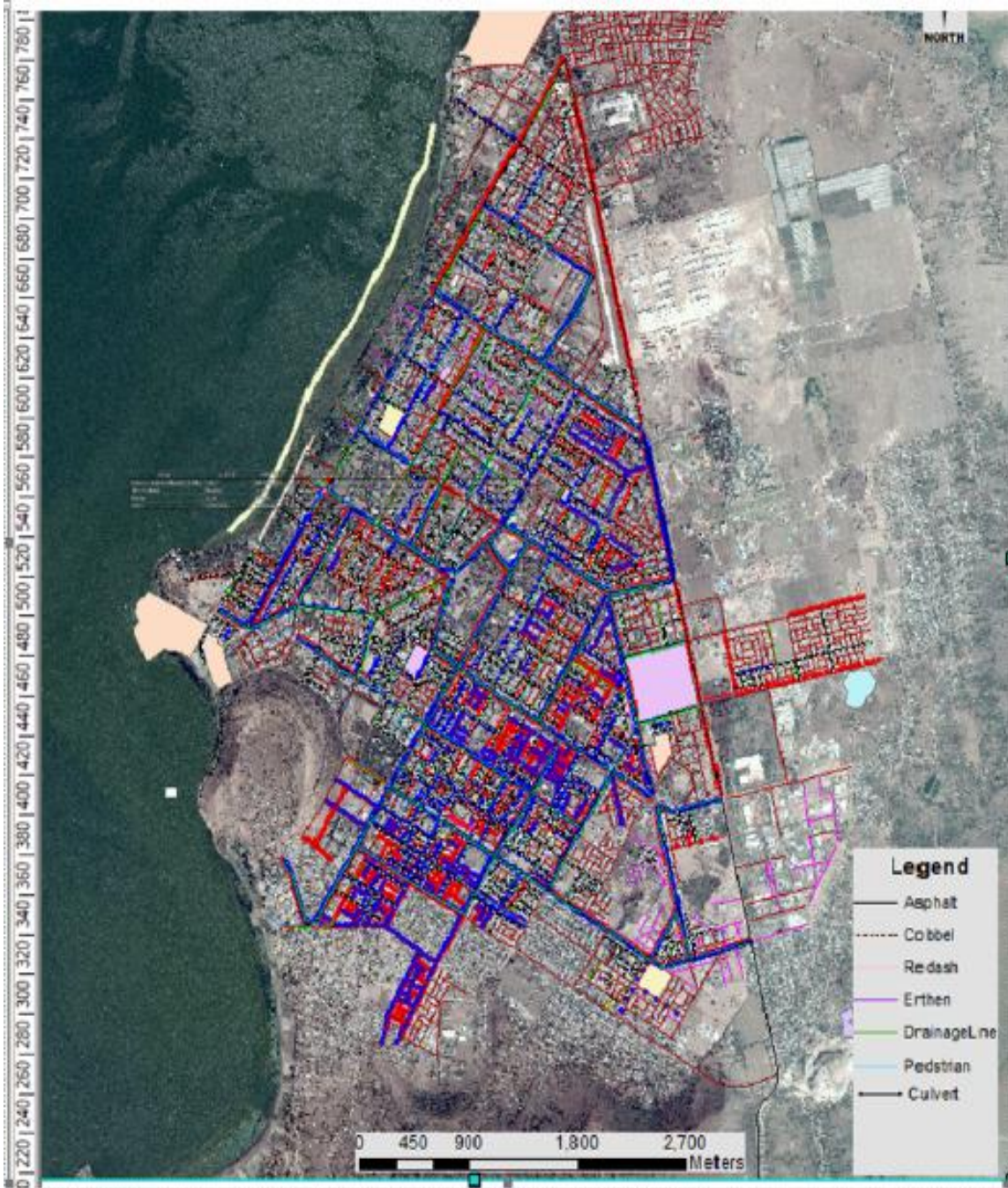


Figure3. 2 Map showing the road network of Hawassa city (Source:Hawassa city administration ,2019)



Figure3. 3Shell Uncontrolled Intersection (Source: Google earth, 2019 scale: 1:50,000)



Figure3. 4Addisu Gabiya Uncontrolled Intersection (Source: Google earth, 2019 scale: 1:50,000)

### 3.3 Study Methodology

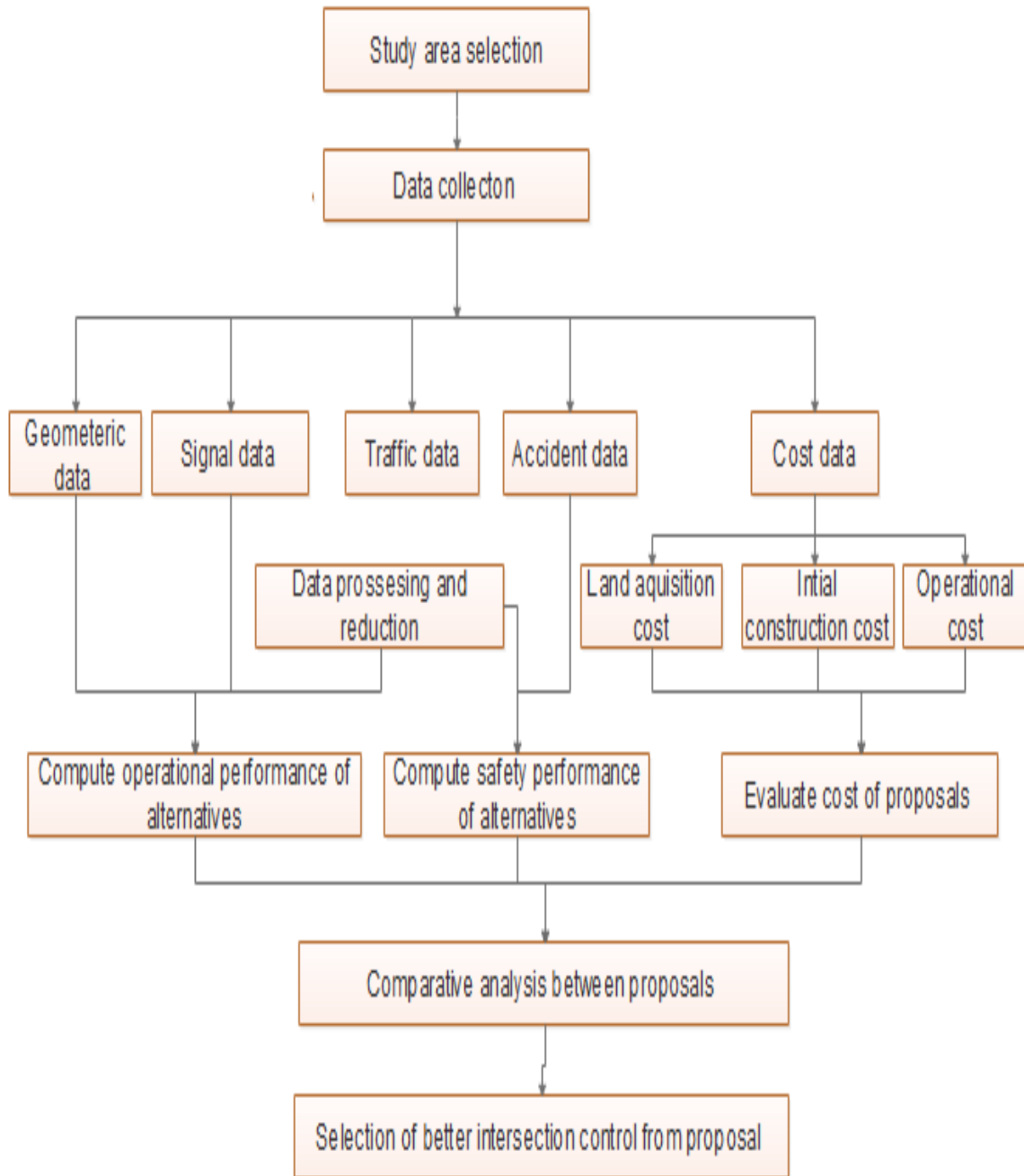


Figure3. 5 Schematics of the research

To achieve the aim of the study and to answer the formulated research questions, different data are required, and these data are categorized into two: (1) Primary data, and (2) Secondary data.

**Primary data** site specific factors that is viewed on intersection these are traffic volumes and the mix of traffic and geometric parameters lane width, number of lanes on each leg, median width used for operational analysis and a current unit prices for construction of roundabout and signalized intersection

**Secondary data** a five years static data on vehicular and pedestrian accident with all crash types are collected, a current unit prices for land acquisition Relocation of utilities and for construction of roundabout and signalized intersection, geometric and traffic parameters are selected from ERA manual, volume 3, intersection selection guideline and Highway capacity manuals, volume 3 are used as input for operational analysis of proposed intersections. After data that are used to compare alternative proposals analyses for three variables i.e. cost, operational and safety performance carried out.

The tasks that are made on collected data to analyze each for each variable are briefly summarized below.

To compare safety performance of alternative roundabout and signalized intersections vehicular and pedestrian crash frequencies, crash rates –exposure relative to traffic volumes for proposals is made.

Crash frequencies to assess typical crash rates for similar types of intersections can be provided by making comparisons of crash rates for intersection of differing types of controls .A five years summarized static data for all crash types that are occurred in Hawassa city on intersections controlled by roundabouts and traffic signals are gathered from the Hawassa city traffic office are used for this purpose. This is expressed with crashes/intersection/year using the total number of roundabout and signal in Hawassa city.

Crash Rates – Exposure Relative to Traffic Volumes When crash frequencies are related to traffic volumes using the intersections; they provide a measure related to exposure and traffic use. Five year Accident collected per year related with a million of entering vehicles to intersection .Causality rate is expressed in terms of Casualty Crashes /

Intersection / Year / 106 entering Vehs.) .For proposed signalized and roundabout intersection controls and the data's are compared.

Data needed to compare initial cost of control proposals: roundabout and signalized intersections are Land acquisition, Relocation of utilities Construction costs. Land acquisition costs are determined using unit price taken from construction office of Hawassa. Costs for Relocation of utilities are made considering unit prices taken from Ethiopia electric power agency and Ethio telecom offices for similar type of relocations,. Construction costs calculated using unit prices awarded through bidding to construct signal and roundabout in city by municipality of Hawassa city. And operational costs determined from operational performance out of SIDRA software. These costs are estimated costs with current price of market. And the total costs are summed for each alternative and compared.

In choosing a form of control for an intersection, operational analyses require an understanding of traffic volumes and the mix of traffic (e.g. percentage and types of heavy Vehicles that are to use the intersection during anticipated periods of peak flow. The traffic volume surveys were carried out at two selected junctions for 12 hours; in the morning from 6:00 AM to afternoon 6:00 PM during working days by setting up video cameras at a month of April 2019 G.C. The peak hour was determined by taking the four consecutive 15-minute periods with the highest total volume.

Measuring existing geometric features with tape meter for lane width, median width for each leg of shell and new bus station are made. Additional geometric and traffic parameters are selected from ERA geometric design manual 2013, volume 3; Mainroads 2015, intersection selection guideline and HCM 2010, interrupted traffic, volume 3 are used as input for operational analysis of proposed intersections.

Using input data's measured directly from existing uncontrolled intersections of shell and new station intersection and manuals for proposed intersection analysis was made .Analyses are best undertaken using SIDRA software which provide the key output measures relating to operational performance for a proposed intersection layout of Level of Service (LOS),Degree of Saturation (DOS) and (in some situations) Length of Queues for evaluating or comparing performance of individual lanes, approaches or the

intersection as a whole. The methodologies selected on SIDRA for evaluation operational performance of junctions is HCM 2010 model of delay calculation .The out puts are compared between two alternative proposed intersections for each study areas.

### **3.4 Data Management and Analysis**

#### **3.4.1 Traffic data analysis**

##### **3.4.1.1 Traffic survey**

Traffic survey are conducted to get the AADT for intersection, entering vehicles to intersection and to calculate the design volume for intersection. ERA conducts traffic counts during three different periods of the year based on economic activities of Ethiopia: high, medium and low. The periods are: February 1 - May 31, June 1 - September 30 and October 1 - December 31. Since the duration of time given for this research was short traffic counts are made from May 24 to May 30 of the first season, from July 19 to July 25 of the second season and from November 15 to November 21 last season. The traffic survey that is used to calculate the AADT for two intersections is made through manual counts for vehicles regardless of the vehicle type's identification. On five days of the week, the counting times are between 6:00 AM and 6:00 P.m. two days of the week (one week day and one weekend day); the counting times are 24 hours. The 24-hour counts are used to establish night factors. The average of the two-day night factors is used to adjust the 12-hour counts of the other days by converting to 24-hour counts. The average of the 7 days counts is considered as average daily traffic (ADT) of the subject quarter. The quarterly ADT is then converted to annual average daily traffic (AADT) using seasonal adjustment factor.

From table 3.2 we can see that a seasonal ADT of one direction traffic flow along industrial park to cherkacherke and cherkacherke to industrial park is 6613 and 6303 respectively. This result show a balanced traffic in both direction and two direction seasonal ADT of 12916 for season from Feb.1–May 31 on major (Industrial park-Cherkacherke) intersecting road of shell intersection

Table3. 2 Show seasonal ADT computation for 1<sup>ST</sup> season from Feb.1–May 31 for major (Industrial park-Cherkacherke) intersecting road of shell intersection

Day of traffic counts made	Industrial Park to Cherkacherke		Cherkacheke to Industrial Park	
	Total	N.F	Total	N.F
May 24/2018	6006		5916	
May 25/2018(weekday )	5214	1.32	5122	1.36
May 25/2018(night count)	1674		1860	
May 26/2018	5168		4862	
May 27/2018	5100		4368	
May 28/2018(weekend day)	5016	1.22	4268	1.31
May 28/2018(night count)	1124		1318	
May 29/2018	5070		4156	
May 30/2018	4804		4332	
Total of 12 hr. Day Traffic	36378		33024	
Average of 12 hr. day Traffic	5197		4718	
Average Night Factor(ANF)	$(1.32+1.22)/2$	1.257	$(1.36+1.31)/2$	1.34
Seasonal ADT of one direction	6613		6303	
Seasonal ADT of both direction	12916			

Table3. 3 Show seasonal ADT computation for 2<sup>nd</sup> season from Jun. 1–Sep. 31 for major (industrial park-Cherkacherke) intersecting road of shell intersection

Day of traffic counts made	Industrial Park to Cherkacherke		Cherkacheke to Industrial Park	
	Total	N.F	Total	N.F
July 19/2018	6524		7462	
July 20/2018	7208		7116	
July 21/2018	8272		7966	
July 22/2018	8156		7926	
July 23/2018(weekend day)	8186	1.20	7726	1.21
July 23/2018(night count)	1604		1604	
July 24/2018(weekday)	7190	1.25	7198	1.25
July 24/2018(night count)	1780		1792	
July 25/2018	6158		7356	
Total of 12 hr. Day Traffic	51694		52750	
Average of 12 hr. day Traffic	7385		7536	
Average Night Factor(ANF)	$(1.2+1.25)/2$	1.22	$(1.21+1.25)/2$	1.23
Seasonal ADT of one direction	9022		9256	
Seasonal ADT of both direction	18278			

From table 3.3 we can see that a seasonal ADT of one direction traffic flow along industrial park to cherkacherke and cherkacherke to industrial park is 9022 and 9256 respectively. This result show a balanced traffic in both direction and two direction seasonal ADT of 18278 for season from Jun 1–Sep. 31 on major (Industrial park-Cherkacherke) intersecting road of shell intersection

Table3. 4 Show seasonal ADT computation for 3<sup>rd</sup> season from Oct. 1–Dec. 31 for major (industrial park-Cherkacherke) intersecting road of shell intersection

Day of traffic counts made	Industrial Park to Cherkacherke		Cherkacheke to Industrial Park	
	Total	N.F	Total	N.F
November 15/2018	4805		4733	
November 16/2018(weekday)	4172	1.32	4098	1.36
November 16/2018(night count)	1339		1488	
November 17/2018	4134		3890	
November 18/2018	4080		3494	
November 19/2018(weekend day)	4013	1.22	3414	1.31
November 19/2018(night count)	899		1054	
November 20/2018	4056		3325	
November 21/2018	3843		3466	
Total of 12 hr. Day Traffic	29102		26419	
Average of 12 hr. day Traffic traffic	4158		3774	
Average Night Factor(ANF)	$(1.32+1.22)/2$	1.27	$(1.36+1.31)/$	1.34
Seasonal ADT of one direction	5291		5042	
Seasonal ADT of both direction	10333			

From table 3.4 we can see that a seasonal ADT of one direction traffic flow along industrial park to cherkacherke and cherkacherke to industrial park is 5291 and 5042 respectively. This result show a balanced traffic in both direction and two direction seasonal ADT of 10333 for season from Nov 15–Nov 21 on major (Industrial park-Cherkacherke) intersecting road of shell intersection

From table 3.5 we can see that a seasonal ADT of one direction traffic flow along Arogawi Menhariya to IOT-HU and IOT-HU to Arogawi Menhariya is 5952 and 3151 respectively. This result show a unbalanced traffic in two directions and two direction seasonal ADT of 9103 for season from Feb.1–May 31 on minor (Arogawi Menhariya to IOT-HU) intersecting road of shell intersection

Table3. 5 Show seasonal ADT computation for 1<sup>ST</sup> season from Feb.1–May 31 for minor (Arogawi Menahriya - IOT-HU) intersecting road of shell intersection

Day of traffic counts made	Arogawi Menhariya to IOT-HU		IOT-HU to Arogawi Menhariya	
	Total	N.F	Total	N.F
May 24/2018	5405		2958	
May 25/2018(weekday count)	4693	1.3	2561	1.36
May 25/2018(night count)	1507		930	
May 26/2018	4651		2431	
May 27/2018	4590		2184	
May 28/2018(week day count)	4514	1.2	2134	1.31
May 28/2018(night count)	1012		659	
May 29/2018	4563		2078	
May 30/2018	4324		2166	
Total of 12 hr. Day Traffic	32740		16512	
Average of 12 hr. day Traffic	4677		2359	
Average Night Factor(ANF)	$(1.3+1.2)/2$	1.25	$(1.36+1.31)/2$	1.34
Seasonal ADT of one direction	$4677*1.25$	5952	$2359*1.34$	3151
Seasonal ADT of both direction	9103			

Table3. 6 Show seasonal ADT computation for 2<sup>nd</sup> season from Jun. 1–Sep. 31 for minor (Arogawi Menahriya - IOT-HU) intersecting road of shell intersection

Day of traffic counts made	Arogawi Menhariya to IOT-HU		IOT-HU to Arogawi Menhariya	
	Total	N.F	Total	N.F
July 19/2018	2936		3731	
July 20/2018	3244		3558	
July 21/2018	3722		3983	
July 22/2018	3670		3963	
July 23/2018(weekday)	3684	1.2	3863	1.21
July 23/2018 (night count)	722		802	
July 24/2018(weekend day)	3236	1.25	3599	1.25
July 24/2018(night count)	801		896	
July 25/2018	2771		3678	
Total of 12 hr. Day Traffic	23262		26375	
Average of 12 hr. day Traffic	3323		3768	
Average Night Factor(ANF)	$(1.2+1.25)/2$	1.22	$(1.21+1.25)/2$	1.23
Seasonal ADT of one direction	$3323*1.22$	4060	$3768*1.23$	4628
Seasonal ADT of both direction	$4060+4628=8688$			

Table 3. 7 Show seasonal ADT computation for 3<sup>rd</sup> season from Oct. 1–Dec. 31 for minor (Arogawi Menhariya - IOT-HU) intersecting road of shell intersection

Day of traffic counts made	Arogawi Menhariya to IOT-HU		IOT-HU to Arogawi Menhariya	
	Total	N.F	Total	N.F
November 15/2018	4324		2366	
November 16/2018(weekday)	3754	1.32	2049	1.36
November 16/2018 (night count)	1205		744	
November 17/2018	3720		1945	
November 18/2018	3672		1747	
November 19/2018(weekend day)	3611	1.22	1707	1.31
November 19/2018(night count)	809		527	
November 20/2018	3650		1662	
November 20/2018	3459		1733	
Total of 12 hr. Day Traffic	26192		13210	
Average of 12 hr. day Traffic	3742		1887	
Average Night Factor(ANF)	$(1.32+1.22)/2$	1.27	$(1.36+1.31)/2$	1.34
Seasonal ADT of one direction	$3742*1.27$	4762	$1887*1.34$	2521
Seasonal ADT of both direction	$4762+2521=7283$			

From table 3.6 we can see that a seasonal ADT of one direction traffic flow along Arogawi Menhariya to IOT-HU and IOT-HU to Arogawi Menhariya is 4060 and 4628 respectively. This result shows balanced traffic in two directions and two directions seasonal ADT of 8688 for season from Jun. 1–Sep. 31 on minor (Arogawi Menhariya to IOT-HU) intersecting road of shell intersection

From table 3.7 we can see that a seasonal ADT of one direction traffic flow along Arogawi Menhariya to IOT-HU and IOT-HU to Arogawi Menhariya is 4762 and 2521 respectively. This result shows unbalanced traffic in two directions and two direction seasonal ADT of 7283 for season from Oct. 1–Dec. 31 on minor (Arogawi Menhariya to IOT-HU) intersecting road of shell intersection

Table3. 8 Show seasonal ADT computation for 1<sup>ST</sup> season from Feb.1–May 31 for major (Cherkacherke to Monopole) intersecting road of Arogawe menhariya intersection

Day of traffic counts made	Cherkacherke to Monopole		Monopole to Cherkacherke	
	Total	N.F	Total	N.F
May 25/2018(week day)	5322	1.4	4842	1.39
May 25/2018 (night count)	2033		1832	
May 26/2018	5966		5826	
May 27/2018	5315		5063	
May 28/2018	4607		4488	
May 29/2018(weekend day)	5403	1.2	4947	1.21
May 29/2018(night count)	1088		1043	
May 30/2018	4638		4598	
May 31/2018	4019		3965	
Total of 12 hr. Day Traffic	35268		33728	
Average of 12 hr. day Traffic	5038		4818	
Average Night Factor(ANF)	1.29		1.29	
Seasonal ADT of one direction	6507		6237	
Seasonal ADT of both direction	12745			

From table 3.8 we can see that a seasonal ADT of one direction traffic flow along cherkacherke to monopole and monopole to chekacherke is 6507 and 6237 respectively. This result show a balanced traffic in both direction and two direction seasonal ADT of 12745 for season from Feb.1–May 31 on major (Cherkacherke - Monopole) intersecting road of Arogawe Menhariya intersection.

From table 3.9 we can see that a seasonal ADT of one direction traffic flow along cherkacherke to monopole and monopole to chekacherke is 5239 and 5573 respectively. This result show a balanced traffic in both direction and two direction seasonal ADT of 10812 for season from Jun. 1–Sep. 31 on major (Cherkacherke - Monopole) intersecting road of Arogawe Menhariya intersection

Table 3. 9 Show seasonal ADT computation for 2<sup>nd</sup> season from Jun. 1–Sep. 31 for major (Cherkacherke to Monopole) intersecting road of shell intersection

Day of traffic counts made	Cherkacherke to Monopole		Monopole to Cherkacherke	
	Total	N.F	Total	N.F
July 21/2018	3399		3201	
July 22/2018	5243		5182	1.23
July 23/2018( week end )	3923	1.29	1171	
July 23/2018(night count)	1176		3903	1.31
July 24/2018(night count)	1157		1203	
July 24/2018(week day)	4085	1.28	4062	
July 25/2018	3671		4566	
July 26/2018	4124		4245	
July 27/2018	3953		5630	
Total of 12 hr. Day Traffic	28395		30789	
Average of 12 hr. day Traffic	4056		4398	
Average Night Factor(ANF)	1.29		1.27	
Seasonal ADT of one direction	5239		5573	
Seasonal ADT of both direction	10812			

Table3. 10 Show seasonal ADT computation for 3<sup>rd</sup> season from Oct. 1–Dec. 31 for major (Cherkacherke to Monopole) intersecting road of shell intersection

Day of traffic counts made	Cherkacherke to Monopole		Monopole to Cherkacherke	
	Total	N.F	Total	N.F
November 15/2018(week day)	6386	1.38	5810	1.38
November 15/2018(night count)	2439		2198	
November 16/2018	7159		6991	
November 17/2018	6377		6075	
November 18/2018	5528		5386	
November 19/2018(weekend day)	6484	1.20	5936	1.21
November 19/2018(night count)	1305		1251	
November 20/2018	5566		5517	
November 21/2018	4822		4757	
Total of 12 hr. Day Traffic	42322		40473	
Average of 12 hr. day Traffic	6046		5782	
Average Night Factor(ANF)	1.29		1.29	
Seasonal ADT of one direction	7809		7485	
Seasonal ADT of both direction	15293			

From table 3.10 we can see that a seasonal ADT of one direction traffic flow along cherkacherke to monopole and monopole to chekacherke is 7809 and 7485 respectively. This result show a balanced traffic in both direction and two direction seasonal ADT of 10812 for season from Oct. 1–Dec. 31 on major (Cherkacherke - Monopole) intersecting road of Arogawe Menhariya intersection

Table3. 11 Show seasonal ADT computation for 1<sup>ST</sup> season from Feb.1–May 31 for minor (Addisu Menhariya to cheff) intersecting road of shell intersection

Day of traffic counts made	Addisu Gabiya to cheff		Cheff to Addisu Gabiya	
	Total	N.F	Total	N.F
May 25/2018(week day)	4789	1.4	2421	1.38
May 25/2018(night count)	1829		916	
May 26/2018	5369		2913	
May 27/2018	4783		2532	
May 28/2018	4146		2244	
May 29/2018(weekend day)	4863	1.2	2474	1.21
May 29/2018(night count)	979		521	
May 30/2018	4174		2299	
May 31/2018	3617		1982	
Total of 12 hr. Day Traffic	31741		16869	
Average of 12 hr. day Traffic	4535		2409	
Average Night Factor(ANF)	1.29		1.3	
Seasonal ADT of one direction	5857		3119	
Seasonal ADT of both direction	8976			

From table 3.11 we can see that a seasonal ADT of one direction traffic flow along Addisu Gabiya to cheff and Cheff to Addisu Gabiya is 5857 and 3119 respectively. This result show a unbalanced traffic in both direction and two direction seasonal ADT 8976 for season from Feb1 –may. 31 for minor (Addisu Menhariya to cheff) intersecting road of Arogawe Menhariya intersection

Table3. 12 Show seasonal ADT computation for 2<sup>nd</sup> season from Jun. 1–Sep. 31 for minor (Addisu Menhariya to cheff) intersecting road of Arogawe Menhariya intersection

Day of traffic counts made	Addisu Gabiya to cheff		Cheff to Addisu Gabiya	
	Total	N.F	Total	N.F
July 21/2018	3059		1601	
July 22/2018	4718		2591	1.23
July 23/2018(weekend day)	3530	1.3	586	
July 23/2018(night count)	1058		1952	1.39
July 24/2018(night count)	1041		602	
July 24/2018(weekday)	3676	1.3	2031	
July 25/2018	3304		2283	
July 26/2018	3711		2123	
July 27/2018	3557		2815	
July 28/2018	25555		15395	
Average of 12 hr. day Traffic	3651		2199	
Average Night Factor(ANF)	1.3		1.27	
Seasonal ADT of one direction	4715		2787	
Seasonal ADT of both direction	7502			

From table 3.12 we can see that a seasonal ADT of one direction traffic flow along Addisu Gabiya to cheff and Cheff to Addisu Gabiya is 4715 and 2787 respectively. This result show a unbalanced traffic for two directions and two direction seasonal ADT of 7502 for season from Jun. 1–Sep. 31 for minor (Addisu Menhariya to cheff) intersecting road of Arogawe Menhariya intersection

From table 3.12 we can see that a seasonal ADT of one direction traffic flow along Addisu Menhariya to cheff and Cheff to Addisu Gabiya is 4685 and 2495 respectively. This result show a un balanced traffic in both direction and two direction seasonal ADT of 10812 for season from Jun. 1–Sep. 31 for minor (Addisu Menhariya to cheff) intersecting road of Arogawe Menhariya intersection

Table3. 13 Show seasonal ADT computation for 3<sup>rd</sup> season from Oct. 1–Dec. 31 for minor (Addisu Menhariya to cheff) intersecting road of Arogawe Menhariya intersection

Day of traffic counts made	Addisu Menhariya to cheff		Cheff to Addisu Gabiya	
	Total	N.F	Total	N.F
November 15/2018(weekday)	3839	1.38	1937	1.38
November 15/2018(night count)	1463		733	
November 16/2018	4295		2330	
November 17/2018	3826		2025	
November 18/2018	3317		1795	
November 19/2018(week day)	3890	1.20	1979	1.21
November 19/2018(night count)	783		417	
November 20/2018	3339		1839	
November 21/2018	2893		1586	
Total of 12 hr. Day Traffic	25393		13491	
Average of 12 hr. day Traffic	3628		1927	
Average Night Factor(ANF)	1.29		1.29	
Seasonal ADT of one direction	4685		2495	
Seasonal ADT of both direction	7180			

Table3. 14 AADT estimation for shell intersection

Period	For major intersecting road of shell intersection		For minor intersecting road of shell intersection	
	Sesonal ADT	Sesonal factor	Sesonal ADT	Sesonal factor
May 24 -30	12916	$13842/12916=1.07$	9103	$8358/9103=0.918$
Jul.19 -25	18278	$13842/18278=0.757$	8688	$8358/8688=0.962$
Nov.15-21	10333	$13842/10333=1.34$	7283	$8358/8688=0.962$
AADT	$(12916+18278+10333)/3=13842$		$(9103+8688+7283)/3=8358$	

AADT values for each intersection are important for selection of appropriate intersection control that will sufficiently manage the existing traffic condition. The AADT values as calculated for existing shell intersection are 13842 veh/day for major and 8358 veh/hr for minor road. As shown on table 3.15. On the other hand the traffic counts made for Adissu Gabiya intersection show that AADT values for this intersection are 12950 veh/hr and 6689 veh/hr for major and minor traffic of the intersection as shown on Table 3.16.

Table3. 15 AADT estimation for Arogawe menareya intersection

	For major intersecting road of Addisu Gabiya intersection		For minor intersecting road of Addisu Gabiya intersection	
Period	Sesonal ADT	Sesonal factor	Sesonal ADT	Sesonal factor
May 25 -31	12745	$12950/12745=1.016$	8976	$6689/8976=0.745$
Jul.21-27	10812	$12950/10812=1.197$	7502	$6689/8976=0.745$
Nov.15-21	15293	$15293/10812=1.414$	3590	$6689/8976=0.745$
Total	$(12745+10812+15293)/3=12950$		$(8976+7502+3590)/3=6689$	

Table3. 16 Average Number of Entering vehicle to shell intersection per day

Legs of the intersection	Average Number of Entering vehicle to shell intersection per day in three different traffic counting seasons				
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	Sum	Average
Industrial park	6613	9256	5290	21159	7053
Arogawi Menharya	5952	4060	4761	14773	4924
Cherkacherke	6302	9022	5042	20366	6789
IOT –HU	3151	4628	3119	10898	3632
Total	22018	26966	18212	67196	22134

These shows entering vehicles to shell intersection are 22134 entering vehicles per day .entering vehicles per year to shell intersection will be 8.078 million entering vehicles /year. to find Mean Casualty Crash Rate in Casualty Crashes / Intersection / Year / 106 entering vehicles for shell intersection we divide Mean Crash Frequency for different Crash Types that s expressed with (Crashes / Intersection / Year) by 8.078 mill enter veh.

Table3. 17 Average number of entering vehicle to Addisu Menhariya intersection per day

Legs of the intersection	Average Number of Entering vehicle to intersection at new bus station per day in three traffic counting seasons				
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	Sum	Average
Monopole	6507	5238	6045	17790	5930
Cherkacherke	6237	5573	7484	19294	6431
Addisu Gabiya	5857	4715	4685	5086	5086
Cheff	3119	2787	2494	8400	2800
Total					20247

The entering vehicles on Addisu Menhariya intersection is 20247 entering vehicles per day when converted to entering vehicles per year it becomes 7.39 million entering vehicles per year. This value used for new bus station intersection to calculate the mean causality crash rate per million of entering vehicles.

#### 3.4.1.2 Traffic volume studies

Traffic volume studies are conducted to determine the number, movements and classification of vehicles at the selected intersection approaches. The traffic was recorded at morning starting from 6 A.M. To 6:00 P.M. for two selected intersections (junctions). The traffic counts are done using the recorded traffic at each junction and then transcribed by manual transcription technique using the tally format on the paper format. Based on this analysis, the summarize traffic volume during survey time in terms of vehicle type (heavy and light traffic) and movement mechanism (through turn, left turn and right turn) for one identified peak hour from 5:00 pm-6:00pm, Thursday of the week shell intersection and 1:30 am-2:30 Monday of the week for Addisu Gabiya intersection. . For the purpose of intersection analysis, SIDRA INTERSECTION defines a Heavy Vehicle as any vehicle with more than two axles or with dual tire's on the rear axle (based on Akçelik 1981, Section 5). Thus, buses, trucks, semi-trailers (articulated vehicles); cars towing trailers or caravans, tractors and other slow-moving vehicles are classified as Heavy Vehicles. All other vehicles are defined as Light Vehicles (cars, vans, small trucks). The US HCM defines a Heavy Vehicle as "a vehicle with more than four wheels touching the pavement during normal operation". The motor cycle and bicycles are converted to equivalent light vehicles using PCE factor 0.5 and the SIDRA needs traffic volumes in light and heavy vehicle .using heavy vehicle equivalent factor that is filled with user considers heavy vehicle percentage for operational analysis .HCM 2010 specify passenger car equivalent of heavy vehicle to be taken 2. The different types of vehicles in a traffic stream have different characteristics like width, length, height and mass; these different size vehicles have different capacity impacts. These vehicle specifications are important in determining operating cost, fuel consumption and emission statistics. The high pedestrian volume also has a significant effect on capacity. For this reason numbers of pedestrian were carried out by using the same method along the direction of their movements.

Table3. 18 Computation of peak hour factory and percentage of heavy vehicles through turnin g vehicles on each legs of Shell intersection at 5:00 pm -6:00pm

LEG		THROUGH TURN during peak hour assuasive 15 min count				TOTAL	%HV	PHF
industrial Park	LV	45	31	42	41	159	32.34	0.79
	HV	29	17	15	15	76		
		74	48	57	56	235		
Cherkacherke	LV	43	48	57	86	235	17.8	0.73
	HV	15	11	14	11	51		
		58	59	71	97	286		
Arogawi Menhariya	LV	4	5	1	26	36	12.2	0.35
	HV	0	2	0	3	5		
		4	7	1	29	41		
IOT –HU	LV	7	6	9	22	44	0	0.50
	HV	0	0	0	0	0		
		7	6	9	22	44		

Table3. 19 Computation of peak hour factory and percentage of heavy vehicles Right turning vehicles on each legs of Shell intersection at 5:00 pm -6:00pm

LEG		RIGHT TURN during peak hour assuasive 15 min count				TOTAL	%HV	PHF
Industrial Park	LV	22	16	24	32	93	34.51	0.70
	HV	29	5	8	7	49		
		51	21	32	39	142		
Cherkacherke	LV	1	6	7	5	18	48.57	0.55
	HV	1	5	9	2	17		
		2	11	16	7	35		
Arogawi Menhariya	LV	24	15	18	29	86	24.56	0.81
	HV	9	8	5	6	28		
		33	23	23	35	114		
IOT –HU	LV	5	6	1	4	15	6.25	0.60
	HV	0	1	0	0	1		
		5	7	1	4	16		

Table3. 20 Computation of peak hour factory and percentage of heavy vehicles Left turning vehicles on each legs of Shell intersection at 5:00 pm -6:00pm

LEG		LEFT TURN during peak hour assuasive 15 min count				TOTAL	%HV	PHF
Industrial Park	LV	7	12	2	19	40	6.98	0.58
	HV	0	2	1	0	3		
		7	14	3	19	43		
Cherkacherke	LV	28	40	63	73	203	21.32	0.80
	HV	23	10	18	4	55		
		51	50	81	77	258		
Arogawi Menhariya	LV	24	22	29	22	97	33.1	0.86
	HV	14	10	15	9	48		
		38	32	44	31	145		
IOT –HU	LV	8	4	7	3	21	4.55	0.80
	HV	1	0	0	0	1		
		9	4	7	3	22		

Table3. 21 Computation of peak hour factory and percentage of heavy vehicles Through turning vehicles on each legs of Addisu Gabiya Intersection. at 1:30 am -2:30am

Leg		THROUGH TURN during peak hour assuasive 15 min count				TOTAL	%HV	PHF
Cherkacherke	LV	30	33	40	60	164	18	0.73
	HV	11	8	10	8	36		
		41	41	50	68	200		
Monopole	LV	36	25	33	33	127	32.45	0.79
	HV	23	14	12	12	61		
		59	38	45	45	188		
Addisu Gabiya	LV	6	7	2	39	54	13.12	0.35
	HV	0	3	0	5	8		
		6	10	2	44	61		
Cheff	LV	6	5	8	20	40	0	0.50
	HV	0	0	0	0	0		
		6	5	8	20	40		

Table3. 22 Computation of peak hour factory and percentage of heavy vehicles Right turning vehicles on each legs of Addisu Gabiya Intersection at 1:30 am -2:30am

Leg		RIGHT TURN during peak hour assuasive 15 min count				TOTAL	%HV	PHF
Cherkacherke	LV	20	28	44	51	142	21.67	0.80
	HV	16	7	13	3	39		
		36	35	56	54	181		
Monopole	LV	6	10	2	15	32	5.88	0.58
	HV	0	2	1	0	2		
		6	11	2	15	34		
Addisu Gabiya	LV	36	23	27	44	129	24.56	0.81
	HV	14	12	8	9	42		
		50	35	35	53	171		
Cheff	LV	4	5	1	3	14	7.14	0.60
	HV	0	1	0	0	1		
		4	6	1	3	14		

Table3. 23 Computation of peak hour factory and percentage of heavy vehicles Left turning vehicles on each legs of Addisu Gabiya Intersection at 1:30 am -2:30am

Leg		LEFT TURN during peak hour assuasive 15 min count				TOTAL	%HV	PHF
Cherkcherke	LV	1	4	5	3	13	48	0.55
	HV	1	4	6	1	12		
		1	7	11	5	25		
Monopole	LV	17	13	19	25	74	34.21	0.70
	HV	23	4	6	6	39		
		41	17	25	31	114		
Addisu Gabiya	LV	36	33	44	33	145	33.18	0.82
	HV	21	15	23	14	72		
		57	48	66	46	217		
Cheff	LV	7	4	6	2	19	5	0.64
	HV	1	0	0	0	1		
		8	4	6	2	20		

In order to see the proportion of the entry flow from every approach legged, the following tabulation is carried out in Table 3.24.

Table3. 24 Total entry traffic and percentage share each leg for shell and Addisu Gabiya intersections. at 1:30 am -2:30am

Sr.no	Junction name	Approach leg	Entry leg on traffic	% of traffic share
1	Shell	Industrial Park	420	30.41
		Cherkacherke	579	41.9
		Arogawi Menhariya	300	21.7
		IOT –HU	82	5.9
2	Addisu Gabiya	Cherkacherke	243	22.4
		Monopole	336	30.97
		Addisu Menhariya	432	39.82
		Cheff	74	6.82

The high pedestrian volume also has a significant effect on capacity. For this reason numbers of pedestrian were carried out by using the same method along the direction of their movements.

Table3. 25 Pedestrian flow in the direction of each leg and PHF values

Sr.no	Junction	Approach leg	Pedestrian number	% PHF
1	Shell	Industrial Park	669	79.6
		Cherkacherke	335	91
		Arogawi	339	94
		IOT –HU	564	77
2	Addisu Gabiya	Cherkacherke	594	86
		Monopole	285	74
		Addisu Menhariya	299	90
		Cheff	589	81

### 3.4.2 Geometric Data analysis

As per the requirement of the SIDRA Intersection Version 5.1, different geometric data are required, such as, island diameter, circulatory width, number of circulatory lanes, entry lanes, entry lane number and average lane width at the entry of junctions for analysis of roundabout and signal. For existing uncontrolled intersection data for median width, entry lanes, entry lane number and average lane width at the entry are taken. These data are measured using tape meter and also by observing on the roundabout existing configuration. The collected geometric data are summarized. Remaining geometric data for proposed intersections are taken from manuals and guidelines specifications for design of roundabout and signals.

Table3. 26 Summary of Geometric data for existing uncontrolled intersections of shell and Addisu Gabiya.

Sr.no	Junction name	Approach leg	Entry lane	average lane width	Median width
1	Shell	Industrial Park	3	3.3	3
		Cherkacherke	3	3.3	3
		Arogawi	2	3.5	2.5
		IOT –HU	1	3.5	-
2	Addisu Gabiya	Cherkacherke	2	3.5	2.5
		Monopole	2	3.5	2.5
		Addisu	2	3.5	2.5
		Cheff	1	3.5	-

### 3.4.3 Safety data analysis

In Hawassa city there exist 17 signals and 9 roundabout intersection controls that are registered by municipality of the city in 2019. The safety performance rates for each accident types for Hawassa city are summarized for each year in crashes /intersection /year obtained by dividing crash number collected in each year on signalized and roundabout intersections with total number of intersection of each type that exist in city .

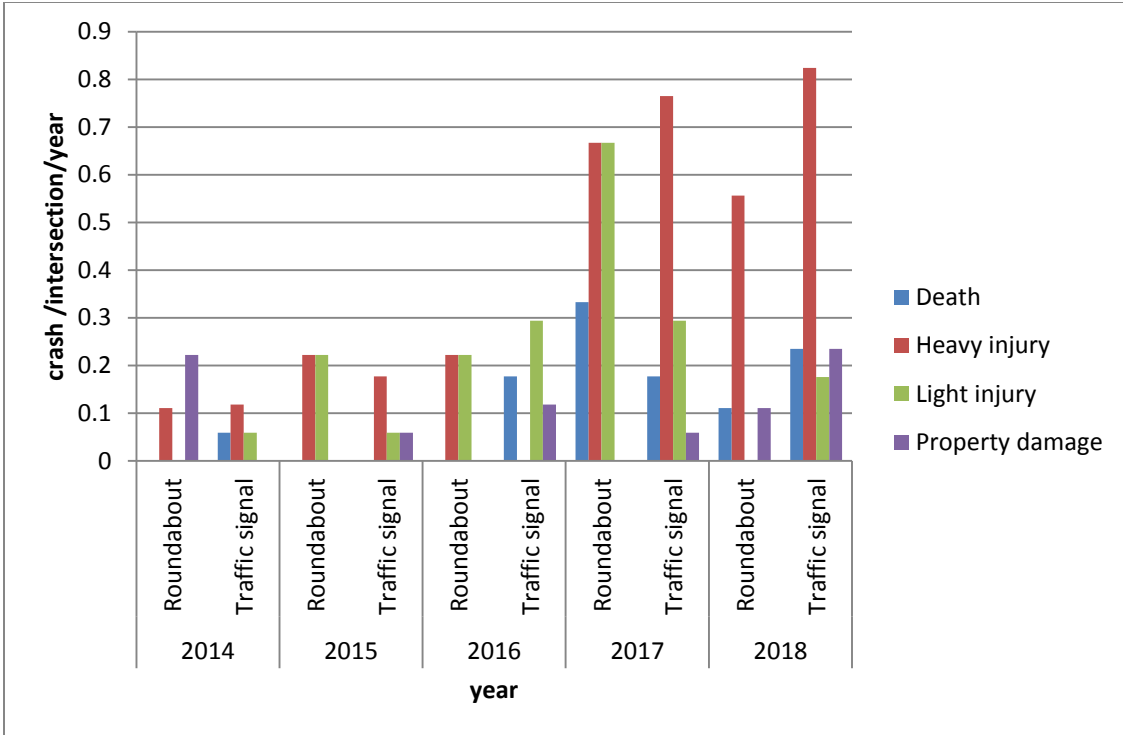


Figure3. 6 Showing crash frequencies for different crash types for roundabout and traffic signals in Hawassa city from year 2014 G.C to 2018 G.C

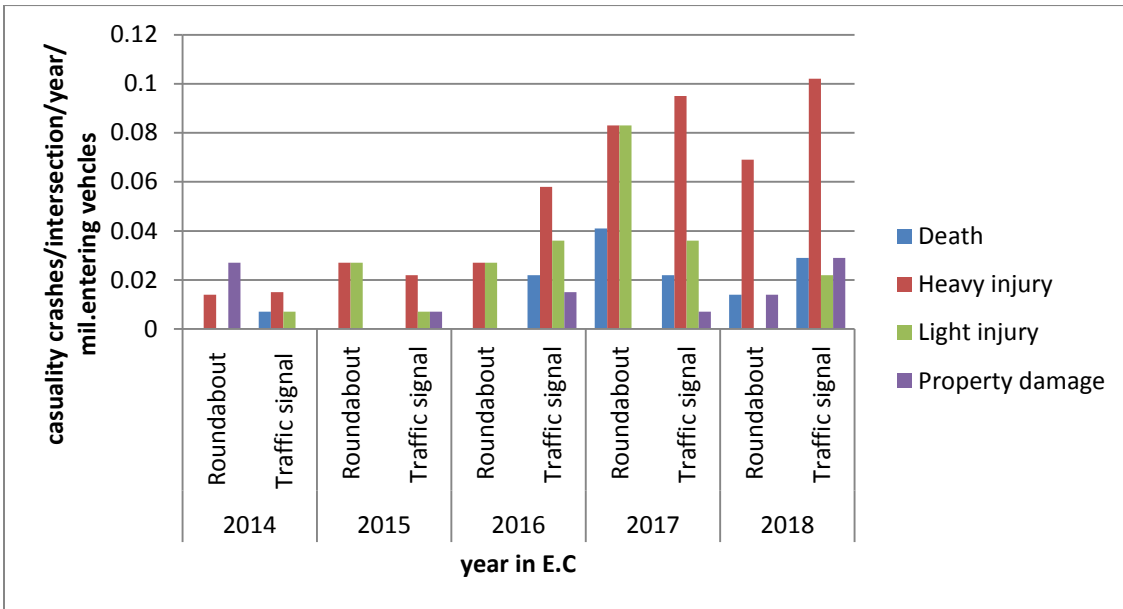


Figure3. 7 Showing causality crash rates for different crash types for roundabout and traffic signals for shell intersection from year 2014 E.C to 2018 E.C

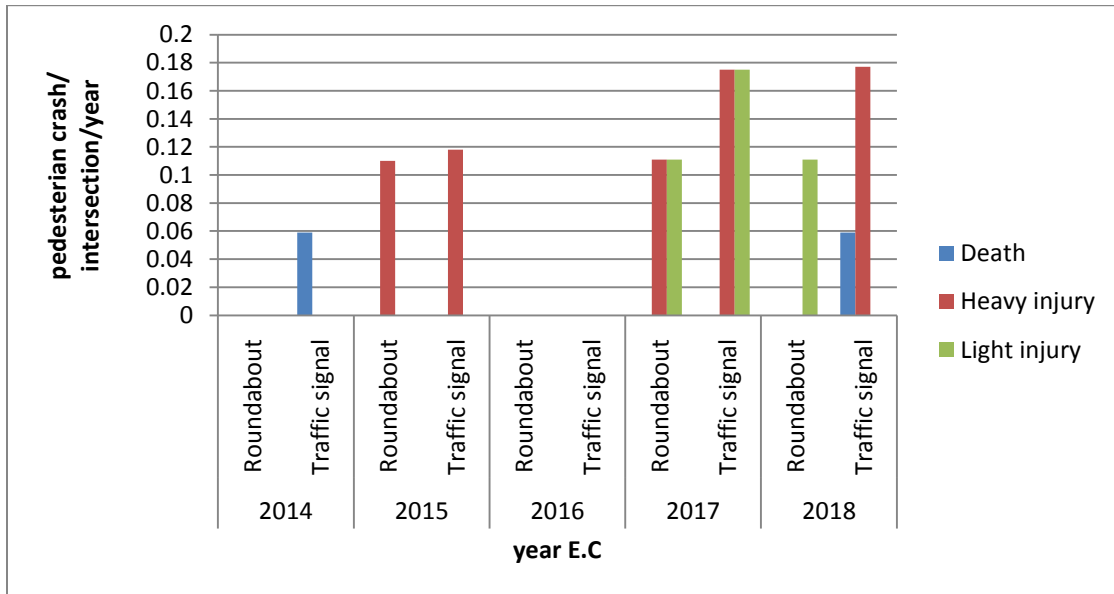


Figure3. 8 Showing pedestrian crash frequencies for different crash types for roundabout and traffic signals in Hawassa city from year 2014 E.C to 2018 E.C

From figure 3.6 showing crash frequencies for different crash types for roundabout and traffic signal in hawassa city from year 2014 G.C to 2018 G.C we can see that crash rate and severity levels are higher for signalized intersection.

From figure 3.7 we can see that the casualties of crashes are greater for signalized intersection for million entering vehicles.

From figure 3.8 we can see that pedestrian crash frequencies for different crash types for signals are higher than roundabouts in hawassa city from year 2014 G.C to 2018 G.C Severity level of crashes occurring on signalized intersection are also greater than roundabout intersection .on the other hand from the graph we can see that crash accidents occurring on signalized and roundabout intersection are increasing from year to year .this can be because of increasing traffic growth and a poor operation of existing signalized and roundabout intersection in Hawass city.

### **3.4.4 Cost data analysis**

#### **3.4.4.1 Right of way for signalized intersection**

The proposed signalized intersection configuration can be accommodated within existing 30 m wide right-of-way limits for intersection at shell and new bus station. No additional property or containers that are found southeast corner of the intersection of shell will be affected nor do the main electric poles that are found on shell and Addisu Menhariya intersections that exist on both sides of major road need relocation.

#### **3.4.4.2 Right of way requirement for Roundabout**

According to ACCRA geometric design manual, the number of circulating lanes from any particular approach be equal to or greater than the maximum number of entry lanes on that approach .For the case of shell and Addisu Menhariya intersection the maximum number of lanes on each entry lanes is 3 and 2 respectively.this will be taken as the number of circulating lanes for proposed roundabout intersection. The circulatory roadway width is a function of swept of the design vehicles and the layout of the exits and entries and generally should be equal to, or slightly greater (1.2 times) the width of the entries. the minimum road way width for two lane operation is of the order of 9 meters and 12..if trucks are present intraffic stream in sufficen number to influence the design ,the circulatory road width should be increased by 3 meters .the circulatory road way width for shell and new bus station taken15m and 12 meters respectively. To accommodate a design semi-trailer turning right at the minimum inside radius of 18 m, the carriageway width of the roundabout taken as 12 m would need to be approximately 18m for a double lane roundabout taken from Table 3.31 and based on table 3.32 a minimum of 20 m for multilane , giving an inscribed circle radius of 30m and 40 m for double and multilane roundabout respectively. Allowing for 5.5m for Road Reserve clearance gives a total footprint roundabout diameter of 71.the property that are affected to maintain desired space for construction of roundabout is given on table . The Cost are calculated from unit prices taken from concerned offices, compensation rate used from the unit prices the construction office applies on payment for affected small shades and building on space needed to accommodate infrastructures .unite price from electric power agency demands for relocation coast for electric poles that will be displaced on right way for newly built infrastructure taken.

Table3. 27 Space requirement for construction of roundabout (Source: intersection selection Guideline, 2015)

Vehicle type	Minimum island radius(m)		Carriageway width (m)		Overall inscribed radius (m)		Total footprint Desirable diameter (m)	
	Single	Dual	Single	Dual	Single	Dual	Single	Dual
19m semi-trailer	10	18	8	9.7	19.75	30	50.5	71
36.5 m A-Double	12	26	9.9	10.6	24	38.6	59	88.2

Table3. 28 suggested initial design ranges (source: FHA, Exhibit 1320-1)

Design elements	Mini <sup>[1]</sup>	Compact	Single –lane	Multilane
Number of lanes	1	1+	1	2+
Inscribed circle diameter <sup>[2]</sup>	45’-80’	65’-120’	80’-150’	120’-165’
Circulating roadway width	N/A	N/A	14’-19’	29’
Entry width	N/A	N/A	16’-18’	25’

Notes  
 The “+” symbol used here means that a portion of the circulating roadway may have more than one lane.  
 [1] Reserved for urban /suburban intersection with a 25 mph or less posted speed.  
 [2] The given diameter assumes a circular roundabout; adjust accordingly for other shapes. Some conditions may require ICDs outside ranges shown here.

Table3. 29 Property that will be affected and utilities that need relocation for space requirement for proposed roundabout intersection of shell and Addisu Menhariya..

Intersection	House	Fence	Electric pole
Shell	-	30m*2m rolled metal sheet.	Two span medium voltage
Addisu Menhariya	11 Metal sheds (3m*4m)	15 m * 3m wooden	Two span medium voltage
	3 Shops made of Bricks(2.5*3)	20 m *3 m	

Table3. 30 Summery of initial costs for property affected and relocation of utilities due to introduction proposed roundabout intersection of shell and Addisu Menhariya.

	Shell intersection			Addisu Menhariya intersection		
	Quantity	Unit price	Total (ETB)	Quantity	Unit price	Total (ETB)
House				132	2400 ETB/m2	316800
				22.5	3600 ETB/m2	81000
Fence	60	540 ETB/m2	32400	45 m2	210 ETB/m2	9450
				60 m2	320 ETB/m2	19200
	Two span	19424 ETB/span	38848	Two span	19424/span	38848
Total			71248			465298

#### 3.4.4.3 Construction cost for proposed signalized intersection

The price for signal purchasing and installation is taken from recent costs that is awarded by bid in Hawassa city for similar works. In 2017 the municipality has installed 9 signals in different sub city of the city with a total of 16888071 ETB including costs for purchasing and installation. Each signal costs 1876452.33 ETB for municipality to purchase and install.

#### 3.4.4.4 Construction cost for proposed Roundabout intersection

The construction cost for roundabout includes costs for making the inscribed circle, planting and beatification works and guarding with fence around it. In addition to this making some geometric modification to road pavement including constructing circulatory lanes and widening of lanes approaching to roundabout.

Unit price for constructing roundabout is taken to be 4040.52 ETB/m<sup>2</sup> which is the price awarded by municipality of Hawassa city by bidding process to winner in 2017. Using this unit price for proposed roundabout to be constructed on shell and Addisu Menhariya intersection in Hawassa city with island diameter of 18 m and 20 m as discussed on previous discussion the cost for construction of roundabouts becomes 4,110,663.4 ETB and 5074893.12 ETB respectively.

The circulating lane with 35 m external radius and with 20 m internal radius gives the area of circulating lane of 2590.5 m<sup>2</sup> for proposed Shell roundabout. Likewise, the circulating lane with 30 m external radius and with 18 m internal radius gives the area of circulating lane of 1808.64 m<sup>2</sup> for proposed Addisu Menhareya roundabout. According to traffic count made for rehabilitation of the road from textile factory to expressway the traffic class for major roads passing through this two intersection is T-8. The design that is made for this road have 275 mm of sub base, 200 mm of road base course and 50 mm of asphalt concrete with thin prime coat binding the base course material. The unit price for each pavement layer is given on table

Table 3.31 Summary of construction cost for paved circulating lane for proposed roundabout intersection on Addisu Menhariya.

Pavement layer	Thickness	Quantity	Unit price	Total cost per layer
Sub base	275 mm		200 ETB/m <sup>3</sup>	99475.2
Road base course	200 mm	1808.64	250 ETB/m <sup>3</sup>	90432
Asphalt concert	50 mm	1808.64	480 ETB/m <sup>2</sup>	868147.2
Prime coat		1808.64	30 ETB/m <sup>2</sup>	54259.2
Total	525 mm			1,112,313.6

From table 3.31 The total cost for construction of circulating lane for roundabouts at Addisu Menhariya will be 1112313.6 ETB

Table 3.32 Summary of construction cost for paved circulating lane for proposed roundabout intersection on shell

Pavement layer	Thickness	Quantity	Unit price	Total cost per layer
Sub base	275 mm	2590.5	200 ETB/m <sup>3</sup>	142477.5
Road base course	200 mm	2590.5	250 ETB/m <sup>3</sup>	129525
Asphalt concert	50 mm	2590.5	480 ETB/m <sup>2</sup>	1243440
Prime coat		2590.5	30 ETB/m <sup>2</sup>	77715
Total	525 mm			1,593,157.5

From Table 3.32 the total cost for construction of circulating lane for roundabouts at shell will be 1593157.5ETB

## 4 RESULTS AND DISCUSSIONS

### 4.1 Comparison of operational performance of alternative proposals

4.1.1 Comparison of operational performance of alternative proposals for shell intersection.

The proposed intersection alternatives to upgrade the existing uncontrolled intersections that are roundabout and signals are compared with their respective operational performances outputs with existing traffic and geometric features of the site .the operational performance outputs from SIDRA Intersection 5.1 that are used for comparison purpose are degree of saturation, average delay and LOS .

#### 4.1.1.1 comparison of Degree of saturation for alternatives

Volume to capacity ratio or degree of saturation provides a direct assessment of the sufficiency of a given intersection. While, there are no absolute standards for the degree of saturation, the Australian design procedure suggests that the degree of saturation for an entry lane should be less than 0.85 for satisfactory operation. When the degree of saturation exceeds this range, the operation of the roundabout will likely deteriorate rapidly. As the output of the analysis in Figure 3.1 shows that the degree of saturation for proposed shell roundabout is 0.589 which is lower than the tolerable value and this indicate that the roundabout is servicing below its capacity. When we look also on each approaches for proposed shell roundabout all approaching lanes will perform satisfactorily below tolerable limit. On other side when we look in to degree of saturation if the existing intersection of shell is controlled by installing signal will be 1.512 .This value indicate demand (arrival )flows for intersection will exceed the capacity which means degree of saturation is above 1 i.e. Which represent oversaturated condition .This show the adverse condition for intersection. The two approach legs of shell intersection the Cherkacherke leg and Arogawi Menhariya legs have DOS 1.512 each and this show arrival flows for both approaches exceed capacity and will become over saturated if signals are installed for existing uncontrolled intersection of shell.

#### .4.1.1.2 comparison of Average delay per vehicle for alternatives

Delay is a standard parameter used to determine the performance of an intersection. The Highway capacity manual identifies delay as the primary measure of effectiveness for both signalized and un-signalized intersection, with the level of service determined from

the delay estimate. The output of the analysis Table 4.1 shows that the average delay per vehicle for proposed shell roundabout is 16.3 seconds, which is below the recommended values. This values can be interpreted as average difference between interrupted and uninterrupted times for all vehicles queued and un queue.

Table4. 1 lane use and performance for proposed roundabout intersection of shell

Lane Use and Performance										
	Demand Flows			Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service
	L veh/h	T veh/h	R veh/h							
South: cherkacherke leg										
Lane 1	323	11	0	333	21.2	566	0.589	100	18.0	LOS C
Lane 2	0	350	0	350	17.8	595	0.589	100	17.3	LOS C
Lane 3	0	30	64	94	38.6	495	0.190	32 <sup>6</sup>	9.9	LOSA
Approach	323	392	64	778	21.8		0.589		16.7	LOS C
East: IOT- HU leg										
Lane 1	28	88	27	142	2.1	521	0.273	100	10.8	LOS B
Approach	28	88	27	142	2.1		0.273		10.8	LOS B
North: industrial park leg										
Lane 1	74	119	0	193	22.6	433	0.446	89 <sup>5</sup>	17.1	LOS C
Lane 2	0	179	0	179	32.3	401	0.446	89 <sup>5</sup>	18.2	LOS C
Lane 3	0	0	203	203	34.5	404	0.502	100	20.0	LOS C
Approach	74	297	203	574	29.8		0.502		18.5	LOS C
West: Arogawe Menharya leg										
Lane 1	169	117	0	286	24.5	542	0.527	100	16.5	LOS C
Lane 2	0	0	141	141	24.6	528	0.266	51 <sup>5</sup>	10.6	LOS B
Approach	169	117	141	426	24.5		0.527		14.5	LOS B
Intersection				1921	23.3		0.589		16.3	LOS C

All legs for proposed roundabouts will perform good average delay less than 17 sec except leg from Industrial park. Industrial Park approach result average delay of 18.5 sec. This is relatively higher when compared with other approaching legs of intersection. This is because of a higher percentage of heavy vehicles and higher pedestrian flows on this

leg .If the existing uncontrolled intersection of shell is replaced with signal delay encountered by vehicles in average will be 110 sec. which is a very poor performance of intersection. All approaching legs except Industrial park will have average delay of worst condition greater than 50 sec. a good condition for operational performance output result will be found for Industrial park legs with average delay of 21.6 sec if signal alternative is installed for shell intersection .This is because of a higher volumes of heavy vehicles and volume counts are made to be prioritized by researcher on inputs for software analysis.

Table4. 2 Lane use and performance for proposed signalized traffic control of shell.

Lane Use and Performance										
	Demand Flows			Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service
	L veh/h	T veh/h	R veh/h							
South: Cherkacherke leg										
Lane 1	323	0	0	323	21.3	213	1.512	100	304.3	LOS F
Lane 2	0	373	0	373	17.8	704	0.530	35 <sup>5</sup>	31.8	LOS C
Lane 3	0	19	64	82	41.6	776	0.106	7 <sup>5</sup>	2.8	LOSA
Approach	323	392	64	778	21.8		1.512		141.7	LOS F
East: IOT-HU leg										
Lane 1	28	88	27	142	2.1	886	0.160	100	166.8	LOS F
Approach	28	88	27	142	2.1		0.160		166.8	LOS F
North: Industrial park leg										
Lane 1	74	62	0	136	18.5	362	0.376	100	41.1	LOS D
Lane 2	0	236	0	236	32.3	627	0.376	100	28.2	LOS C
Lane 3	0	0	203	203	34.5	928	0.219	58 <sup>5</sup>	0.9	LOSA
Approach	74	297	203	574	29.8		0.376		21.6	LOS C
West: Arogawe menhareya leg										
Lane 1	169	24	0	192	30.5	128	1.503	100	329.8	LOS F
Lane 2	0	93	141	234	19.6	768	0.305	20 <sup>6</sup>	6.7	LOSA
Approach	169	117	141	426	24.5		1.503		152.4	LOS F
Intersection				1921	23.3		1.512		110.0	LOS F

When we compare on output average delay for proposed roundabout and signal intersection we see greater average delays for signalized intersection .This is because a roundabout operating within design volumes will manage peak traffic flows in a self-regulating manner and provide acceptable delays under usual roundabout priority control. Even with relatively high traffic flows on each approach, traffic is generally broken up to create gaps in the circulating flow for entering traffic.

#### 4.1.1.3 Compression of Level of service (LOS) for alternatives

Quality of service requires quantitative measures to characterize operational conditions. Level of service (LOS) is a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience. Six levels of service (LOS) are defined for each type of facility that has analysis procedures available. Letters designate each level, from A to F, with LOS A representing the best operating conditions and LOS F the worst.

Accordingly, the output of the analysis using SIDRA intersection version 5.1 Software indicates that the level of service for proposed shell Roundabout is C which is satisfactory .LOS output result for shell signalized intersection is F this indicates that the quality of service is the worst,.

If we look LOS on approach basis legs from Cherkacherke and leg HU-IOT are both performing satisfactorily. Approaching traffic from Arogawi Menhariya will perform with LOS B which indicates good quality of level of service. Industrial park approach of intersection result LOS C showing relatively lower quality of operational performance on proposed roundabout intersection of shell. If we look on to software out for LOS for proposed signalized intersection at shell all intersection legs except the industrial park leg will perform in worst condition with LOS F .The LOS output for industrial park show LOS C which satisfactory performance quality relative to other legs of proposed signalized intersection of shell. This due to priority is given by researcher for a high volume major traffic of N-S direction.

Generally from output results of v/c or degree of saturation, average delay and LOS results we can see that roundabout options will perform better over proposed signalized traffic control for existing uncontrolled intersection of shell.

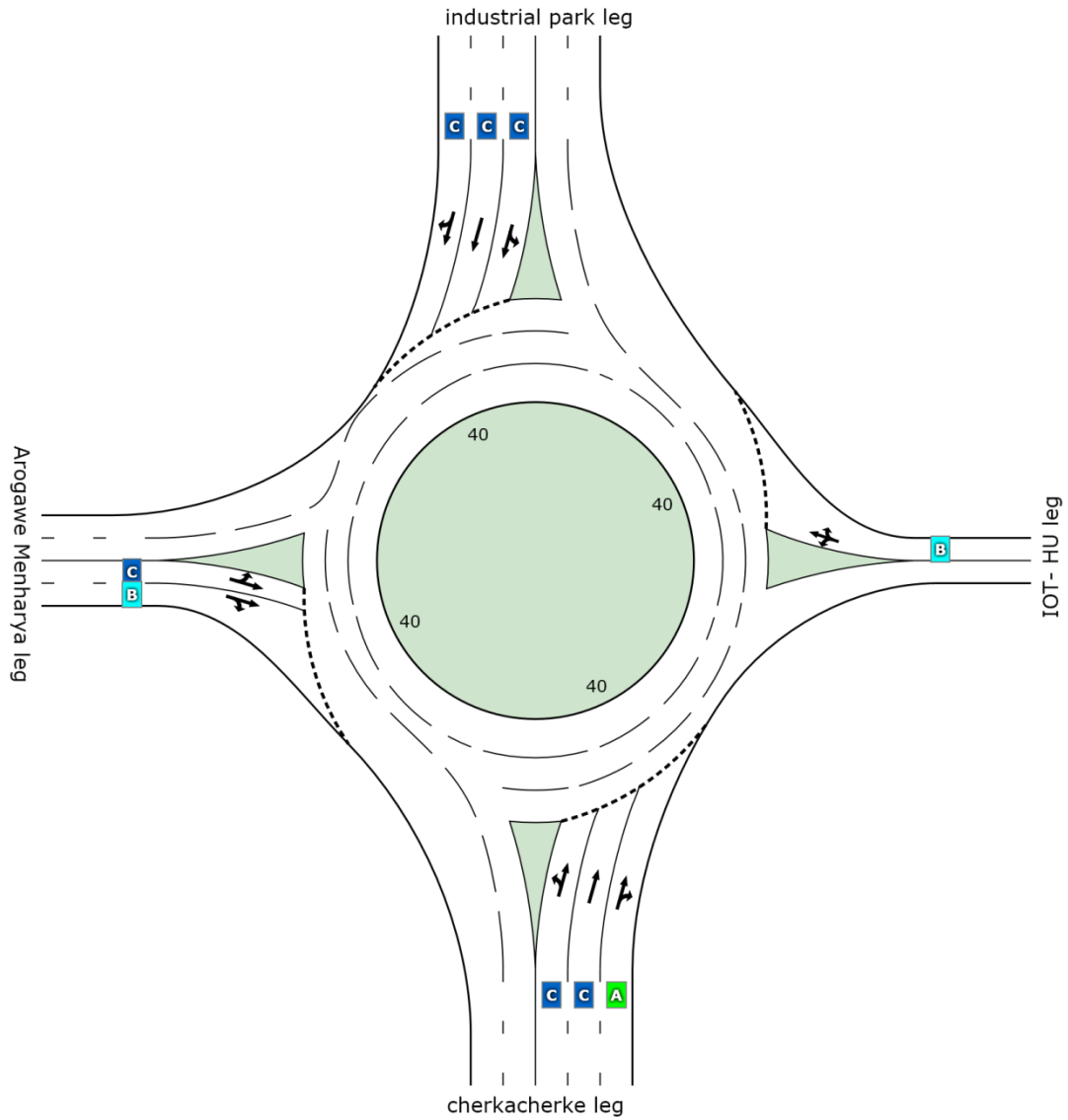
Table4. 3 Compression of operation performance values for proposed roundabout and signalized intersection

Performance measure	Round about option	Signalized traffic control option
Demand flow	1921 veh/hr	1921 veh/hr
Effective intersection capacity	3261 veh/hr.	1270 veh/hr
Degree of saturation	0.589	1.512
Average control delay	16.3 sec.	110 sec.
95 % back of queed vehicles	1.8 veh.	418 veh.
95% back of queed distance	16 m	46.6 m
Level of service	LOS C	LOC F

# LEVEL OF SERVICE SUMMARY

Site: proposed shell Roundabout

shell four legged Roundabout



	South	East	North	West	Intersection
LOS	C	B	C	B	C

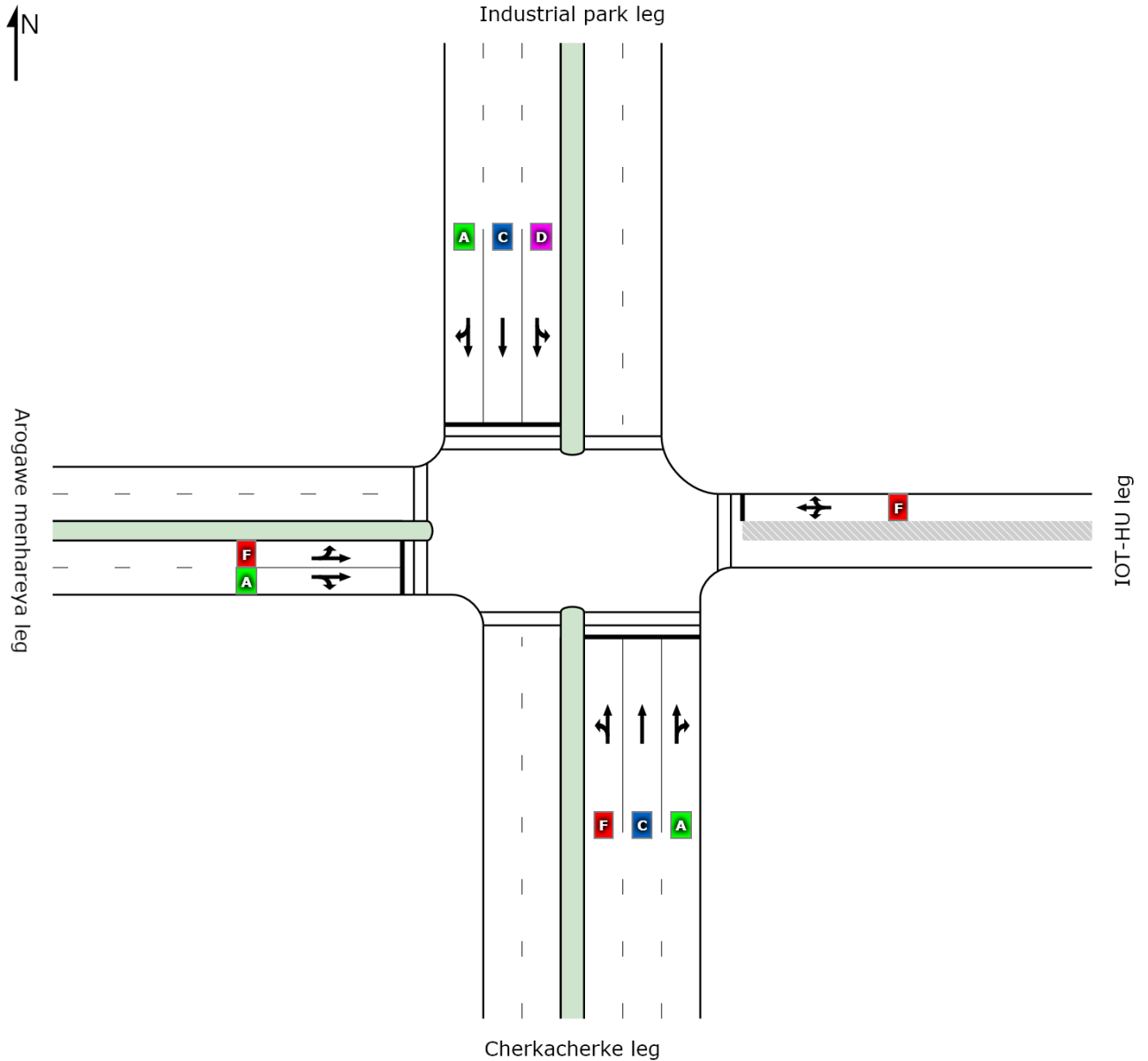
Figure4. 1 Level of service summary for proposed signaled intersection at shell

## LEVEL OF SERVICE SUMMARY

Site: shell signal

shell four legged signal intersection

Signals - Fixed Time Cycle Time = 150 seconds (Practical Cycle Time)



	South	East	North	West	Intersection
LOS	F	F	C	F	F

Figure 4. 2 Level of service summary for proposed signalized intersection of Shell

4.1.2 Comparssion for operational performance of alternative proposals for Addisu Gabiya intersection

4.1.2.1 Comparssion of Degree of saturation for alternatives for Addisu Gabiya intersection

Table4. 4 Lane use and performance for prposed roundabout intersection at Addisu Menhariya

Lane Use and Performance										
	Demand Flows			Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service
	L veh/h	T veh/h	R veh/h							
South: Monpole leg										
Lane 1	161	57	0	218	34.0	451	0.485	100	17.7	LOS C
Lane 2	0	181	59	240	25.9	494	0.485	100	16.4	LOS C
Approach	161	238	59	458	29.8		0.485		17.0	LOS C
East: Cheff leg										
Lane 1	31	80	25	136	2.4	594	0.229	100	9.0	LOS A
Approach	31	80	25	136	2.4		0.229		9.0	LOS A
North: Cherekacherke leg										
Lane 1	45	223	0	268	23.1	524	0.511	100	16.4	LOS C
Lane 2	0	51	226	278	20.9	543	0.511	100	15.9	LOS C
Approach	45	274	226	546	22.0		0.511		16.2	LOS C
West: Adisu Menareya leg										
Lane 1	265	177	0	442	25.0	575	0.769	100	27.9	LOS D
Lane 2	0	0	211	211	24.6	562	0.375	49 <sup>5</sup>	12.1	LOS B
Approach	265	177	211	653	24.9		0.769		22.8	LOS C
Intersection				1793	23.5		0.769		18.2	LOS C

The intersection v/c or degree of saturation for proposed newbusstation roundabout is 0.769 which is less than the tolirable level of saturation . Also all approaching legs of intersection for roundabout of Addisu Menhariya have v/c ratio less than o.85 .This shows for all arrivals at approaches for proposed intersection are performing below the

capacity .The demand flows for this intersection is lesser than the capacity i.e undersaturation.

On other side if alternative signalized intersection was installed all approaches except cheff will oversaturate, the demand will become above their capacity . The only approach that will operate undersaturation level for this alternative option is cheff leg with V/C 0.114 .This is due to alow arrivals (demand) on this approach.The v/c for intersection from performance anlysis output for proposed signalized intersection is 4.113 which means demands/arrivals are four fold of capacity.

Table4. 5 Lane use and performance for signalized intersection of Addisu Menhariya

Lane Use and Performance										
	Demand Flows			Total	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service
	L veh/h	T veh/h	R veh/h							
South: Monpole leg										
Lane 1	161	0	0	161	34.5	39	4.113	100	1532.8	LOS F
Lane 2	0	238	59	297	27.2	320	0.927	23 <sup>5</sup>	87.1	LOS F
Approach	161	238	59	458	29.8		4.113		596.6	LOS F
East: Cheff leg										
Lane 1	31	80	25	136	2.4	1196 <sup>1</sup>	0.114	100	49.2	LOS D
Approach	31	80	25	136	2.4		0.114		49.2	LOS D
North: Cherkacherke leg										
Lane 1	45	20	0	65	38.9	47	1.395	100	339.9	LOS F
Lane 2	0	254	226	480	19.7	344	1.395	100	243.2	LOS F
Approach	45	274	226	546	22.0		1.395		254.8	LOS F
West: Adisu menhareya leg										
Lane 1	265	93	0	358	27.9	239	1.495	100	303.7	LOS F
Lane 2	0	84	211	295	21.3	986	0.299	20 <sup>6</sup>	5.1	LOS A
Approach	265	177	211	653	24.9		1.495		168.9	LOS F
Intersection				1793	23.5		4.113		295.2	LOS F

#### 4.1.2.2 Comparison for Average delay per vehicle for alternatives proposals of Addisu Menhariya intersection

Average delay for proposed roundabout intersection of Addisu Menhariya is 18.2 sec which is less than 25 sec which is satisfactory and indicate acceptable delay for roundabout. Each intersection approaches result in average delay below 18.2 sec. Monpole leg 17 sec., Cheff leg 9 sec, Cherkacherke leg 16.2 sec. and Addisu Gabiya leg 18.2 sec. This shows all approaching lanes are performing within acceptable range of average delay of vehicles. Other alternative which is proposed to upgrade existing uncontrolled intersection is signals this intersection will yield average delay of 295.2 sec. if applied. Which is the worst condition above tolerable limit that result adverse condition for passengers resulting in increased travel time. The delays outputs for each approaching legs intersection are 596.6 sec. on Monpole leg, 49.2 sec for Cheff leg, 254.8 sec. for Cherkacherke leg and 168.9 sec for Addisu Gabiya leg. On monpole approach of intersection a higher delay values are found this is due aggregate effect of higher number pedestrian flow and higher volumes of traffic on this approach.

#### 4.1.2.3 Comparison of Level of Service for Alternative Proposals of Addisu Menhariya Intersection

The last and quality measure of operational performance that is used to compare alternative proposals to upgrade existing uncontrolled intersection is Level of service. The proposed roundabout alternative will perform with LOS C which indicate a satisfactory operational performance quality of intersection. Except cheff leg which perform LOS A remaining approaching legs will provide LOS C if roundabout option is selected.

Intersection LOS for signalized alternative option of traffic control mechanism for existing uncontrolled intersection of Addisu Menhariya is LOS F. LOS F according HCM2010 performance for unsignalized intersection is if average delay encountered is greater than 80 sec. This show worst intersection condition to be seen on poorly operating intersection.

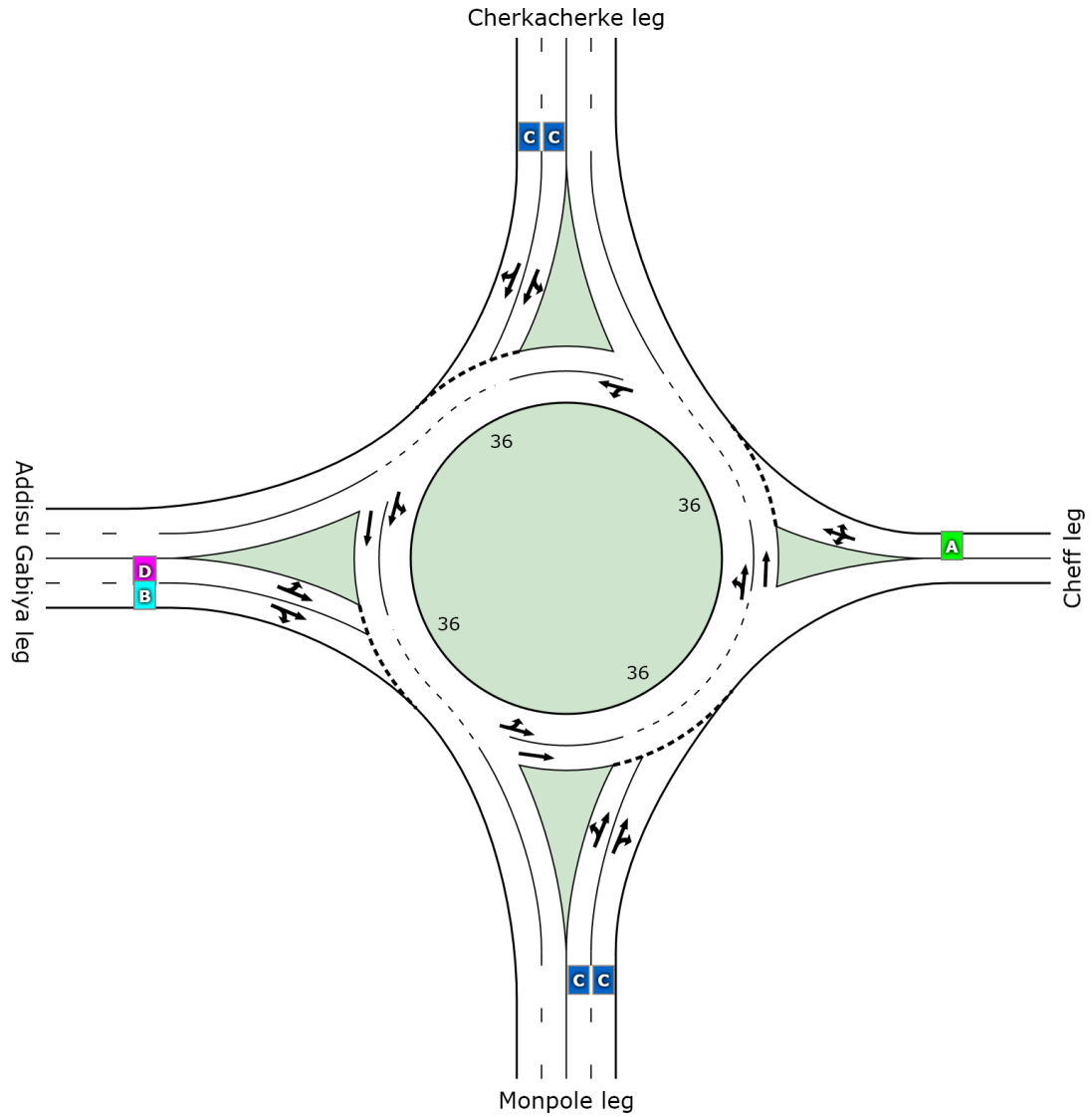
Table4. 6 Comparison of operation performance for roundabout andsignalized intersection of Addisu Menhariya.

Performance measure	Round about option	Signalized control option
Demand flow	1793 veh/hr	1793 veh/hr.
Effective intersection capacity	25834 veh/hr.	435 veh/hr.
Degree of saturation	0.769	4.113
Average control delay	18.2 sec.	295.2 sec.
95 % back of queed vehicles	3 veh.	61.9 veh.
95% back of queed distance	27.4 m	548.7 m
Level of service	LOS C	LOS F

# LEVEL OF SERVICE SUMMARY

Site: Addisu Menhariya Roundabout

Addisu Menhariya Roundabout



	South	East	North	West	Intersection
LOS	C	A	C	C	C

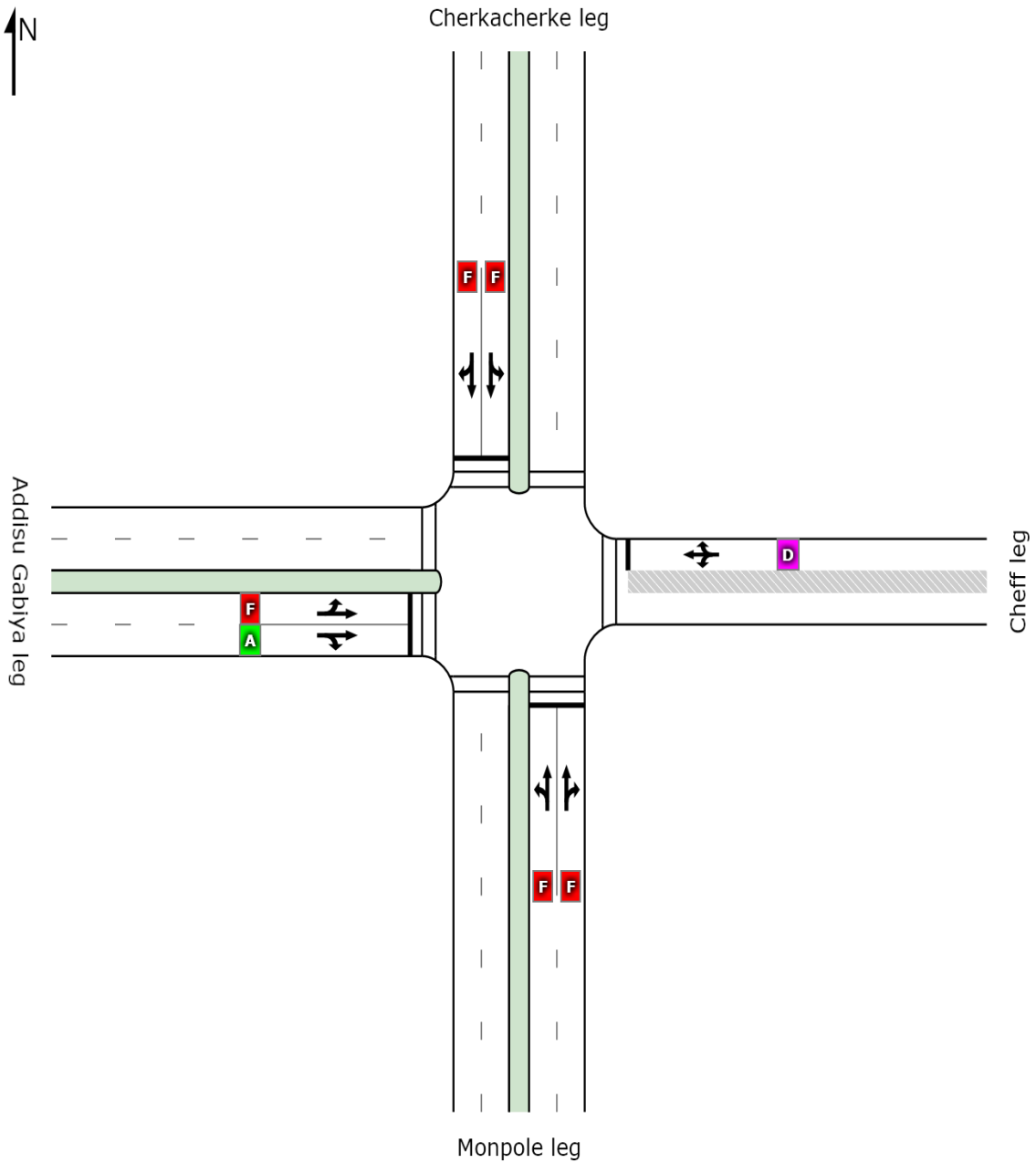
Figure 4. 3 Level of service summary for proposed Roundabout intersection at Of Addisu Menhariya.

# LEVEL OF SERVICE SUMMARY

Site: Proposed Addisu Menhariya signal

Addisu Menhariya four legged signal

Signals - Fixed Time Cycle Time = 150 seconds (Practical Cycle Time)



	South	East	North	West	Intersection
LOS	F	D	F	F	F

Figure 4. 4 Level of service summary for proposed signalized intersection of Addisu Menhariy.

## 4.2 Comparison of safety performance for alternative roundabout and signal intersections of Shell and Addisu Menhariya uncontrolled intersections.

### 4.2.1 Comparison of Vehicular Safety for Alternative Proposals of Shell And Addisu Menhariya Uncontrolled Intersections

#### 4.2.1.1 comparison of Crash Frequencies for alternative proposals of shell and Addisu Menhariya intersections.

Typical crash rates for similar types of intersections can provide a basis for assessing safety

I. A comparison of performance for intersections of differing types or traffic control.

II. A benchmark against which a specific intersection can be compared.

Summary statistical data for the five year period 2014 to 2018 for Hawassa city provides averaged safety performance data for road intersections controlled by roundabouts and traffic signals. These average rates may be used to compare a specific intersection. The safety performance rates roundabout and signalized intersection different crash types are summarized in Table 4.6

Table4. 7 Summary of mean crush frequencies for different crash types for roundabout and signalized intersection in Hawassa city.

Traffic intersection control type	Mean Crash Frequency for different Crash Types (Crashes / Intersection / Year)				Total
	Death	Heavy injury	Light injury	Property	
Roundabout	0.089	0.356	0.222	0.066	0.733
Traffic signal	0.13	0.471	0.177	0.094	0.872
TVs /Ra	1.46	1.32	0.8	1.424	1.2

From the above table it is quite clear that intersections controlled by roundabouts have a significantly lower crash rate than intersections controlled by traffic signals. . It should be noted that while these figures are based on limited data, similar trends have been observed in similar studies made on Victoria and Perth Even where traffic volumes are higher, roundabouts have less crash rate than intersections controlled by traffic signals

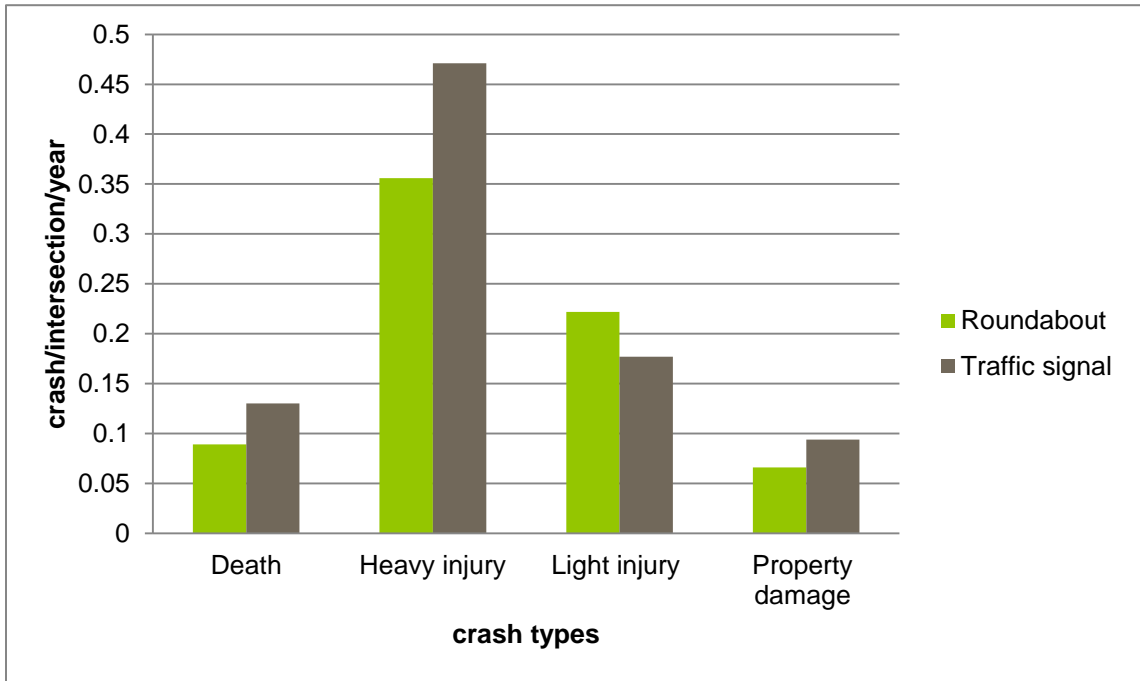


Figure 4.5 Summary of mean crash frequencies for different crash types for roundabout and signalized intersection in Hawassa city.

#### 4.2.1.2 comparison of Casualty crash rates for alternative proposals of shell and Addisu Menhariya intersections

When crash frequencies are related to traffic volumes using the intersections, they provide a measure related to exposure and traffic use. The mean safety performance rates for different intersection types for casualty crashes only are summarized in Table 2.2. In this case the crash rates are per million entering vehicles.

Table 4.8 Summary of mean Casualty crash rates for alternative proposals at shell intersections

Traffic intersection control type	Mean Casualty Crash Rate for shell (Casualty Crashes / Intersection / Year / 106 entering)				Total
	Death	Heavy injury	Light injury	Property damage	
Roundabout	0.011	0.044	0.027	0.008	0.091
Traffic signal	0.016	0.058	0.022	0.012	0.108
Ts /Ra	1.461	1.323	0.797	1.424	1.190

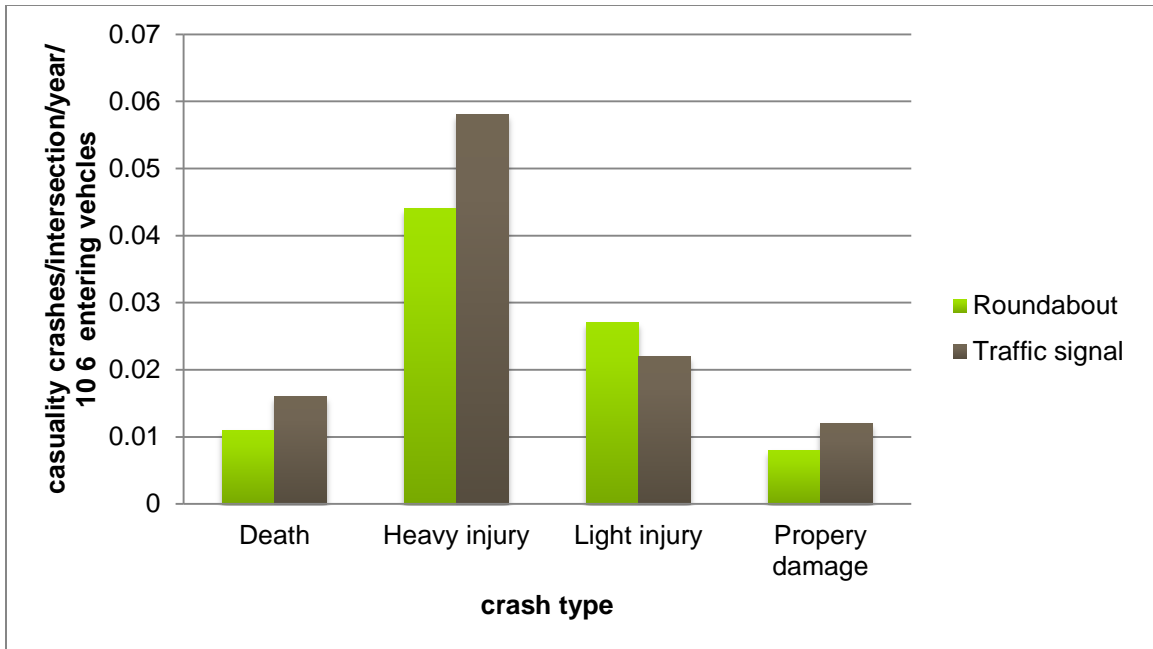


Figure4. 6 Summaries of mean Causality crash rates for alternative proposals of Shell intersections

The summary data generally indicates that the casualty crash exposure rate at roundabouts in Hawassa city is approximately nineteen percent less than the casualty crash exposure rate of signalized intersections, when averaged across all crash types. It should be noted that a similar trend was observed in Melbourne (Vic Roads, 2005), where the crash exposure rate for roundabouts was typically 20 – 25% less than for signalized intersections.

Table4. 9 Summary of mean Causality crash rates for alternative proposals of Addisu Menhariya intersections

Traffic intersection control type	Casualty Crash Rate new bus station (Casualty Crashes / Intersection / Year / 106 entering vehs)				Total
	Death	Heavy injury	Light injury	Property damage	
Roundabout	0.012	0.048	0.030	0.009	0.099
Traffic signal	0.018	0.064	0.024	0.013	0.118
Ts /Ra	1.461	1.323	0.797	1.424	1.190

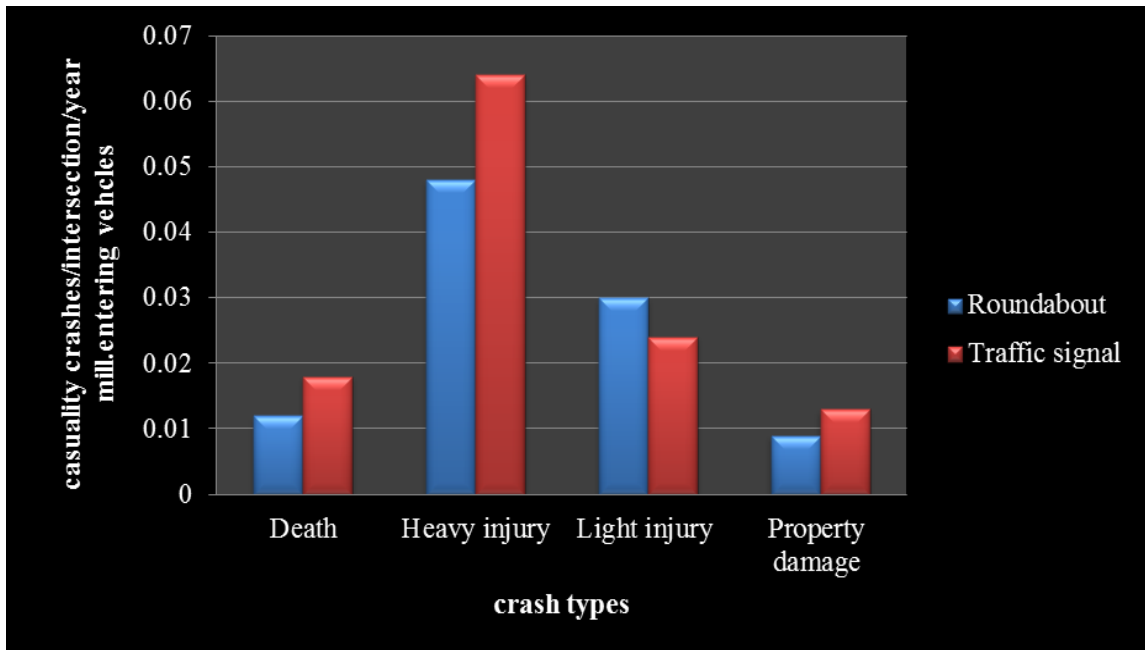


Figure4. 7 Summaries of mean Causality crash rates for alternative proposals of Addisu Menhariya intersections.

#### 4.2.2 Comparison of Pedestrian Safety For Proposals

Table4. 10 Summary of mean Pedestrian crush frequencies for different crash types for roundabout and signalized intersection in Hawassa city.

Traffic intersection control type	Pedestrian Crash Frequency for different Crash Types (Crashes / Intersection / Year)			Total
	Death	Heavy injury	Light injury	
Roundabout	-	0.044	0.044	0.088
Traffic signal	0.024	0.094	0.035	0.153
Ts /Ra	-	2.136	0.795	1.739

A summary for pedestrian safety at roundabout and signalized intersection show that about 74 % greater mean crash rates occurred on signalized intersection in Hawassa city.

The results also indicate that the severity of crashes involving pedestrians at roundabout is lower than signalized intersection control.

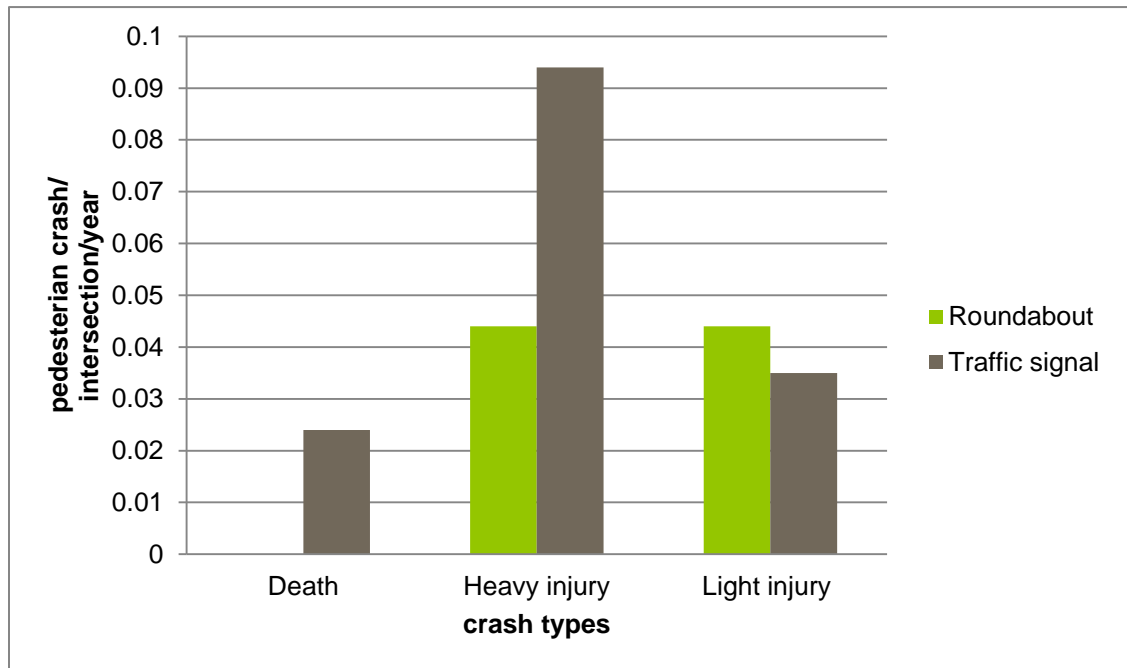


Figure4. 8. Summary of mean crash frequencies for different crash types for roundabout and signalized intersection in Hawassa city.

Evidence suggests that roundabouts are at least as safe for pedestrians as other forms of intersection control possibly because pedestrians are able to cross one direction of traffic at a time by staging on the splitter islands. A Review of Pedestrian Safety at Roundabouts (Charmaine Tumber, 1997) was carried out by Vic Roads in 1997. The review considered available investigations and literature from Australia and overseas as well as an evaluation of data for roundabouts constructed on arterial roads in the Melbourne metropolitan area over the period 1987 – 1994. The review concluded that there is not a demonstrated safety problem for pedestrians at roundabouts. The Melbourne data indicated that there is an average of 0.02 pedestrian crashes per roundabout per year at roundabouts. The findings also indicated that the severity of crashes involving pedestrians is lower than for other forms of control at intersections.

### 4.3 Comparison of Operational Costs for Alternative Roundabout And Signalized Intersection of Shell And Addisu Menhariya Intersection.

#### 4.3.1 Comparison Of Initial Cost For Proposals of Shell And Addisu Menhariya.

Table 4.10 compare the estimated initial costs for proposed intersection controls of shell we find the estimated costs for roundabout is approximately 4862846.62 ETB more than the signalized intersection.

Table4. 11 Comparison of estimated initial costs for proposed roundabout and signal traffic controls for shell intersection

Estimated Cost	Proposed Shell roundabout	Proposed shell signal
Utilities relocation cost	38848 ETB	-
Property affected due to space requirement	32400 ETB	-
Construction cost for alternatives	6668050.62 ETB	1876452 ETB
Total cost	6739298.62 ETB	1876452 ETB

Likewise Table 4.11 show the comparison made between alternatives for Addisu Menhariya for their estimated initial costs for construction of roundabout is approximately 3783173 ETB more than that of signalized intersection

Table4. 12 Comparison of estimated initial costs for proposed roundabout and signal traffic controls for Addisu Menhriya intersection

Estimated Cost	Proposed Addisu Menhariya roundabout	Proposed Addisu Menhariya signal
Utilities relocation cost	38848 ETB	-
Property affected due to space requirement	397800 ETB	-
Construction cost for alternatives	5222977 ETB	1876452 ETB
Total cost	5659625 ETB	1876452 ETB

A higher initial cost values are found when we estimates for roundabout this because roundabout need relatively wider space to accommodate the size of intersection splays as well as the Road Reserve width, the availability and/or cost of land is also taken in to consideration when choosing a form of control to adopt. The cost needed for modification of existing geometry to roundabout i.e. constructing inside circle and a circulating lane make initial cost for roundabout to become costly.

#### 4.3.2 Comparison for Operating Cost Estimates For Proposal of Shell and Addisu Menhariya Intersection

Using SIDRA 5.1 software the operating cost estimate for each proposed intersection controls is made for comparison purpose .the cost parameters that are used to calibrate the operating cost model are according to HCM 2010 model. Calibration parameters include Cost Unit (user's own currency), Pump Price of Fuel, Fuel Resource Cost Factor, Ratio of Running Cost to Fuel Cost, Average Income, Time Value Factor, Average Occupancy (persons/veh), Light Vehicle Mass, heavy vehicle mass, and heavy vehicle maximum power . The operating cost estimates include the direct vehicle operating cost (the resource cost of fuel and additional running costs including tire, oil, repair and maintenance as a factor of the cost of fuel), and the time cost to driver and passengers.

When we compare the time cost to driver and passenger with calibrated inputs values we get 468844\$/y for roundabout and 792719 \$/y for signalized intersection. A higher time cost for signalized intersection is because higher delays values that increase travel time were found on this proposed intersection.

A fuel consumption for proposed shell roundabout and signalized alternatives result in 165168 L /y and 205012 L/y respectively .increased fuel consumption for signalized intersection is due to With a roundabout, it is not necessary for traffic to come to a complete stop when no conflicts are present. But For signals vehicles are obliged to stop when red phase for vehicles reached .this will increase the engine fuel consumption for vehicle to begin moving when green for vehicles starts.

If we consider the environmental impact of alternative proposals we see that greenhouse gases emission is greater due to application of stop on signal make rate of emission of this gases increase when the stopping vehicles begin to move.

Table4. 13 Operating cost estimates –annual values for proposed roundabout traffic control mechanism for shell intersection

Performance Measure	Vehicles		Persons	
Cost	468,844	\$/y	468,844	\$/y
Fuel Consumption	165,168	L/y		
Carbon Dioxide	417,172	kg/y		
Hydrocarbons	422	kg/y		
Carbon Monoxide	31,983	kg/y		
NOx	1,296	kg/y		

Table4. 14 Intersection performance –annual values for proposed signalized traffic control for shell intersection

Performance Measure	Vehicles		Pedestrians		Persons	
Cost	792,719	\$/y	164,179	\$/y	956,898	\$/y
Fuel Consumption	205,012	L/y				
Carbon Dioxide	517,750	kg/y				
Hydrocarbons	632	kg/y				
Carbon Monoxide	35,377	kg/y				
NOx	1,400	kg/y				

If we compare indirect operational cost estimates for newly built roundabout it becomes 428030\$/y and corresponding estimate for roundabout will be 1528 636 \$/y .this indicate travel time costs that is related mainly with average delay of vehicles for signal is higher. The estimated SIDRA -5.1 output for fuel consumption at fuel at intersection for roundabout intersection like ashell site it yields 154855 \$/y lesser value than signalized option which consumes a total of 282853 L/year.

Finally if we consider environmental impact of alternative roundabout and signalized intersection we see that proposed signalized intersection at new bus station anticipate to emit a higher amount of greenhouse gases (carbon dioxide, hydrocarbons, carbon monoxide, and nitrogen monoxide) than alternative roundabout intersection option.

Table 4.15 operating cost estimates –annual values for proposed roundabout traffic control mechanism for Addisu Menhariya intersection

Performance Measure	Vehicles		Persons	
Cost	428,030	\$/y	428,030	\$/y
Fuel Consumption	154,855	L/y		
Carbon Dioxide	391,207	kg/y		
Hydrocarbons	384	kg/y		
Carbon Monoxide	30,044	kg/y		
NOx	1,233	kg/y		

Table 4.16 operating cost estimates –annual values for proposed signalized traffic control mechanism for Addisu Mehariya intersection

Performance Measure	Vehicles		Pedestrians		Persons	
Cost	1,380,293	\$/y	148,343	\$/y	1,528,636	\$/y
Fuel Consumption	282,853	L/y				
Carbon Dioxide	714,904	kg/y				
Hydrocarbons	1,034	kg/y				
Carbon Monoxide	43,962	kg/y				
NOx	1,637	kg/y				

When operating within their capacity, roundabouts typically operate with lower vehicle delays than signalized intersections. With a roundabout, it is not necessary for traffic to come to a complete stop when no conflicts are present. When there are queues on one or more approaches, traffic within the queues usually continues to move. The performance of roundabouts during off-peak hours is particularly good when compared to signalized intersections, usually with very low average delays. These lower vehicle delays translate to increased fuel savings, reduced greenhouse gases, and reduced vehicle noise.

#### 4.4 Summary of Findings

A summary of the analysis is presented in the following table.

Table 4.17 Comparative Ratings

Factors considered for evaluation	Shell Intersection		Addisu Menhariy Intersection	
	Roundabout	Signalized intersection	Roundabout	Signalized intersection
Operational performance	+	-	+	-
Safety performance	+	-	+	-
Initial cost	-	+	-	+
Operational cost	+	-	+	-
Environmental impact	+	-	+	-

Comparative Ratings: + (Advantage) ; - (Disadvantage); = (equal or no significant difference)

## 5. CONCLUSION AND RECOMMENDATION

### 5.1 Conclusions

A multivariate comparative analysis that involve cost, safety and operational performances as evaluation criteria that is used to select appropriate intersection control from proposals reveal the following conclusion.

Based on result DOS of shell alternative proposed round about and signal option have v/c of 0.589 and 1.512 respectively .This means the roundabout option will operate satisfactorily and the signalized intersection will oversaturate if they were selected. For satisfactory operation the degree of saturation should be less than 0.85.likewise, the average delay of vehicles at roundabout and signalized intersection 16.3 sec in the range of tolerable limit and 110 sec beyond the range of tolerable limit respectively .Moreover, the researcher conclude that the overall level of service based on the results, is rated C for roundabout option and F for proposed signalized intersection. Level of service results for proposal indicates the roundabout option will serve a better quality if it was selected and the signalized one will serve at a poor level of service.

If we compare alternative proposals of roundabout and signalized intersection of Addisu Menhariya intersection for degree of saturation we found v/c values 0.769 and 4.113 respectively .This show signalized intersection will be oversaturated and the roundabout option will serve satisfactorily. The average control delay for proposed roundabout and signalized intersection will be 18.2 sec and 295.2 sec if they were selected respectively. The roundabout option will operate within the acceptable limit and the signalized one beyond the tolerable limit. The study reveals the Level of service for alternative roundabout option is C and signalized option will have LOS Generally from above results we can deduct that proposed alternative roundabouts intersection have a better operational performance than signalized intersection.

The second criterion that was used by researcher to compare alternative proposal of shell and Addisu Menhariya is safety performance values. Crash frequencies for different crash types on environment the intersection exist i.e. on Hawassa city between similar intersection types on roundabout and signalized intersection indicate roundabouts have a significantly lower crash rate than intersections controlled by traffic signals. Mean Crash Frequency for different Crash Types in Crashes / Intersection / Year for alternative

roundabout and signalized intersection are 0.733 and 0.872 respectively. This shows frequency of crashes for signalized intersection is approximately twenty percent more than alternative roundabout intersections in Hawassa city. The causality crash exposure rate in Casualty Crashes / Intersection / Year / 106 entering veh for alternative roundabout and signalized intersection for Shell intersection is 0.091 and 0.108 respectively. Similarly causality crashes for Alternative roundabout and signalized intersection for Addisu Menhariya intersection are 0.099 and 0.118 respectively. The summary data generally indicates that the casualty crash exposure rate at roundabouts in Hawassa city is approximately nineteen percent less than the casualty crash exposure rate of signalized intersections, when averaged across all crash types.

The pedestrian crash frequencies for different crash types in crash/intersection /year for proposed alternative roundabout and signalized intersection are 0.088 and 0.153 respectively.

From this we can conclude that mean crash rates occurred on signalized intersection involving pedestrian are about 74 % greater than mean crash rates that occurred on roundabout intersection in Hawassa city.

Generally results indicate that roundabout option are safer than signalized intersection for case of study areas since causality and severity of crashes involving vehicles and pedestrians at roundabout is lower than signalized intersection control in Hawassa city.

Finally alternative proposals are compared for their initial cost and operating cost they require if they were applied for study areas. The research found out the initial cost estimate for roundabout and signalized intersection if they were built for shell will cost 6,739,298.62 ETB and 1876452 ETB respectively. Likewise initial cost for Addisu Menhariya intersection for alternative roundabout and signalized intersection will be approximately 5,659,625 ETB and 1876452 ETB respectively. Relatively A higher initial cost values are found for roundabouts option than signalized intersection on both intersections. On the other hand a lower operational cost values are obtained for roundabout option due to operational condition of roundabout increase fuel savings, and reduced greenhouse gases.

## **5.2 Recommendation**

In Hawassa city intersection selection follow traditional way with no systematic and creditable way of evaluation. The concerned offices should consider factors that affect selection fully before they apply new traffic control to existing intersections.

This research showed that existing traffic flows of shell and Addisu Menhariya intersection need selection of appropriate intersection control that upgrade performances of existing intersection.

The AADT counts measured on both intersections recommend roundabout and signals as alternative intersection that should be selected based on comparing cost, operational and safety performance of alternative proposed intersection.

As the result of comparison reveal for proposed roundabout and signalized intersection for the concern of study show the operational and safety performance of roundabout intersection are better than alternative signalized intersections and costs are lesser with roundabout option. Roundabout options are appropriate intersection for existing uncontrolled intersection of Shell and Addisu Menhariya. I recommend roundabouts to be installed for existing uncontrolled intersection of shell and Addisu Menhariya..

## **6. FUTURE STUDIES**

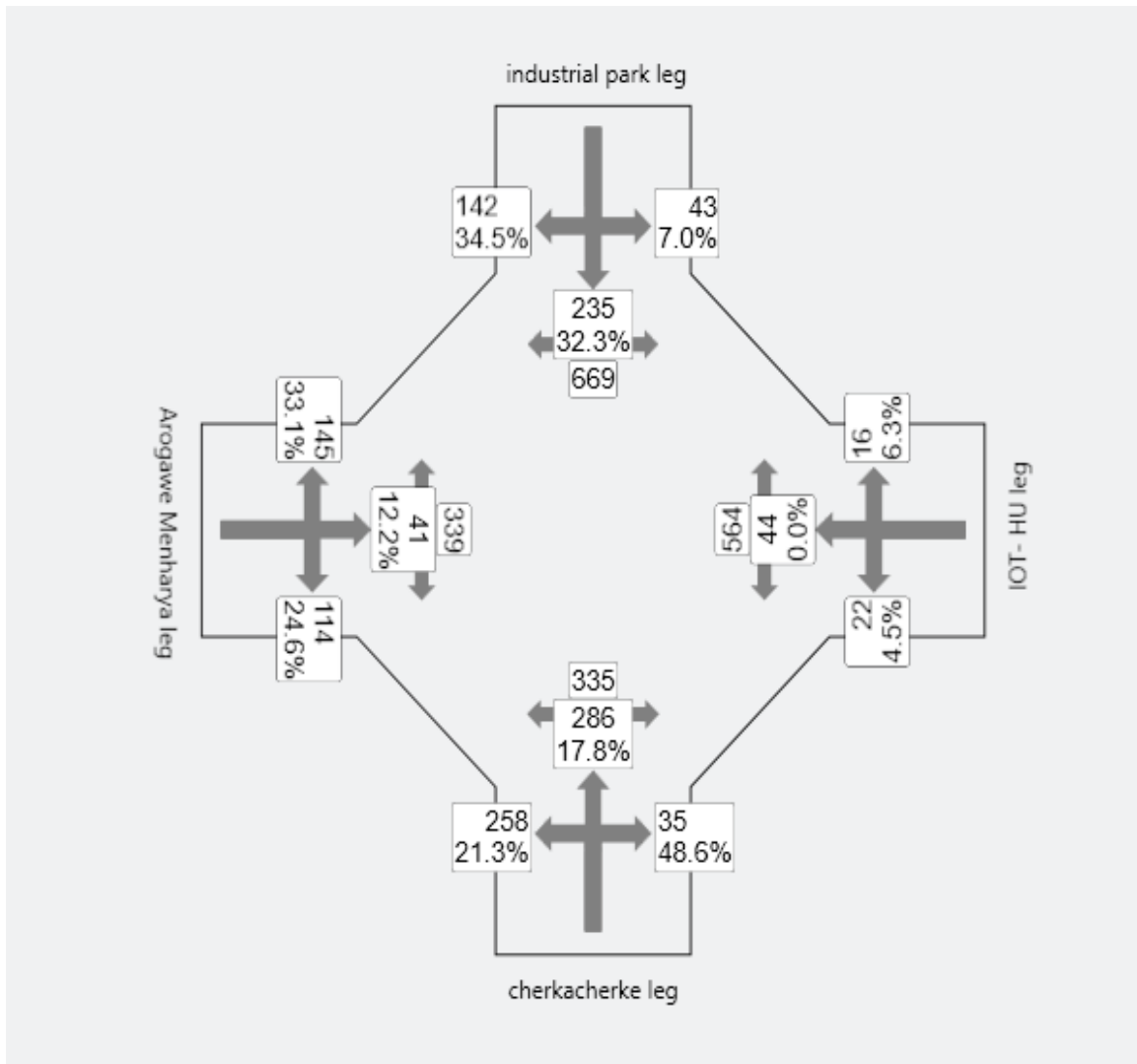
The current method adopted by ERA manual for junction selection is not self-sufficient .In order to fill the gaps practitioners and researchers need to refer different manuals from different countries .This manuals consider their countries traffic condition as well as travel behaviors of road users, current costs for installing junctions and causality rates of accident for their own countries .Therefore ,to overcome this problem further study need to be carried out to develop the Ethiopian intersection selection guideline.

## 7. REFERANCE

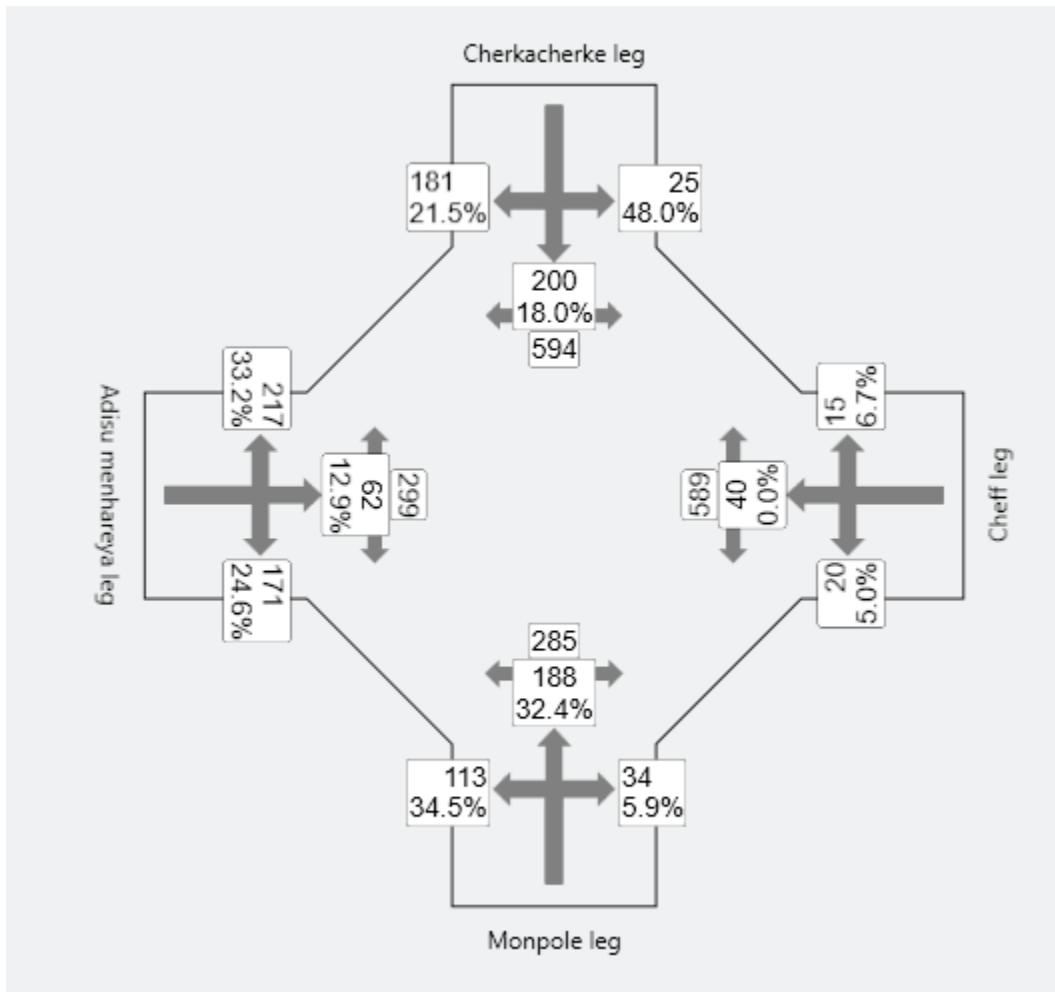
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## 8. APPENDIX



Appendix 8. 1: volume summary of shell intersection



Appendix8. 2 : Volume summary of Addisu Menhareya

## PHASING SUMMARY

Site: proposed shell signal

shell four legged signal intersection

Signals - Fixed Time Cycle Time = 150 seconds (Practical Cycle Time)

Phase times determined by the program

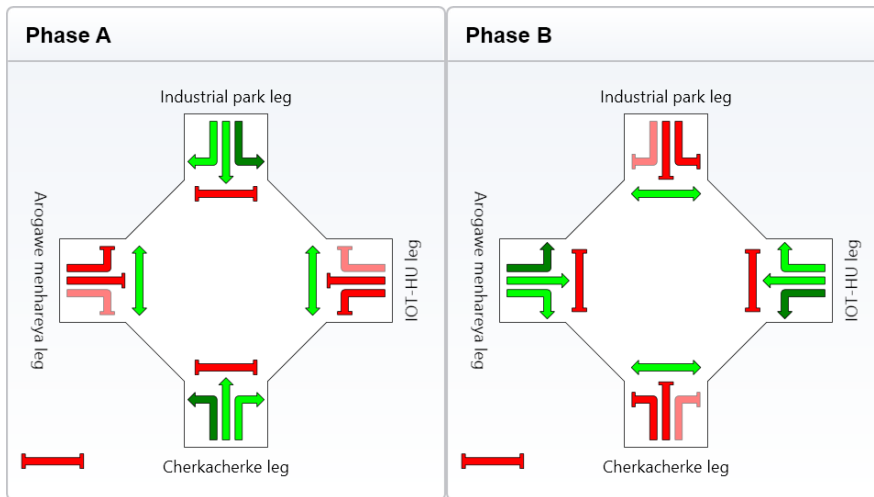
Sequence: Two-Phase

Input Sequence: A, B

Output Sequence: A, B

### Phase Timing Results

Phase	A	B
Green Time (sec)	69	73
Yellow Time (sec)	3	3
All-Red Time (sec)	1	1
Phase Time (sec)	73	77
Phase Split	49 %	51 %



	Normal Movement		Permitted/Opposed
	Slip-Lane Movement		Opposed Slip-Lane
	Stopped Movement		Continuous Movement
	Turn On Red		Undetected Movement

Appendix8. 3 Phase summary of proposed shell signal

# PHASING SUMMARY

Site: Proposed Addisu Menhareya signal

Addisu menhareya four legged signal

Signals - Fixed Time Cycle Time = 150 seconds (Practical Cycle Time)

Phase times determined by the program

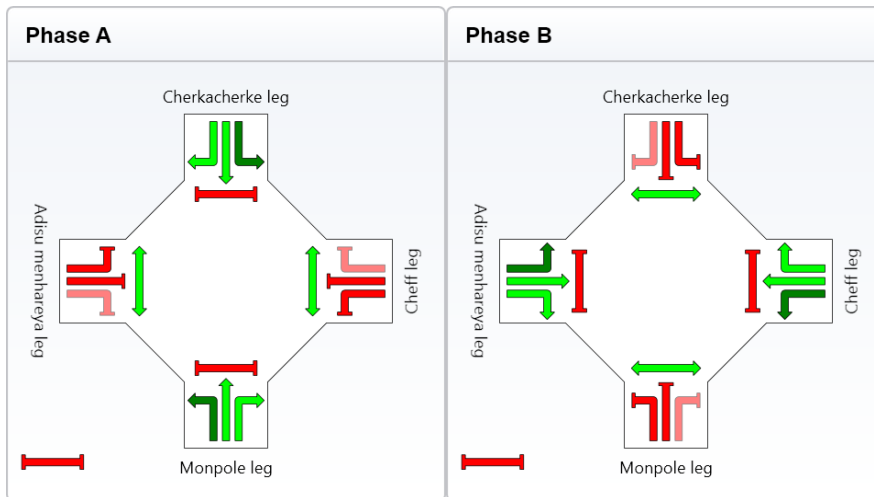
Sequence: Two-Phase

Input Sequence: A, B

Output Sequence: A, B

## Phase Timing Results

Phase	A	B
Green Time (sec)	35	107
Yellow Time (sec)	3	3
All-Red Time (sec)	1	1
Phase Time (sec)	39	111
Phase Split	26 %	74 %



	Normal Movement		Permitted/Opposed
	Slip-Lane Movement		Opposed Slip-Lane
	Stopped Movement		Continuous Movement
	Turn On Red		Undetected Movement
			Phase Transition Applied

Appendix8. 4: Phase summary of proposed Addisu Menhareya signal