

Development of Fixed Time Traffic Signal Design for Selected Roundabout, the Case of Gerji-Imperial in Addis Ababa

Abdi Mohammed¹, Kathiresen Karuppanan²

¹Adama Science & Technology University, Civil Engineering & Architecture Department

²Adama Science & Technology University, Civil Engineering & Architecture Department

Abstract

Traffic congestion is a critical problem in Addis Ababa due to the fast growing economy, car ownership and population in the country. It has negative environmental and health consequences as a result of increased fuel consumption and air pollution. The critical traffic problems and accidents are majorly observed in the intersection without traffic signal. To avoid such traffic problems, there is a need of assessment of current traffic condition and conducted level of service for the intersection and round about is very important. The objective of the study was to develop Fixed Time Traffic Signal design for Gerji-Imperial Roundabout in Addis Ababa after assessing the current conditions and the level of service around there. To conduct this study, first the traffic was counted manually for seven days, and then the peak hour volume was taken for traffic signal design. Fixed time signal approach using Webster method was used for signal design. Before the design is come up, the assessment was conducted. The major problems in Gerji-Imperial Roundabout is geometric or topography, traffic conflicts in the round about unexpectedly, conflict between pedestrian and vehicle and it hosted the traffic police man in the four approach. In Level of service assessment, the quality of Gerji-Imperial Roundabout was investigated in terms of delay and the comparison is done with the condition of after signal design. Based on the HCM, the Gerji-Imperial Roundabout about is under 'F' which is highly delayed with more than 50 second whereas with this second the delay condition would be lower and indicated by 'E' for case of signalized condition. This show that signal design has better level of service than round about in case Gerji-Imperial. The result of signal design in Gerji-Imperial Roundabout was based on the peak hrs., volume and the total cycle length is 180 second with effective green time of 43, 41, 43 and 39 second in Bole (A), Gerji (B), Megenagna (C) and Hayahulet (D) approaches. The yellow interval for each approach was 3 seconds. Finally, it is advisable to design traffic signal for any round about is advisable to give better level of service as well as to minimize traffic accident and conflict.

Keywords: Delay, Fixe Time, Level of Service, Signal Design, Traffic Signal.

I. INTRODUCTION

Traffic signal design in highly congested round about is the main solution to avoid traffic delay, traffic conflict and specifically traffic accident. Basically the design approach has been conducted by different designers all over the world. By taking this in consideration, this study will focus on the analysis and design of traffic on the selected round about at Gerji-Imperial. Now-a-days, controlling traffic congestion relies on having an efficient and well-managed traffic signal control policy. Traffic signals design and operate is either pre-timed or actuated mode or some combination of the two. Pre-timed control consists of a series of intervals that are fixed in duration. They repeat a preset constant cycle time. In contrast to pre-timed signals, actuated signals have the capability to respond to the presence of vehicles or pedestrians at the intersection. Actuated control consists of intervals that are called and extended in response to vehicle detectors. The controllers are capable of not only varying the cycle length & green times in response to detector actuation, but of altering the order and sequence of phases. Reacting to these volume variations generally results in reduced delays, shorter queues and decreased travel times. Coordinating traffic signals along a single route so that vehicles get progressive green signal at each junction's another important aspect of area traffic control systems (ATCS).

There are many causes of traffic congestion, such as weather, vehicular accidents, reckless driving, and poor road design and road construction work zones. Although there are strategies employed to minimize these contributing factors, they rely heavily on the compliance of individual drivers; therefore, they are not always effective. As such, there is a need to focus on factors that can be more effectively controlled. Some of these factors include improved road infrastructure, access limitations and traffic controls. While all of these factors can be altered in order to reduce traffic congestion, some of these factors are more difficult to alter than others. One of the most obvious means of reducing traffic is the construction of more roadways; however, that approach has serious limitations. Traffic congestion and its associated problems will continue to increase, because roads and highways are unlikely to expand enough to alleviate the problems due to the cost and limited land supply.

Therefore, other more cost efficient and feasible strategies are needed. One of the most promising ways to reduce traffic congestion is better utilization and control of the existing infrastructure through efficient management of traffic systems. It is quite evident that the efficiency of traffic control directly depends on the efficiency and relevance of the control methodologies. Poor traffic control can lead to traffic congestion, whereas well-designed traffic control plans, such as efficient traffic signal timings, can significantly reduce traffic congestion. In fact, in traffic systems that contain traffic signals, control of traffic light signal timings is one of the least expensive and most effective means of reducing vehicular congestion in metropolitan road networks. This is especially true in times of peak traffic flow, such as during morning and evening rush hours. Traffic signal management is one of the fastest methods to achieve traffic congestion improvements.

Traffic congestion can be tackled by demand management of a given road intersection by adjusting a traffic light's cycle time according to the design. Hence, before conducting a design, traffic data prediction or estimation is of prime importance. For collecting these traffic data, manual counting methods are used. The proposed method adjusts the knowledge-based cycle time of a traffic light in accordance with the congestion.

Thus, this research selected to design a traffic signal for Gerji-Imperial Roundabout in Addis Ababa which has highly traffic without signal control system. To design the signal for the roundabout, Webster design approach is applied.

Statement of the Problem

Traffic congestion poses an ever increasing problem for major metropolitan areas across Addis Ababa. As the population continues to grow and the number of licensed drivers increases, the problem will inevitably worsen. The cost of traffic congestion goes far beyond the numerous lost hours by vehicle drivers due to congestion delays. Traffic congestion has negative environmental and health consequences as well. Environmentally, traffic congestion results in increased fuel consumption and air pollution. In terms of health consequences, traffic congestion leads to increased stress and mental and physical discomfort, which may contribute to a lower quality of life. Additionally, congestion slows the transportation of goods and services, which results in higher prices for consumers. Traffic signal is the process by which the passage of vehicles through the intersection or roundabout is governed. Traffic problems are controlled by appropriate traffic signal plan and design. This design approach was come up to avoid the traffic problems in Gerji-Imperial Roundabout which didn't have signal design yet.

Objectives of the Study

i. General objective

The general objective was to develop Fixed Time Traffic Signal design for Gerji-Imperial Roundabout in Addis Ababa

ii. Specific Objectives

The specific objectives of the study were:-

- ✓ To assess the current traffic conditions at Gerji-Imperial Roundabout.
- ✓ To investigate the level of service (LOS) in Gerji-Imperial Roundabout.
- ✓ To design appropriate fixed time signal control system for Selected Roundabout.

Significance of the study

Traffic congestion has a direct effect on our quality of life since most people suffer from the daily inconvenience of traffic pollution, traffic delay and traffic costs. It includes considerable costs for the community and a great deal of effort is devoted in every large city to reduce the negative impact of this phenomenon. Design appropriate signal at the intersection and at roundabout which have high traffic volume is an important solution to avoid traffic accidents.

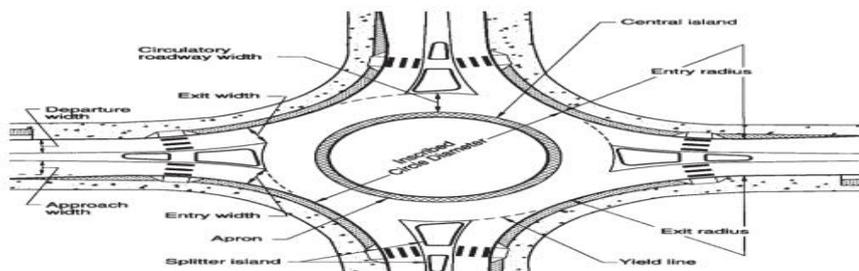
LITERATURE REVIEW

Traffic congestion is a critical problem in Addis Ababa-Ethiopia due to the fast growing economy, car ownership and population in the country. The road improvement practices also contribute to the reduction in roadway capacity which in turn aggravates traffic congestion and delay. Locations of traffic congestion in Addis Ababa may include straight and level road sections, approaches, signalized intersections and un-signalized intersection. Congestion problem on roundabout drastically increases due to massive amount of approaching traffic volumes, the size of roundabouts and capacity of approaching road streets. This incurs too much delay and environment pollution, which exaggerates the discomfort of people leaving in this city. Therefore there were researches done previously on the problem of congestion on roundabouts, signalized and un-signalized intersection. Among them here are the basic reviews which relates with this studies.

Traffic Controlling Elements

Roundabout Definition

Roundabout is a circular intersection with a central island, yield control for entering traffic, channelized approaches, one way continuous flow within a circulatory road way and an appropriate geometric curvature to keep circulating speed low



(FHWA,2000).

Figure 1.Round about for four approach traffic

Inscribed Circle Diameter: -The inscribed circle diameter is the distance across the circle inscribed by the outer curb (or edge) of the circulatory roadway. As stated on Table 1Recommended Inscribed Circle Diameter Ranges (FHWA 2000.) Table 1it is the sum of the central island diameter (which includes the apron, if present) and twice the circulatory roadway.

Table 1. Recommended inscribed circle diameter ranges (FHWA 2000.P.146)

Site category	Typical design vehicle	Inscribed circle diameter
Mini roundabout	Single unit truck	13-25 m (45-80 ft)
Urban roundabout	Single-unit truck/bus	25-30 m (80-100 ft)
Urban single lane	WB-15 (WB-50)	30-40 m (100-130 ft)
Urban double lane	WB-15 (WB-50)	45-55 m (150-180 ft)
Rural single lane	WB-20 (WB-67)	35-40 m (115-130 ft)
Rural double lane	WB-20 (WB-67)	55-60 m (180-200 ft)

* Assume 90-degree angle between entries and no more than four legs

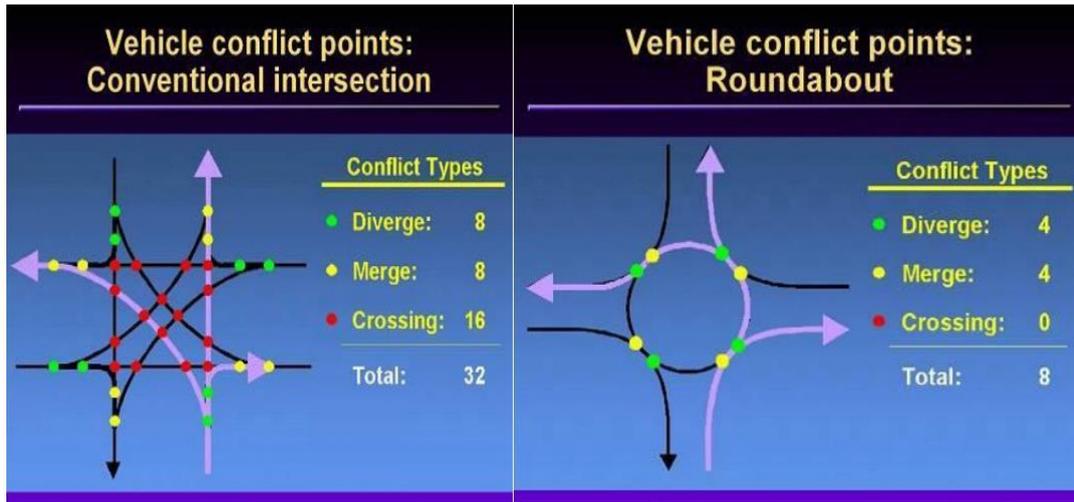


Figure 2. Vehicles conflict point (source, Mallikarjuna, 2014)

The circulating vehicles are not subjected to any other right-of-way conflicts and weaving is kept to a minimum. This provides the means by which the priority is distributed and alternated among vehicles. A vehicle entering as a subordinate vehicle immediately becomes a priority vehicle until it exits the roundabout. Some traffic circles Highway Capacity Manual 2000 Signalized Intersections impose control measures within the circulating roadway, or are designed with weaving areas to resolve conflicts between movements.

The speed at which a vehicle is able to negotiate the circulating roadway is controlled by the location of the central island with respect to the alignment of the right entry curb and the circulating roadway cross section. It is important that the speeds of vehicles on the roundabout are low. This feature is responsible for the improved safety record of roundabouts. Some large traffic circles provide straight paths for major movements or are designed for higher speeds within the circulating roadway. Some small traffic circles do not achieve adequate deflection for speed control because of the small central island diameter.

No parking is allowed on the circulating roadway. Parking maneuvers, if allowed, would prevent the roundabout from operating in a manner consistent with its design. Some larger traffic circles permit parking within the circulating roadway. No pedestrian activities take place on the central island. Pedestrians are not intended to cross the circulating roadway. Some larger traffic circles provide for pedestrian crossing to, and activities on, the central island. All vehicles circulate counterclockwise (in countries with a drive right policy), passing to the right of the central island. In some small traffic circles (sometimes called mini-traffic circles) left-turning vehicles are expected to pass to the left of the centralist. Roundabouts are designed to properly accommodate specified design vehicles. Some smaller traffic circles are often unable to accommodate large vehicles usually because of right-of-way constraints. Roundabouts have raised splitter islands on all approaches. Splitter islands area essential safety feature, required to separate traffic moving in opposite directions and to provide refuge for pedestrians. Some smaller traffic circles do not provide raised splitter islands. When pedestrian crossings are provided for on the approach roads, they are placed approximately one car length back from the entry point. Some traffic circles accommodate pedestrians in other places, such as the yield point. The entry deflection is the result of physical features of a roundabout. Some traffic circles rely on pavement markings to promote deflection.

Components of a Signal Cycle

The following terms describe portions and sub portions of a signal cycle. The most fundamental in signal design and timing is the cycle, as defined below (Roger p. et al, 2004).

Cycle: A signal cycle is one complete rotation through all of the indications provided. In general every legal vehicular movement receives a “green” indication during each cycle, although there are some exceptions to this rule.

Cycle Length: The cycle length is the time (in seconds) that it takes to complete one full cycle of indications. It is given the symbol “C.”

Interval: The interval is a period of time during which no signal indication changes. It is the smallest unit of time described within a signal cycle. There are several types of intervals with in a signal cycle (Roger p. et al, 2004).

Advantages of Traffic Signal Control

The MUTCD lists the following advantages of traffic control signals that are “properly designed, located, operated and maintained” (MUTCD.2001). These advantages include: They provide for the orderly movement of traffic, They increase the traffic handling capacity of the intersection if proper physical layouts and control measures are used and if the signal timing is reviewed and updated on a regular basis (every two years) to ensure that it satisfies the current traffic demands. They reduce the frequency and severity of certain types of crashes, especially right-angle collisions. They are coordinated to provide for continuous or nearly continuous movement at a definite speed along a given route under favorable conditions. They are used to interrupt heavy traffic at interval so permit other traffic, vehicular or pedestrian, to cross. These specific advantages address the primary reasons why a traffic signal would be installed to increase capacity (there by improving level of service), to improve safety, and to provide for orderly movement through a complex situation. Coordination of signals provides other benefits, but not all signals are necessarily coordinated and Signal timing can reduce head and rear collision do to stop and go movement during peak hour.

Disadvantages of Improperly Design Traffic Signal Control

The description of the second advantage in the fore going list indicates that capacity is increased by a well-designed signal at a well-designed intersection. Poor design of either the signalization or the geometry of the intersection can significantly reduce the benefits achieved or negate them entirely. Improperly design & traffic signals, or the placement of a signal where it is not justified, can lead to some of the following disadvantages (MUTCD.2001). Those disadvantages are Excessive delay, Excessive disobedience of the signal indications, Increased use of less adequate routes as road users attempt to avoid the traffic control signal and Significant increases in the frequency of collisions (especially rear-end collisions)

Performance Measures

There are four measures which are used to describe the performance of two-way stop- controlled intersections. These are

Delay

A critical performance measure on interrupted flow facilities is delay. There are several types of delay, but this study uses control delay as the principal service measure in evaluating level of service at signalized and un-signalized intersections. Although the definition of control delay is consistent among signalized and un-signalized intersections, its application, including LOS threshold values, differs for these facilities. Control Delay involves movements at slower speeds and stops on intersection approaches, as vehicles move up in the queue or slow down up stream of an intersection Drivers frequently reduce speed when a downstream signal is red or a queue is present at the downstream intersection approach. Control delay requires the determination of a realistic average speed for each roadway segment. It is implied in the estimates of the average travel speed on urban streets. (HCM, 2000). Roundabout scan increase delays in locations where traffic would otherwise often not be required to stop. For example, at the junction of a high-volume and a low-volume road, traffic on the congested road stop only when cross traffic was present, otherwise not having to slow for the roundabout. When the volumes on the roadways are relatively equal, around about can reduce delays, because half of the time a full stop required. Dedicated left turn signals (in countries where traffic drives on the right) further reduce through put.

Level of Service (LOS)

Level of service is a qualitative measure used to relate the quality of traffic service. LOS is used to analyze highway by categorizing traffic flow and assigning quality levels of traffic based on performance measure. The HCM defines LOS for signalized and un-signalized intersections as a function of the average vehicle control delay. LOS may be calculated per movement or per approach for any intersection configuration but LOS for the intersection as a whole is only defined for signalized and all way stop configuration. Roundabout scan reduce delays for pedestrians compared to traffic signals, because pedestrians are able to cross during any safe gap rather than waiting for a signal. During peak flows when large gaps are infrequent, the slower speed of traffic entering and exiting can still allow crossing, despite the smaller gaps. The primary measure which is used to provide an estimate of level of service (LOS) is control delay. This measure can be estimated for any movement on the minor (i.e., the stop- controlled) street.

By summing delay estimates for individual movements, a delay estimate for each minor street movement and approach can be achieved. (HCM, 2000).

Travel Time

Travel time is the time taken by a vehicle to traverse a given section of a highway. A travel time study determines the amount of time required to travel from one point to another on a given route. In conducting such a study, information may also be collected on the locations, durations, and causes of delays. When this is done, the study is known as a travel time and delay study. Data obtained from travel time and delay studies give a good indication of the level of service on the study section. These data also aid the traffic engineer in identifying problem locations, which may require special attention in order to improve the overall flow of traffic on the route (Nicholas J. Garber and Lester A. Hoel 2009).

Queue

When demand exceeds capacity for a period of time or arrival time head way is less than the service time at a specific location, a queue is formed. A queue is also formed when arrivals wait at a service area for service. This service can be the arrival of an accepted gap in a major street traffic stream, the collection of tolls at a toll booth, the payment of parking fees at a parking garage and so forth. The term back of queue refers to the number of vehicles that are queue data approach of a signalized intersection

depending on the arrival patterns of vehicles during their phase and vehicles that do not clear the intersection during a given green phase.

To mathematically predict the characteristics of a queuing system, it is necessary to specify the following system characteristics and parameters (Tan J, 2001).

- ✓ Arrival pattern characteristics including average rate of arrival and the statistical distribution of time between arrivals,
- ✓ Service facility characteristics including service time average rates and distribution and the number of customers that can be served simultaneously or number of channels available and
- ✓ Queue discipline characteristics, such as the means by which the next customer to be served is selected.

Oversaturated queues are those in which the arrival rate is higher than the service rate and under saturated queues are those in which the arrival rate is less than the service rate. The length of an under saturated queue may vary but will reach a steady state with the arrival of vehicles. The length of an oversaturated queue will, however, never reach a steady state but will continue to increase with the arrival of vehicles.

Roundabout Capacity

The capacity of round about varies based on entry angle, lane width and the number of entry and circulating lanes. As with other types of junctions, operational performance depends heavily on the flow volumes from various approaches. A single-lane roundabout can handle approximately 20,000–26,000 vehicles per day, while a two-lane design supports 40,000 to 50,000. (FHWA, 2000). Under many traffic conditions, round about operates with less delay than signalized or [all-way stop](#) approaches. Roundabouts do not stop all entering vehicles, reducing both individual and queuing delays. Through put further improves because drivers proceed when traffic is clear without waiting for a signal to change.

Roundabout can increase delays in locations where traffic would otherwise often not be required to stop. For example, at the junction of a high-volume and a low-volume road, traffic on the busier road would stop only when cross traffic was present, otherwise not having to slow for the roundabout. When the volumes on the roadways are relatively equal, a roundabout can reduce delays, because half of the time a full stop would be required. Dedicated left turn signals (in countries where traffic drives on the right) further reduce through put. Roundabouts can reduce delays for pedestrians compared to traffic signals, because pedestrians are able to cross during any safe gap rather than waiting for a signal. During peak flows when large gaps are infrequent, the slower speed of traffic entering and exiting can still allow crossing, despite the smaller gaps. Studies of roundabouts that replaced stop signs and/or traffic signals found that vehicle delays were reduced 13%–89% and the proportion of vehicles that stopped was reduced 14%– 56% percent. Delays on major approaches increased as vehicles slowed to enter the roundabouts ([IIHSHLDI](#), 2016).

Roundabouts have been found to reduce [carbon monoxide](#) emissions by 15% upto 45% percent, [nitrous oxide](#) emissions by 21% upto 44%, [carbondioxide](#) emissions by 23% upto 37% percent and [hydrocarbone](#) emissions by 0%–42% percent. Fuel consumption was reduced by an estimated 23% up to 34% percent

Traffic Volume Studies

Saturation flow rate is defined as the flow rate per lane at which vehicles can pass through. The saturation flow rate represents the number of vehicles per hour per lane that can pass through

Signalized intersections if the green signal were available for the full hour, the flow of vehicles were ever halted, and no large headways occurred at signalized intersection (HCM 2000).

Base Saturation Flow Rate

Base saturation flow rate is affected by approaching speed. Approaches with lower approaching speed (less than 50km/h) use 1800pc/h/ln and approaches with higher approaching speed (greater than 80km/h) use higher than 1900pc/h/ln. (HCM, 2000). Saturation flow rate for signalized intersection is computed using head difference and but for round about is very complicated to do an experiment (head difference due to stop and go movement). No single study in Ethiopia was conducted to have roundabout signalization and to determine base saturation flow rate.

Computations begin with these lection of a base saturation flow rate, usually 1,800 passenger cars per hour per lane (pc/h/ln) and adjust of base saturation flow rate were done for variety of existing conditions. Those adjustments are Number of lanes in the lane group, Adjustment factor for lane width (3.6 mis base condition), Adjustment factor for heavy vehicles in the traffic stream, Adjustment factor for approach grade, Adjustment factor for the existence of parking lane and parking activity adjacent to the lane group, Adjustment factor for blocking effect of local buses that stop within the intersection area, Adjustment factor for area type, Adjustment factor for lane utilization, Adjustment factor for left-turning the lane group, Adjustment factor for right-turning the lane group, Pedestrian adjustment factor for left-turning movements and Pedestrian/bicycle adjustment factor for right-turn movements. Traffic volume study is conducted to determine the number, movements and classifications of roadway vehicles at a given location.

These data can help

- ✓ To identify critical flow time periods (peak hour),
- ✓ To determine the influence of large vehicles or pedestrians on vehicular traffic flow, or
- ✓ To document traffic volume trends.

RESEARCH METHODOLOGY

Description of the Study area

This study was conducted in the roundabout of Gerji-Imperial in Addis Ababa. Addis Ababa is found in central part of Ethiopia. As the main city of the country, it is highly congested area. To conduct fixed time signal design at the Gerji-Imperial Roundabout, traffic volume is needed.



Figure 3. Gerji-Imperial Roundabout

To collect the required data, four direction intersections in Gerji-Imperial Roundabout, were manually counted. These intersections were Hayahulet ('Approach A'), Gerji ('Approach B'), Megenagna ('Approach C') and Bole ('Approach D'),

Manual Traffic Count Method

Any traffic study requires accurate traffic counts. Determining how many vehicles use a section of roadway is necessary for analyzing, designing the signals, determining capacity and estimating the level of service that will be needed. Accurate counts of current traffic flow provide a departure point for estimates of future traffic volume data. Moreover, most application of manual counts require small sample of data at selected location. Manual counts are sometimes used when the effort and expense of cost is very high. While taking the manual count we use tally method on prepared data sheet format at the selected intersection. The data for the movement of vehicle was recorded in 60 minute intervals. The traffic volume data of the selected intersections along the Gerji-Imperial Roundabout across road for 3 hours during seven consecutive days from **June 13, 2021** were collected manually.

Traffic Volume Study

Traffic volume count was conducted for seven consecutive days during peak hour and off peak hour time for the selected study areas from 7:00 am to 6:00pm. Fifteen minute traffic count was conducted to represent one hour traffic volume count. This study utilizes passenger and freight car unit as indicated to convert each vehicle type count into passenger car and freight car. Roundabout traffic volume study on respective of each study areas are majorly classified based on their turning movement. Those turning movements are U-turn movement, Left turn movement, Right turn movement and through vehicle movement. During the 1st day observation at Gerji-Imperial Roundabout traffic counted were on **June 13, 2021** at evening time for the peak hour, the traffic flow from Bole approach exhibit high traffic volume and from **Gerji** (Approach B) were observed the minim traffic flow at lunch time shown in the Table 2 below

Table 2. Traffic volume data of Gerji-Imperial Roundabout counted on June 13, 2021

Time period		Hayahulet (Approach A)		Gerji (Approach B)		Megenagna (Approach C)		Bole (Approach D)		
Fro M	To	Freight car	Passenger car	Freight car	Passenger car	Freight car	Passenger car	Freight car	Passenger car	
1	7:00 AM	7:15AM	24	167	75	210	40	92	106	289
2	7:15 AM	7:30AM	23	73	55	70	39	154	94	350
3	7:30 AM	7:45AM	21	254	65	115	24	176	98	311
4	7:45 AM	8:00AM	23	210	76	165	45	167	43	389
1	12:00PM	12:15PM	22	156	69	125	31	83	86	365
2	12:15PM	12:30PM	12	87	39	57	59	153	75	298
3	12:30PM	12:45PM	22	265	56	105	37	145	87	263
4	12:45PM	1:00PM	27	220	79	151	38	172	97	369
1	5:00PM	5:15PM	31	194	76	159	33	83	96	389
2	5:15PM	5:30PM	29	143	54	60	29	121	94	294
3	5:30PM	5:45PM	19	212	67	99	32	143	89	201
4	5:45PM	6:00PM	26	238	59	163	32	143	88	391

The 2nd day observation at Gerji-Imperial Roundabout counted on **June 14, 2021** at morning time for the peak hour, the traffic

Time period		Hayahulet (Approach A)		Gerji (Approach B)		Megenagna (Approach C)		Bole (Approach D)	
From	To	Freight car	Passenger car	Freight car	Passenger car	Freight car	Passenger car	Freight car	Passenger car
7:00 AM	7:15AM	21	187	85	167	40	92	101	412
7:15 AM	7:30AM	12	73	55	70	39	132	94	290
7:30 AM	7:45AM	19	254	89	121	24	147	98	284
7:45 AM	8:00AM	22	212	87	174	39	145	105	392
12:00PM	12:15PM	23	157	85	126	27	92	86	381
12:15PM	12:30PM	26	99	49	67	59	154	84	265
12:30PM	12:45PM	23	263	69	111	27	147	93	235
12:45PM	1:00PM	25	212	78	159	42	153	97	342
5:00PM	5:15PM	27	183	85	140	35	83	96	396
5:15PM	5:30PM	18	136	53	70	38	139	94	255
5:30PM	5:45PM	26	232	95	101	33	136	99	243
5:45PM	6:00AM	35	229	69	145	43	152	107	381

flow study cover from Bole (Approach D) since it has high traffic volume in addition from Megenagna (Approach C) were observed the minim traffic flow at evening time shown in the Table 3 below

Table 3. Traffic Volume data of Gerji-Imperial Roundabout counted in June 14, 2021

During the 3rd day observation at Gerji-Imperial Roundabout traffic volume counted on **June 15, 2021** at evening time for the peak hour, the traffic flow from Bole (Approach D) has high traffic volume. This traffic volume were used for the design purpose because the peak hour volume count held at 11:00PM up to 12:00 PM since it governed, but from Megenagna (Approach C) has the minimum traffic flow at morning shown in the Table 4 below

Table 4. Traffic Volume Data of Gerji-Imperial Roundabout counted in June 15, 2021

No	Time period		Hayahulet (Approach A)		Gerji (Approach B)		Megenagna (Approach C)		Bole (Approach D)	
	From	To	Freight Car	Passenger car	Freight car	Passenger car	Freight car	Passenger car	Freight car	Passenger car
1	7:00 AM	7:15AM	23	167	85	150	50	92	106	363
2	7:15 AM	7:30AM	19	83	65	70	49	132	94	270
3	7:30 AM	7:45AM	21	244	75	125	24	139	75	254
4	7:45 AM	8:00AM	23	108	87	159	46	155	104	372
1	12:00PM	12:15PM	19	137	85	121	36	83	96	331
2	12:15PM	12:30PM	24	97	59	87	99	151	74	245
3	12:30PM	12:45PM	33	253	79	126	27	150	87	234
4	12:45PM	1:00PM	20	232	99	199	92	193	110	362
1	5:00PM	5:15PM	37	243	75	140	43	138	96	386
2	5:15PM	5:30PM	32	126	73	89	39	131	123	265
3	5:30PM	5:45PM	38	263	78	171	43	136	108	271
4	5:45PM	6:00PM	54	292	99	195	121	172	119	341

During the 4th day observation at Gerji-Imperial Roundabout the traffic volume were counted on **June 16, 2021** at evening time for the peak hour, the traffic flow from Bole (Approach D) approach has high traffic volume and from Megenagna (Approach C) has the minimum traffic flow at evening time shown in the Table.5 below

Table 5. Traffic Volume Data of Gerji-Imperial Roundabout counted in June 16, 2021

No	Time period		Hayahulet (Approach A)		Gerji (Approach B)		Megenagna (Approach C)		Bole (Approach D)	
	From	To	Freight car	Passenger car	Freight car	Passenger car	Freight car	Passenger car	Freight car	Passenger car
1	7:00 AM	7:15AM	25	177	95	170	60	92	106	353
2	7:15 AM	7:30AM	19	73	65	80	59	142	94	280
3	7:30 AM	7:45AM	23	254	85	121	34	139	95	254
4	7:45 AM	8:00AM	22	108	87	179	46	145	103	382
1	12:00PM	12:15PM	29	157	85	121	39	83	96	331
2	12:15PM	12:30PM	16	87	49	67	59	121	74	225
3	12:30PM	12:45PM	33	263	79	95	37	150	97	244
4	12:45PM	1:00PM	19	204	89	149	62	173	98	352
1	5:00PM	5:15PM	28	183	85	140	35	93	96	396

2	5:15PM	5:30PM	25	146	53	70	49	132	89	255
3	5:30PM	5:45PM	26	220	75	104	33	146	87	254
4	5:45PM	6:00AM	24	231	78	135	43	132	87	391

During the 5th day observation at Gerji-Imperial Roundabout the traffic volume were counted on **June 17, 2021** at morning time for the peak hour, the traffic flow from **Bole (Approach D)** has high traffic volume and from **Megenagna (Approach C)** has the minimum traffic flow at evening time shown in the Table .6 below



Table 6. Traffic Volume Data of Gerji-Imperial Roundabout counted in June 17, 2021

No	Time period		Hayahulet (Approach A)		Gerji (Approach B)		Megenagna (Approach C)		Bole (Approach D)	
	From	To	Freight Car	Passenger car	Freight car	Passenger car	Freight car	Passenger car	Freight car	Passenger car
1	7:00 AM	7:15AM	29	267	181	189	29	97	96	383
2	7:15 AM	7:30AM	21	88	55	59	39	152	76	267
3	7:30 AM	7:45AM	19	244	65	105	18	139	65	324
4	7:45 AM	8:00AM	9	201	45	144	27	135	97	372
1	12:00PM	12:15PM	13	135	35	108	24	83	69	341
2	12:15PM	12:30PM	9	77	79	67	19	121	64	265
3	12:30PM	12:45PM	17	263	56	87	37	144	43	255
4	12:45PM	1:00PM	11	198	51	139	25	143	67	352
1	5:00PM	5:15PM	15	173	58	140	16	68	76	386
2	5:15PM	5:30PM	8	116	43	50	29	97	54	295
3	5:30PM	5:45PM	2	199	54	105	33	136	57	264
4	5:45PM	6:00AM	21	209	69	125	43	132	67	376

During the 6th day observation at Gerji-Imperial Roundabout the traffic volume were counted on **June 18, 2021** at morning time for the peak hour, the traffic flow from **Bole (Approach D)** has high traffic volume and from Megenagna (Approach C) has the minim traffic flow at evening time shown in the Table.7 below

Table 7. Traffic Volume Data of Gerji-Imperial Roundabout counted in June 18, 2021

No	Time period		Hayahulet (Approach A)		Gerji (Approach B)		Megenagna (Approach C)		Bole (Approach D)	
	From	To	Freight Car	Passenger	Freight	Passenger	Freight	Passenger	Freight	Passenger
1	7:00 AM	7:15AM	12	147	65	120	20	72	86	333
2	7:15 AM	7:30AM	3	53	35	50	29	112	74	250
3	7:30 AM	7:45AM	10	214	55	95	14	119	75	234
4	7:45 AM	8:00AM	8	188	57	139	26	125	87	352
1	12:00PM	12:15PM	9	127	55	98	19	63	66	301
2	12:15PM	12:30PM	6	67	29	47	39	101	54	205
3	12:30PM	12:45PM	13	233	49	85	17	120	67	214
4	12:45PM	1:00PM	7	198	59	129	22	133	77	312
1	5:00PM	5:15PM	11	153	55	110	15	63	66	366
2	5:15PM	5:30PM	5	106	33	40	19	99	74	225
3	5:30PM	5:45PM	8	189	45	85	13	106	67	214
4	5:45PM	6:00AM	14	199	49	105	23	102	77	361

During the 7th day observation at Gerji-Imperial Roundabout the traffic volume were counted on **June 19, 2021** at morning time for the peak hour, the traffic flow from **Bole (Approach D)** has high traffic volume and from Megenagna (Approach C) has the minim traffic flow at evening time shown in the Table 8 below

Table 8. Traffic Volume Data of Gerji-Imperial Roundabout counted in June 19, 2021

No	Time period		Hayahulet (Approach A)		Gerji (Approach B)		Megenagna (Approach C)		Bole (Approach D)	
	From	To	Freight Car	Passenger	Freight	Passenger	Freight	Passenger	Freight	Passenger
1	7:00 AM	7:15AM	7	104	49	101	17	66	66	257
2	7:15 AM	7:30AM	2	43	25	47	19	102	64	199
3	7:30 AM	7:45AM	7	197	45	77	9	109	65	197
4	7:45 AM	8:00AM	6	147	47	119	21	112	59	302

1	12:00PM	12:15PM	7	99	49	91	13	53	56	277
2	12:15PM	12:30PM	4	47	19	37	29	97	44	186
3	12:30PM	12:45PM	11	183	39	59	15	93	57	188
4	12:45PM	1:00PM	5	178	39	109	18	103	67	292
1	5:00PM	5:15PM	9	103	45	97	11	53	46	306
2	5:15PM	5:30PM	3	85	23	37	13	79	64	175
3	5:30PM	5:45PM	7	153	33	71	9	96	57	189
4	5:45PM	6:00PM	6	109	19	98	19	99	87	261

The peak hour traffic volumes were counted from 5pm to 6 pm on the day of **June 15, 2021**. This was described on table 3 above, with pink color. Therefore, the traffic signal designs were analyzed and computed by utilizing the mentioned data.

Design Approach and Input Data

To design a signal, we have some of data those should be collected around the Gerji-Imperial Roundabout. After collecting data, appropriate design was come up using Webster formula. For this design Webster approach is used. Where is the discharge headway(s); is the driver response time (s); is queue space per vehicle (include vehicle length, m); is the queued vehicle speed (m/s). From this, saturation time headway and Saturation flow are important one. According to (Shao & Liu, 2012) Discharge headways at signalized intersections are defined as the time intervals between two successive vehicles passing a stop line or any predetermined reference line at the intersections, spacing between vehicle in queue and queue discharge speed are here in following

$$h_{avg} = 1/n \sum_{i=0}^n h_{si} \text{-----e.q 1}$$

Where, h_{avg} is the saturation headway; h_{si} is the headway of vehicle i in the queue $i=1, 2, 3,4$ etc. And, consequently, the saturation flow rate is determined by the saturation headway:

$$S=3600/h_{avg}$$

Where, S is the saturation flow rate (veh/h). Peak-hour factor (PHF) is a measure of the variability of demand during the peak hour.

$$PHF = \frac{\text{Volume during peak hour}}{4 * \text{Volume during peak 15 min within peak hour}} \text{----- eq 2}$$

The PHF may be used in signal timing design to compensate for the possibility that peak arrival rates for short periods during the peak hour may be much higher than the average for the full hour. Design hourly volume (DHV) can then be obtained as

$$DHV = \frac{\text{peak hour volume}}{PHF} \text{-----eq 3}$$

Webster Method. Webster has shown that for a wide range of practical conditions minimum intersection delay is obtained when the cycle length is obtained by the equation

$$CO = \frac{1.5L+5}{1 - \sum_{i=1}^f Y_i} \text{-----eq 4}$$

Where

Co = optimum cycle length

L = total lost time per cycle

Y_i = maximum value of the ratios of approach flows to saturation flows for all lane groups using phase i (i.e., q_{ij}/S_j)

f = number of phases

q_{ij} = flow on lane groups having the right of way during phase i

S_j = saturation flow on lane group j

Total Lost Time is vehicles loose a various times during a green phase of a signal cycle at an intersection. Sometime it lost before the vehicles start moving

$$l_i = G_{ai} + T_i - G_{ei} \text{-----eq 5}$$

Where

l_i = lost time for phase i

G_{ai} = actual green time for phase i not including yellow time²

T_i =yellow time for phase i

G_{ei} =effective green time for phase i

$$d_j = \left(\frac{CA+B}{V_j} \right) \frac{100-p}{100} \text{eq6}$$

Where;

d_j =average delay per vehicle in j th approach during i th phase

$$A = \frac{(1 - \lambda i)^2}{2(1 - \lambda i x_j)}$$

$$B = \frac{x_j^2}{2(1 - x_j)}$$

C=cycle length 1sec

V_j = actual volume on jth approach 1vehicles/lane/sec

λ=proportion of cycle length that is effectively green (that is, G_{ei}/C, where

G_{ei} is effective green time for phase i)

x_j = degree of saturation for the jth approach =V_j/ λ s_j

s_j = saturation flow for the jth approach vehicles/lane/sec

P = percentage correction, ranging from 5 percent to 15 percent.

the λ value would be calculated by the ratio of effective green time to total cycle length of all phase

$$\tau_{\min} = \delta + \frac{W + L}{u_0} + \frac{u_0}{2(a + Gg)} \dots \dots \dots eq7$$

Where

w=width of intersection in m

L=length of vehicle in m

δ=perception reaction time in sec

a, =constant rate of braking declaration in m/s²

g=gravitational acceleration

G= Grade of the approach

RESULTS AND DISCUSSIONS

Traffic signals are designed to ensure an orderly flow of traffic, provide an opportunity for pedestrians or vehicles to cross an intersection and help reduce the number of conflicts between vehicles entering intersections from different directions. Properly designed, located and maintained traffic signals have one or more of these advantages:

- ✓ Provide for orderly movement of traffic;
- ✓ Increase traffic-handling capacity of an intersection;
- ✓ Reduce frequency and severity of certain types of crashes, especially right-angle collisions;
- ✓ Provide for continuous movement of traffic at a definite speed along a given route;
- ✓ Interrupt heavy traffic at intervals to permit other vehicles or pedestrians to cross.

Fixed-time signals follow a predetermined sequence of signal operation, always providing the same amount of time to each traffic movement, whether traffic is present or not. Actuated signals change the lights according to the amount of traffic in each direction. They use various types of sensors to detect vehicles, and adjust the length of the green time to allow as many vehicles as possible through the intersection before responding to the presence of vehicles on another approach.

Signal timing and design involve several important components, including the physical design and layout of the intersection itself. The key elements in signal design and timing are:

- ✓ Development of safe and effective phase plan and sequence
- ✓ Determination of vehicular signal needs:
 - Timing of “Yellow” (change) and “all red” (clearance) intervals for each signal phase
 - Determination of the sum of critical lane
 - Allocation of effective green time to the various phases defined in the phase plan

Current Traffic Condition around Gerji-Imperial Roundabout

Based on this study, there were high traffic congestion during the morning, lunch time and evening time. Moreover the topography of the study area has made its own contribution to traffic congestion due to high grade slope from Bole road. Whenever the data was taken from the traffic polices about the traffic condition in the area orally, they respond that traffic operation is performed by four traffic police man at each approach for serving pedestrians and vehicles. According to the study conducted at Gerji-Imperial Roundabout there were inefficient drainage condition, improper pedestrian crossing, there is also tendency of vehicle accident. Gerji-Imperial Roundabout the current geometric condition, traffic delay and saturation flow rate was discussed in sections 7.3 in detail as follows:

The capacity of Gerji Imperial Roundabout is inadequate to control traffic flow at peak hour time due to the following problems observed;

- ✓ Inadequacy of inscribed circle diameter;
- ✓ Unbalanced traffic flow;
- ✓ Percentage of heavy traffic; and
- ✓ Pedestrian volume.

Hence, this is also one of the problems that have great impact on the capacity and other factors that have impact on Level of Service at Gerji Imperial Roundabout since the junction connects high speed primary Bole to Megenagna road and Gerji to Hayahulet access road. Furthermore, the percentage of heavy vehicle which is greater than 5% and the pedestrian number is high and separate pedestrian cross is not provided; as a result, the pedestrian conflict with vehicle at approaches reduce speed and increases delay at junction lowering the Level of Service of the roundabout. Therefore currently at peak hour the Gerji- Imperial Roundabout is not functioning well and so traffic police man regulates traffic flow.

Level of Service for Gerji-Imperial Roundabout

Level of service is a qualitative measure used to relate the quality of traffic service. LOS is used to analyze highway by categorizing traffic flow and assigning quality levels of traffic based on performance measure. The HCM defines LOS for signalized and un-signalized intersections as a function of the average vehicle control delay is stated on Table 2. LOS may be calculated per movement or per approach for any intersection configuration but LOS for the intersection as a whole is only defined for signalized and all way stop configuration.

Delay at Signalized Intersections

One of the main objectives of installing a signal system at an intersection is to reduce the average delay of vehicles at the intersection. Delay is therefore an important measure of effectiveness to use in the evaluation of a signalized intersection. Delay at a signalized intersection can be estimated by using an expression developed by Webster and given in Eq. 6. It gives the average delay experienced per vehicle on the jth approach during the ith phase, assuming a uniform arrival of vehicles at the intersection.

$$d_j = \left(\frac{CA+B}{V_j} \right) \frac{100-p}{100}$$

Where;

d_j = average delay per vehicle in jth approach during ith phase

$$A = \frac{(1 - \lambda_i)^2}{2(1 - \lambda_i x_j)}$$

$$B = \frac{x_j^2}{2(1 - x_j)}$$

C = cycle length 1sec

V_j = actual volume on jth approach 1vehicles/lane/sec

λ = proportion of cycle length that is effectively green (that is, G_{ei}/C , where G_{ei} is effective green time for phase i)

x_j = degree of saturation for the jth approach = $V_j / \lambda s_j$

s_j = saturation flow for the jth approach vehicles/lane/sec

P = percentage correction, ranging from 5 percent to 15 percent.

the λ value would be calculated by the ratio of effective green time to total cycle length of all phase

$$\lambda A = \frac{43}{180} = 0.24$$

$$\lambda B = \frac{41}{180} = 0.23$$

$$\lambda C = \frac{43}{180} = 0.2$$

$$\lambda D = \frac{39}{180} = 0.22$$

Then, x_j the degree of saturation would be computed for each phase

For phase A

$$\text{Lane } x_1 = \frac{192}{0.24 \cdot 1925} = 0.415$$

$$x_2 = \frac{412}{0.24 \cdot 1856} = 0.925$$

$$x_3 = \frac{219}{0.24 \cdot 1935} = 0.472$$

For phase B

$$\text{Lane } x_1 = \frac{129}{0.23 \cdot 1905} = 0.294$$

$$x_2 = \frac{731}{0.23 \cdot 3462} = 0.918$$

$$x_3 = \frac{846}{0.23 \cdot 5143} = 0.715$$

For phase C

$$\begin{aligned} \text{Lane } x1 &= \frac{603}{0.24*2791}=0.900 \\ x2 &= \frac{284}{0.24*1915}=0.617 \\ x3 &= \frac{198}{0.24*1989}=0.415 \end{aligned}$$

For phase D

$$\begin{aligned} \text{Lane } x1 &= \frac{329}{0.22*2011}=0.744 \\ x2 &= \frac{418}{0.22*2093}=0.907 \\ x3 &= \frac{173}{0.22*1989}=0.395 \end{aligned}$$

After calculating x_j the degree of saturation and the λ value for each phase the constant A and B would be computed using equation.

To calculate the constant value of A by using the equation

$$A = \frac{(1 - \lambda_i)^2}{2(1 - \lambda_{ixj})}$$

For phase A,

$$\begin{aligned} \text{Lane } 1A &= \frac{(1-0.24)^2}{2(1-0.24*0.415)} = 0.32 \\ 2A &= \frac{(1-0.24)^2}{2(1-0.24*0.925)} = 0.370 \\ 3A &= \frac{(1-0.24)^2}{2(1-0.24*0.472)} = 0.371 \end{aligned}$$

For phase B

$$\begin{aligned} \text{Lane } 1A &= \frac{(1-0.24)^2}{2(1-0.24*0.294)} = 0.31 \\ 2A &= \frac{(1-0.23)^2}{2(1-0.23*0.918)} = 0.376 \\ 3A &= \frac{(1-0.24)^2}{2(1-0.24*0.715)} = 0.348 \end{aligned}$$

For phase C

$$\begin{aligned} \text{Lane } 1A &= \frac{(1-0.24)^2}{2(1-0.24*0.9)} = 0.388 \\ 2A &= \frac{(1-0.24)^2}{2(1-0.24*0.617)} = 0.338 \\ 3A &= \frac{(1-0.24)^2}{2(1-0.24*0.415)} = 0.32 \end{aligned}$$

For phase D

$$\begin{aligned} \text{Lane } 1A &= \frac{(1-0.24)^2}{2(1-0.24*0.744)} = 0.352 \\ 2A &= \frac{(1-0.22)^2}{2(1-0.22*0.907)} = 0.380 \\ 3A &= \frac{(1-0.24)^2}{2(1-0.24*0.395)} = 0.319 \end{aligned}$$

to calculate the constant value of B by using the equation

$$B = \frac{x_j^2}{2(1 - x_j)}$$

For phase A

$$\begin{aligned} \text{Lane } 1B &= \frac{0.415^2}{2(1-0.415)} = 0.147 \\ 2B &= \frac{0.925^2}{2(1-0.925)} = 5.704 \\ 3B &= \frac{0.472^2}{2(1-0.472)} = 0.21 \end{aligned}$$

For phase B

$$\begin{aligned} \text{Lane } 1B &= \frac{0.294^2}{2(1-0.294)} = 0.06 \\ 2B &= \frac{0.918^2}{2(1-0.918)} = 5.14 \end{aligned}$$

$$3 \quad B = \frac{0.715^2}{2(1-0.715)} = 0.897$$

For phase C

$$\text{Lane 1} \quad B = \frac{0.9^2}{2(1-0.9)} = 4.05$$

$$2 \quad B = \frac{0.617^2}{2(1-0.617)} = 0.497$$

$$3 \quad B = \frac{0.415^2}{2(1-0.415)} = 0.14$$

For phase D

$$\text{Lane} \quad 1B = \frac{0.744^2}{2(1-0.744)} = 1.08$$

$$2B = \frac{0.907^2}{2(1-0.907)} = 4.42$$

$$3 \quad B = \frac{0.395^2}{2(1-0.395)} = 0.129$$

Finally the average delay would be computed for each phase using the equation

Assume p, percentage correction is 12%

$$d_j = \left(CA + \frac{B}{v_j} \right) \frac{100-p}{100}$$

For phase A the delay

$$\text{Lane} \quad d1 = \left(180 * 0.32 + \frac{0.147}{192} \right) \frac{100-12}{100} = 50.69 \text{sec}$$

$$d2 = \left(180 * 0.37 + \frac{5.704}{412} \right) \frac{100-12}{100} = 58.61 \text{sec}$$

$$d3 = \left(180 * 0.371 + \frac{0.21}{219} \right) \frac{100-12}{100} = 58.76 \text{sec}$$

For phase B the delay ;

$$\text{Lane} \quad d1 = \left(180 * 0.31 + \frac{0.06}{129} \right) \frac{100-12}{100} = 49.10 \text{sec}$$

$$d2 = \left(180 * 0.376 + \frac{5.14}{731} \right) \frac{100-12}{100} = 59.56 \text{sec}$$

$$d3 = \left(180 * 0.348 + \frac{0.897}{846} \right) \frac{100-12}{100} = 55.12 \text{sec}$$

For phase C the delay will be

$$\text{Lane} \quad d1 = \left(180 * 0.388 + \frac{4.05}{603} \right) \frac{100-12}{100} = 61.5 \text{sec}$$

$$d2 = \left(180 * 0.338 + \frac{0.497}{284} \right) \frac{100-12}{100} = 53.5 \text{sec}$$

$$d3 = \left(180 * 0.32 + \frac{0.147}{198} \right) \frac{100-12}{100} = 50.68 \text{sec}$$

For phase D the delay

$$\text{Lane} \quad d1 = \left(180 * 0.352 + \frac{1.08}{329} \right) \frac{100-12}{100} = 55.76 \text{sec}$$

$$d2 = \left(180 * 0.38 + \frac{4.42}{418} \right) \frac{100-12}{100} = 60.2 \text{sec}$$

$$d3 = \left(180 * 0.319 + \frac{0.129}{173} \right) \frac{100-12}{100} = 50.53 \text{sec}$$

According to Highway capacity manual level of service can be indicated by the delay time in the intersection. The following table shows it the delay amount from less of 10 second to above 80 second for signalized intersection. For these delay time the LOS is indicated by A to F. 'A' indicated as there is no delay, because the time taken for signalized intersection is less than 10 second.

Table 9. Level of criteria (Source HCM, 2000)

LOS	Signalized Intersection delay	Un signalized Intersection
A	≤ 10 sec	≤ 10 sec
B	10-20 sec	10-25 sec
C	20-35 sec	15-25 sec
D	35-55 sec	25-35 sec
E	55-80 sec	35-50 sec
F	>80 sec	>50 sec

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Based on the level of service criteria, the following table is designed to show the level of service (LOS) in Gerji-Imperial Roundabout by the assessment in case of signalized (future condition, or after the signal design) and un signalized (current condition).

Table10. Level of service evaluation result at Gerji-Imperial Roundabout

<i>Current condition (un signalized condition)</i>												
<i>Approach</i>	<i>Phase A</i>			<i>Phase B</i>			<i>Phase C</i>			<i>Phase D</i>		
	<i>West bound</i>			<i>South bound</i>			<i>East bound</i>			<i>North bound</i>		
<i>Movement</i>	<i>LT</i>	<i>TH</i>	<i>RT</i>	<i>LT</i>	<i>TH</i>	<i>RT</i>	<i>LT</i>	<i>TH</i>	<i>RT</i>	<i>LT</i>	<i>TH</i>	<i>RT</i>
<i>Lane LOS</i>	F	F	E	F	F	F	F	F	F	F	F	F
<i>Approach LOS</i>	F			F			F			F		
<i>Intersection LOS</i>	F											
<i>Future Condition(signalized condition)</i>												
<i>Approach</i>	<i>Torhailoch</i>			<i>Bisrategebreiel</i>			<i>Sarbet</i>			<i>Lideta</i>		
	<i>West bound</i>			<i>South bound</i>			<i>East bound</i>			<i>North bound</i>		
<i>Movement</i>	<i>LT</i>	<i>TH</i>	<i>RT</i>	<i>LT</i>	<i>TH</i>	<i>RT</i>	<i>LT</i>	<i>TH</i>	<i>RT</i>	<i>LT</i>	<i>TH</i>	<i>RT</i>
<i>Lane LOS</i>	D	E	E	D	E	E	E	D	D	E	E	D
<i>Approach LOS</i>	E			E			D			E		
<i>Intersection LOS</i>	E											

The above table shows that signalized intersection has less delay time. The signalized table is indicated by E and D for each lane. But for round about (un signalized intersection, that is the current condition) is indicated by E and F (See table 10).

In each approach while the future condition in **LOS was E** which means the average delays at each approach is moderate. Therefore signalized intersection would be proposed at the study area instead of roundabout to give immediate solution for traffic congestion.

Pedestrian Volume Study: - Pedestrian volumes were observed during morning rush hour (AM peak hour) and afternoon rush hour (PM peak hour) for each fifteen minutes. This study incorporates pedestrian volume crosses each roundabout legs.

Roundabouts Geometry Study: -Roundabout geometry study is vital for computation of saturation flow rate, for allocation of traffic signal timing and for roundabout simulation. Those collected data were Approaching road gradient (road profile), approaching Lane width (carriage way), number of Approaching lanes and legs, number of circulating lanes, inscribed circle diameter, exit and entry radius. Methods used to collect those data were Google-earth map and manual tape.

Saturation Flow Rate: -A saturation flow rate for each lane group is computed according with average headway. Those factors are as a function of roundabout geometry, traffic volume and study area. Therefore this table is useful for computation of roundabout approaching saturation flow rate.**Signal Design**

Traffic signal timing allocation is used on this study as a primary mitigation solution to regulate traffic flow at intersection instead of roundabouts. In Table 14 results of traffic signal timing is presented which includes, vehicular green time, yellow interval and all red interval. Vehicular green time interval on major approaches (Bole, Gerji , Megenagna ,Hayahulet) and from this approach has relatively highest green time because of in excess of traffic volume and higher saturation flow rate as indicated in Figure 14 and Table 13 respectively. Yellow interval for all approaches doesn't show significant variation but it is as a function of 85th percentile speed and approaching grade. Thus change in speed and approaching grade may show variation relatively to the other approaches. Allred interval increment was due to lengthy roundabout geometry to cross from one approach to the other far side to dissipate and 15th percentile speed decrement leads to have highest all red values.

Signal design control vehicle and pedestrian traffic by assigning priorities to various traffic movements to influence traffic flow. Properly designed, located and maintained traffic signals have one or more of these advantages:

- ✓ Provide for orderly movement of traffic;
- ✓ Increase traffic-handling capacity of an intersection;
- ✓ Reduce frequency and severity of certain types of crashes, especially right-angle collisions;
- ✓ Provide for continuous movement of traffic at a definite speed along a given route;
- ✓ Interrupt heavy traffic at intervals to permit other vehicles or pedestrians to cross.

Time head way and saturation flow

Time head way is the time interval among consecutive vehicles in the highway as well as in the intersection. For this study, the average time head way is taken by considering 21 vehicles those can make 20 consecutive head time in the intersection for each approach lane.

Table 11. Time headway estimation from consecutive vehicles of phase

	Approach A			Approach B			Approach C			Approach D		
	Lane 1	Lane 2	Lane 3	Lane 1	Lane 2	Lane 3	Lane 1	Lane 2	Lane 3	Lane 1	Lane 2	Lane 3
V1t-V2t	1.8	2	1.6	1.9	1.2	0.9	1.4	2	2.1	2	1.5	2
V2t-V3t	2	2	2.3	2	1	0.78	1.35	2.1	2	1.36	1.4	2.1
V3t-V4t	2.2	1.5	1.4	1.8	0.8	0.89	1.45	1.4	1.96	1.5	1.8	1.9
V4t-V5t	1.65	1.85	1.5	2.1	1	0.88	1.5	1.9	1.7	2.1	1.7	1.5
V5t-V6t	2.3	2.12	1.7	2.2	0.9	0.58	1.6	2	1.5	1.96	1.6	1.76
V6t-V7t	1.5	1.9	2.1	1.8	0.7	0.59	1.2	2.1	2	2.1	1.7	2.1
V7t-V8t	1.76	2.1	2.3	1.8	1.2	0.6	1.3	2	2.1	1.56	1.8	2
V8t-V9t	1.8	2.12	1.9	1.7	1.1	0.79	1.4	1.5	1.7	1.7	1.7	1.4
V9t-V10t	2	1.85	1.8	1.6	0.85	0.8	1.3	1.6	1.8	1.8	1.9	1.3
V10t-V11t	1.9	1.99	1.9	2.1	1.2	0.7	1.5	1.9	1.6	2	1.5	1.6
V11t-V12t	1.4	2.21	2.2	1.6	1.15	0.65	1.45	2	1.4	1.9	1.8	1.76
V12t-V13t	2.12	2.31	2.1	1.8	1.3	0.75	1.25	2.1	1.5	1.8	1.9	1.89
V13t-V14t	2.1	1.92	1.8	1.6	0.95	0.56	1.3	1.95	1.8	1.7	1.8	1.9
V14t-V15t	1.9	1.45	1.5	1.6	1	0.9	1.4	1.85	1.7	2	1.8	1.46
V15t-V16t	1.4	2.1	1.6	2	0.78	0.4	1.3	1.8	1.5	1.4	1.7	1.7
V16t-V17t	1.5	2.08	2	2.3	0.98	0.3	1.2	1.84	1.6	2	1.76	2.1
V17t-V18t	2.23	2.12	1.8	2.1	1.1	0.7	1.3	1.7	2	1.4	1.78	2.2
V18t-V19t	1.8	1.9	1.6	2	1.25	0.6	1.5	2	2.1	1.6	1.46	2.06
V19t-V20t	2.1	1.8	2.1	1.9	1.2	0.8	1.2	2.1	2	2	2	1.7
V20t-V21t	1.87	1.65	2	1.9	1.4	0.85	1.4	1.76	2.1	2.1	1.8	1.8

Based on the equation, $avg = 1/n \sum_{i=0}^n hsi$
The following results are calculated.

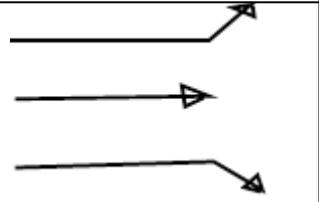
Table 12. Average head way for each lane. in Karl Square.

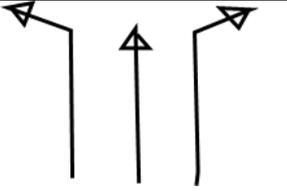
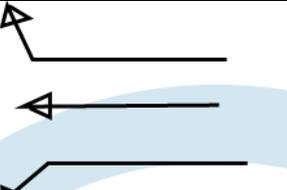
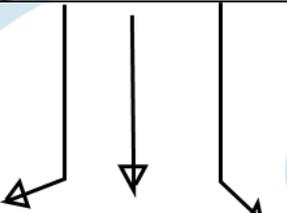
	Phase A	Phase B	Phase C	Phase D
Lane 1	1.87	1.89	1.29	1.79
Lane 2	1.94	1.04	1.88	1.72
Lane 3	1.86	0.7	1.81	1.81

The saturation flow is the number of vehicle that is saturated in the lane for each approach. The unit is veh/hr. Saturation flow for signalized intersection is computed using saturated headway time. The estimation system of saturation flow is based on the estimation saturation headway. Saturation flow is the inverse of saturated time head way

$S=1/t$ is in second, for normal unit of saturation flow second should change to hrs, (1/3600hrs) therefore; Saturation flow=3600/t veh/hrs.

Table 13. Saturation flow for each lane in Gerji Roundabout

Phase	Lane Group	Saturation flow
A		1925 1856 1935

B		1905 3462 5143
C		2791 1915 1989
D		2011 2093 1989

Peak hour factor (PHF): indicates peak one hour traffic data collection and peak hour factor value for Gerji-Imperial Roundabout. The peak hour factor (PHF) is the hourly volume during the maximum-volume hour of the day divided by the peak 15-minute flow rate within the peak hour. It is also a measure of traffic demand fluctuations within the peak hour.

When peak hour approximate to one, means one hour traffic volume data variability is for each 15 minute period is minimum, which leads to equal amount of traffic volume was observed for one hour peak period. Demand fluctuation at Bole approach is relatively small due to PHF highest value. Use of peak hour factor ensures that the timing is appropriate for the peak 15 minutes of the design hour.

Where taking the equation 2 previously:

$$PHF = \frac{\text{Volume during peak hour}}{4 * \text{Volume during peak 15 min within peak hour}}$$

$$= \frac{1709}{4 * 482} = 0.89$$

The 3rd day traffic count data from 5:45PM up to 6:00 PM there is maximum number of traffic volume from Bole approach and there is minimum number traffic volume from 5:00PM to 5:15 PM Hayahulet Approach.

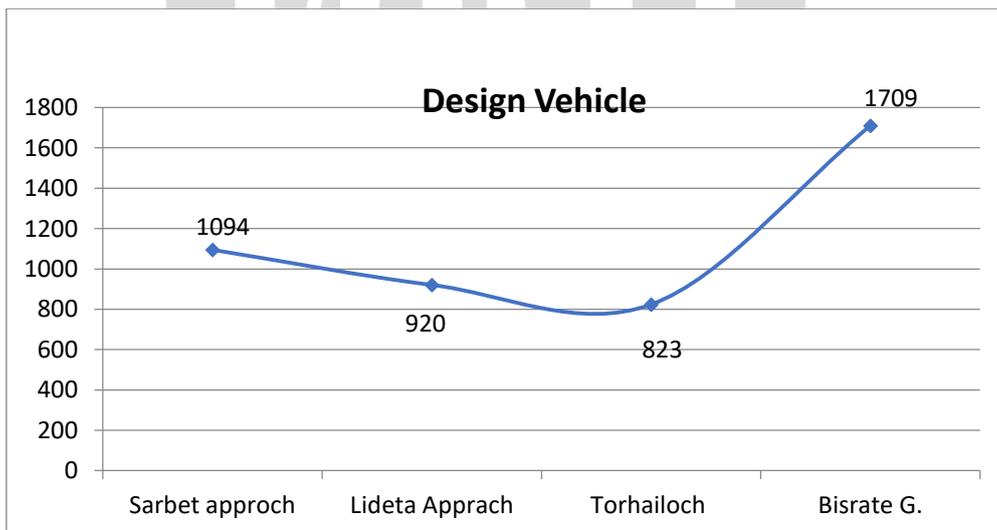


Figure 4. Design vehicle for signal design

The traffic volumes counted at Gerji-Imperial Roundabout for each approach were considering the manual count method. This traffic volume were collected at evening time from Bisrate Gebriel -Karl square, Torhailoch- Karl square, Lideta - Karl square and Sarbet- Karl square used for the sake of hourly design purpose and also it describes the total traffic volume for each lane.

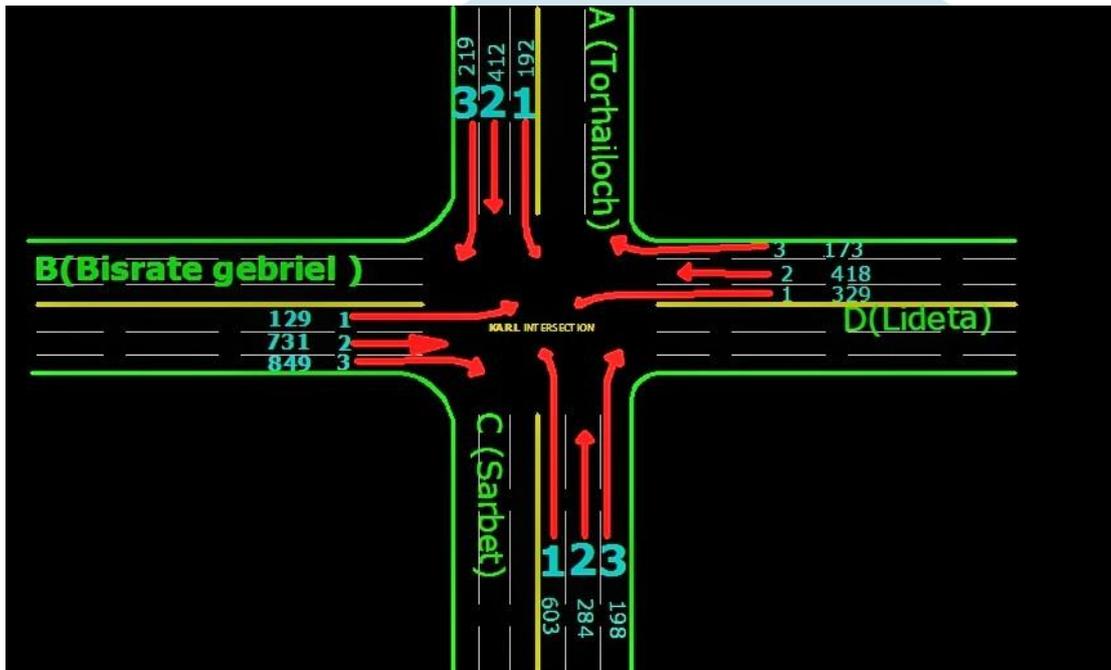


Figure 5. Traffic Volume for each approach in Gerji-Imperial Roundabout

Equivalent Factor for Left and Right Turn Vehicles: To estimate an appropriate cycle length and to split the cycle length into appropriate green times for each phase, it is necessary to find the critical-lane volume for each discrete phase. Simple volumes cannot be simply compared, Trucks require more time than passenger cars, left and right-turns require more time than through vehicles, vehicles on a downgrade approach require less time than vehicles on a level or upgrade approach. Thus, intensity of demand is not measured accurately by simple volume. Where phase plans involve overlapping elements, the ring diagram must be carefully examined to determine which flows constitute critical lane volume flows. Ideally, demand volumes would be converted to equivalents based on all of the traffic and roadway factors that might affect intensity.

Obtain design hourly volume from Eq.3 we get the following value.

$$DHV = \frac{\text{peak hour volume}}{PHF}$$

Table 14.Hourly design volume for each lane

Design Hourly Volume				
Lane	Phase A	Phase B	Phase C	Phase D
1	216	145	678	370
2	463	821	319	470
3	246	954	222	194

The design hourly volume for each approach was computed. This design hour volume were calculated at evening time from Bisrate Gebriel -Karl square, Torhailoch- Karl square, Lideta - Karl square and Sarbet- Karl square used for the sake of hourly design purpose and also it describes the total traffic volume for each lane.

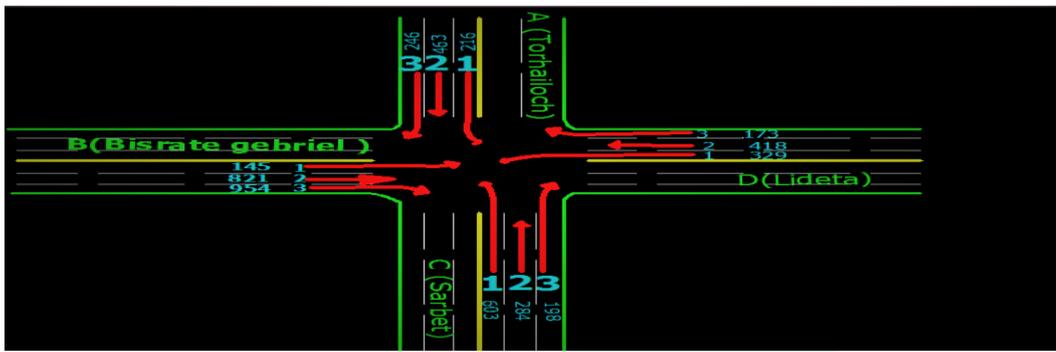


Figure 6. Design Hourly Volume for Karl Square

The critical design hourly volume of each lane shown in the following table.13

Table 15. Critical Lane Volume per hour

Phase	Critical lane volume (veh/hr)
A	463
B	954
C	678
D	470
Sum	2565

Lost time: initially some time is lost before the vehicles start moving, and then the rate of discharge increases to a maximum. This maximum rate of discharge is the saturation flow. If there are sufficient vehicles in the queue to use the available green time, the maximum rate of discharge will be sustained until the yellow phase occurs. The rate of discharge will then fall to zero when the yellow signal changes to red. The number of vehicles that go through the intersection is represented by the area under the curve. Dividing the number of vehicles that go through the intersection by the saturation flow will give the effective green time, which is less than the sum of the green and yellow times. This difference is considered lost time, since it is not used by any other phase for the discharge of vehicles; it can be expressed as sometime is lost before the vehicles start moving, and then the rate of discharge increases to a maximum. Then we compute the total lost time of four phases. The lost time per phase is assumed to be 3.5 sec, $L = \sum 4 * 3.5 = 14 \text{sec}$

Table 16. Design procedures for cycle time at each approach

Lane group	Phase A			Phase B			Phase C			Phase D		
	1	2	3	1	2	3	1	2	3	1	2	3
Qi	192	412	219	129	731	846	603	284	198	329	418	173
Sj	1925	1856	1935	1905	3462	5143	2791	1915	1989	2011	2093	1989
Qij/Sj	0.1	0.22	0.11	0.07	0.21	0.16	0.22	0.15	0.1	0.16	0.2	0.09
yi	0.22			0.21			0.22			0.2		

$\sum y_i = 0.22 + 0.21 + 0.22 + 0.20 = 0.85$ since the value < 1 it's Ok

Cycle Length: to describing the max sum of critical lane volume that could be handled by a signal was manipulated to find a desirable cycle length its the time required to complete a prescribed sequence of phases. There are various techniques that may be applied to establishing cycle length. The sum of computed green times, yellow times, and all-red times equals the cycle length. This sum is usually adjusted upward to a number divisible by 5&10 to assure that critical lane volumes will be adequately serviced; a capacity check should be conducted for each green time. This equation is used to find the desirable cycle length based on the volumes find cycle length of the intersection.

$$C = \frac{1.5L + 5}{1 - \sum_{i=1}^n Y_i} = \frac{1.5 * 14 + 5}{1 - 0.85} = 173 \text{sec} = 180 \text{sec}$$



Minimum Green Time Each actuated phase has a minimum green time, which serves as the smallest amount of green time that may be allocated to a phase when it is initiated. Minimum green times must be set for each phase in an actuated signalization, **Effective Green Time:** the available effective green time in the cycle must be divided signal phases. Total available green time in the cycle is found by deducting the lost time per cycle from cycle length as equation. The total effective green time will be $G_{te} = C - L = 180 - 14 = 166 \text{sec}$

The concept of effective green time was introduced as a means of determined the number of vehicles that could cross a stop line over the whole of the cycle.

The effective green time the number of vehicles crossing the stop line depends on traffic composition, saturation flow, the effective green time, then the time during which the signal is effectively green. A cycle is complete sequence of signal indication, green, red and amber.

The effective green time for each phase by using equation 8

$$G_{ei} = \frac{G_{te}}{1 + 2 + \dots + n} G_{te}$$

For phase A the effective green time (G_{eA})

$$G_{eA} = \frac{0.22}{0.85} * 166 = 43 \text{sec}$$

Table 17. Effective green time at each approach

	Phase A (G_{eA})	Phase B (G_{eB})	Phase C (G_{eC})	Phase D (G_{eD})
Effective green time (G_{ei})	43sec	41sec	43sec	39sec

Change Interval (Yellow Interval, τ): -The main purpose of the yellow indication after the green is to alert motorists to the fact that the green light is about to change to red and to allow vehicles already in the intersection to cross it. A bad choice of yellow interval may lead to the creation of a *dilemma zone*, an area close to an intersection in which a vehicle can neither stop safely before the intersection nor clear the intersection without speeding before the red signal comes on.

$$\tau_{min} = \frac{w}{a} + \frac{L}{g} + \frac{w}{2(a + g)}$$

Where

w=width of intersection in m

L=length of vehicle in m

δ =perception reaction time in sec

a, =constant rate of braking declaration in m/s²

g=gravitational acceleration

G= Grade of the approach

To calculate the yellow interval for each approach taken

$$\tau_{min} = 2.4 \text{ sec} + \frac{3.6+2.4}{30} + \frac{30}{2(3.85+4.5*9.8)} = 2.91 \text{sec} = 3.0 \text{ sec}$$

$$\tau_{min} = 2.4 \text{ sec} + \frac{3.6+2.4}{30} + \frac{30}{2(3.85+4.5*9.8)} = 2.91 \text{sec} = 3.0 \text{ sec}$$

$$\tau_{\min} = 2.4 \text{ sec} + \frac{3.6+2.4}{30} + \frac{30}{2(2.85+2.6*9.8)} = 3.12 \text{ sec} = 3.0 \text{ sec}$$

$$\tau_{\min} = 2.4 \text{ sec} + \frac{3.6+2.4}{30} + \frac{30}{2(2.85+2.6*9.8)} = 3.12 \text{ sec} = 3.0 \text{ sec}$$

The required yellow interval is the time period that guarantees that an approaching vehicle can either stop safely or proceed through the intersection without speeding. This interval allows a vehicle that one is safe stopping distance away from the stop line when the green is withdrawn to continue at the approach speed and enter the intersection legally on yellow Taking Yellow time $\tau = 3.0 \text{ sec}$

The actual green time:



G_{ai} for each phase is obtained from Eq. 9 as follows

$$G_{ai} = G_{ei} + \ell_i - \tau_i$$

For phase A: the actual green time (G_{aA})

$$G_{aA} = 43 + 3.5 - 3 = 43 \text{ sec}$$

Table 18. The actual green time at each approach

	Phase A(G_{aA})	Phase B(G_{aB})	Phase C(G_{aC})	Phase D(G_{aD})
Actual green time(G_{ai})	43sec	42sec	43sec	40sec

Table 19. Traffic signal timing result summary at each approach

Signal components	Cycle	Gerji Round bout			
		Phase A	Phase B	Phase C	Phase D
Green time (sec)		43	42	43	40
Yellow interval (sec)		3	3	3	3
Lost time		3.5	3.5	3.5	3.5

Conclusion and Recommendation

Conclusion

Traffic signal design is the most important solution for controlling traffic accident and traffic delay. In developing countries like Ethiopia, traffic flow is highly increasing due to urbanization. At any intersection, there is a traffic conflict and delay. Traffic accidents and delay are avoided by either round about or traffic signal in the intersection. But, still there is traffic problem and unsuitable level of service in the roundabout. By taking this in consideration, this study was focused on the analysis and design of fixed time traffic signal at Gerji Roundabout in Addis Ababa. There are many causes of traffic congestion, such as weather, vehicular accidents, reckless driving, and poor road design and road construction work zones. Traffic congestion can be tackled by demand management of a given road intersection by adjusting a traffic light's cycle time according to the design. Hence, before conducting a design, traffic data prediction or estimation is of prime importance. For collecting these traffic data, manual counting methods are used. The proposed method adjusts the knowledge-based cycle time of a traffic light in accordance with the congestion. Traffic congestion has negative environmental and health consequences as well. Environmentally, traffic congestion results in increased fuel consumption and air pollution. In terms of health consequences, traffic congestion leads to increased stress and mental and physical discomfort, which may contribute to a lower quality of life. Traffic problems are controlled by appropriate traffic signal plan and design. This design approach was come up to avoid the traffic problems in Gerji Roundabout which didn't have signal design yet. To come up of the objective, assessment of the current traffic conditions at Gerji Roundabout, determination of level of service and finally design appropriate signal controlling system were conducted. Level of service is a qualitative measure used to relate the quality of traffic service. It is used to analyze highway by categorizing traffic flow and assigning quality levels of traffic based on performance measure. One of the main objectives of installing a signal system at an intersection is to reduce the average delay of vehicles at the intersection. Delay is therefore an important measure of effectiveness to use in the evaluation of a signalized intersection. Based on the highway capacity manual (HCM),

- ✓ The Gerji Roundabout about is under 'F' condition which is highly delayed with more than 50 second whereas with this second the delay condition would be lower and indicated by 'E' for case of signalized condition.
- ✓ In this study, signal design has better level of service than round about in case Karl square.
- ✓ The result of signal design in Karl square was based on the peak hrs, volume and the total cycle length is 180 second with effective green time of 43, 41, 43 and 39 second in *Bole (A)*, *Gerji (B)*, *Megenagna (C)* and *Hayahulet (D)* approaches
- ✓ The yellow interval for each approach was 3 seconds.
- ✓ Design traffic signal for any round about is advisable because it gives better level of service as well as it minimizes traffic accident and delay

Recommendation

From the output of the study, the following recommendation are given for Addis Ababa city transport administration and for the ACCRA

- ✓ It is better, designing a traffic signal for all roundabouts found in the city
- ✓ The intersection should be kept its geometric and slope condition to give better level of service
- ✓ The transport minister should initiate the investigators to conduct further studies

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