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Assessing Traffic Congestion and Cost Analysis in Addis Ababa: The Case of Megenagna Diaspora and Lamberat Semen Bus Terminal Square, Yeka Sub – City

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Abstract

Traffic congestion has always been a major issue in any country. Congestions are generating many problems due to inefficiency and with congested roads, the vehicle's speed was simultaneously up and down and lost costs in the world.Ethiopia is one of the countries whichhas been caused by traffic congestion on the road intersections. In Addis Ababa city due to economic growth andprivate vehicle ownership growth; the congestion problem was increasing faster. The Megenagna Diaspora and Lamberat semen Bus square were affected by traffic congestion.Congestion was affected by many sectors in different ways either directly or indirectly and imposes a cost. The problem of this congestion waslosing productivity from more time spent traveling rather than working and missing meetings. As a result, those are associating with costs including lost time, increasing vehicle operating costs, gas emissions on the intersection.The general objective of this study was to Assessing Traffic Congestion and Cost Analysis in Addis Ababa: The case of Megenagna diaspora and Lamberat semen bus terminal square, Yeka Sub-City.

This study was specifically focusing on the economic costs of traffic congestion imposes.Furthermore, the study was an analysis of the costs of congestion using recurrent traffic congestion rather than non-recurrent traffic congestion. The three componentsofrecurrent traffic congestion calculated in this study were; Gas emission cost, Travel time cost, and Vehicle operating cost for vehicle types.The method used to analyzingtraffic congestion cost of a base year and forecasting byexcel,using their every formula and analyzed the level of service by SIDRA software.

The results of thisstudywere includingtravel time cost, delay, vehicle operating cost, gas emission cost, and level of service at both intersections. The level of service result was worst (F values). The total *traffic congestion casts of a base year and forecasting year were including the costs of vehicles lost at both intersections. The annual total cost of the base year (2020) was **1,933,050.262**ETB and the annual total cost of the forecasting year (2040) was **35,595,326.89**ETB.*

In this study, the occurrence of traffic congestion was showing that the performance of intersections used for vehicles was lower than the design capacity and the total cost analyzed thatlost on intersections due to congestion was increases year to year. To analyzing the accurate value of total cost by adding non-recurrent traffic congestion and recording vehicle volume separately.

Keywords: *Traffic Congestion, Cost, Delay, Forecast congestion cost*

1. INTRODUCTION

1.1 Background of the Study

Traffic congestion is a serious social problem and has been for some time. Carole Sauve writes that during the Roman Civilization, Julius Caesar became so frustrated by traffic congestion that he banned the movement of carts during daylight hours. [1]. Traffic in cities continues to grow meteorically especially in major cities of developing countries, which are characterized by heavy economic and population growth and assimilation in business and residential districts [2]. Traffic congestion costs consist of incremental delay, vehicle operating costs, fuel costs, pollution emissions, and stress that result from interference among vehicles in the traffic stream, particularly as traffic volumes approach a road's capacity [3].

Traffic congestion in Addis Ababa, Yeka sub-city would be crowded atboth intersections of peak hour. Among these, Lamberat Semen Bus Terminal Square and Megenagna Diaspora road intersection was crowded by different types of vehicles. The study area was one of the Addis Ababa sub-city which having a bus station and car station at the side of the road and near the road intersections that distributes passengers into a different place of work and sub-city of Addis Ababa. The road intersections are serving heterogeneous traffic which includes light and heavy vehicles through the roundabout. Those road intersections were feasible for commercial activities, government work, and individual work because passengers are crossing those intersections totravel in Oromia region like Sendafa Sheno and Amhara region like Debra Birhan. Traffic congestion aggravates and affects social activities day to day by increases delay time, excess fuel consumption, excess vehicle operating costs, gas emission, and losing unnecessary costs.

1.2 Statement of Problem

Traffic congestion has become one of the plagues of modern life in a big city in the world and traffic congestion has always been a major issue in any country. The problem of traffic congestion in major cities of the world like Karachi is a frequent phenomenon. The traffic congestion tends to prolong, hinder, and counterproductive for the number of economic activities in the city [4].

The rapid economic growth currently experienced in Addis Ababa city leads to attracting business organizations, growth in private vehicle ownership which is also provoking the challenges. As a result of increasing urbanization and industrialization, Addis Ababa has been experiencing over the years traffic congestion problems which hinder citizens' mobility and timely delivery of commodities. Growth in urbanization and industrialization requires more vehicle usage which tends to create an imbalance between the available infrastructures and mobility demand [5].

Yeka is one of the Addis Ababasub-cities that exhibit a higher amount of traffic congestion problem at different places of road intersections. Nowadays it is common to see traffic congestion at Megenagna Diaspora square and Lamberat Semen Bus Terminal squareat peak hours of the morning, middy day, and evening. The road intersections are crowded by different types of vehicles (Car, Bus, and Truck) commonly large trucks, buses, minibusses, taxis, and private cars. Currently, traffic congestion increases at the Megenagna Diaspora and Lambert Semen Bus Terminalroad intersection. The main impacts of traffic congestion on these intersectionsarecauses delays which may bring about late arrival at job, meetings, training, education, and bringing about lost business, disciplinary activity, or other individual misfortunes.

1.3 Objectives

1.3.1 General Objective

The general objective of this studyis Assessing Traffic Congestion and Cost Analysis in Addis Ababa: The Case of Megenagna Diaspora and Lamberat Semen Bus Terminal Square, Yeka Sub – City.

1.3.2 Specific Objectives

To achieve the above aim, the following specific objectives were formulated:

- ✓ To identify major causes for traffic congestion on Megenagna Diaspora and Lamberat Semen Bus Terminal intersection.
- ✓ To analyses the level of service at the intersections.
- ✓ To determine the cost of traffic congestion on the Megenagna Diaspora and Lamberat Semen Bus terminal intersections.
- ✓ Forecasting the cost of traffic congestion after twenty years (2040).

1.4 Significance of the Study

The traffic congestion of Addis Ababa city was the main problem on activities of society from day to day. The studying of travel time, level of service, delay, and traffic volume associated withtraffic congestion are helpful to understand the situationof road intersections. This study was helpfulfor policymakers and planners to review urban development and transport policies. Ethiopia road authority (ERA) was used to re-design the geometric road intersection to improve the traffic congestion problem.This study was also helpful for different vehicle users that came from different regional states of Ethiopia, the peoplesof Addis Ababa city who living different sub-cities for the selected period, and routeselection totravel (cross) the intersection.

2. LITERATURE REVIEW

Traffic congestion is a widely recognized transport cost. It is a significant factor in transport system performance evaluation and affects transport planning decisions. As a road reaches its capacity, each additional vehicle imposes more total delay on others than they bear, resulting in economically excessive traffic volumes. Congestion tends to increase travel time, fuel consumption, pollution emissions, and driver stress, and reduce life satisfaction[2].Congestion cost calculations have often incorporated unrealistic assumptions relating to baseline travel conditions. Often, such estimates have sought to determine a total cost of congestion by assigning a value to the difference between free-flow travel speeds and realized on the transport network a difference that has alternatively been labeled lost time[6].As statedin the international journal of traffic and transport engineeringwhen the vehicle is moving under congested conditions, it has to undergo many operations like acceleration, deceleration, gear changes, brake applications, etc. [7].

The resulting traffic slowdowns can have a wide range of negative effects on people and on the business economy, including impacts on air quality (due to additional vehicle emissions), quality of life (due to personal time delays), and business activity (due to the additional costs and reduced service areas for the workforce, supplier, and customer markets)[8].Traffic streams are described by three variables, density K (vehicles per lane per kilometer), speed (V) km/h, and flow (q)veh./ln/hr. Traffic flow is the product of traffic density (vehicles/km) and speed (km/h), so these three variables are related by the equation $q = K * V$. All things being equal, as more vehicles enter the same road, traffic density increases, travel speed falls, and travel time increases [9].Different researches and reports identified many interrelated factors that cause traffic congestion in developed and developing countries where the road network and road user's behavior are different[10].Congestion also has a range of indirect impacts including the marginal environmental and resource impacts of congestion, impacts on quality of life, stress, and safety as well as impacts on non-vehicular road space users such as the users of sidewalks and road frontage properties [11]. The capacity of a facility is defined as the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given period under the prevailing roadway, traffic, and control conditions[12]. The demand is the principal measure of the amount of traffic using a given facility. The term demand relates to vehicles arriving, while the term volumerelates to vehicles discharging [13].The traffic flow on any given section of road is composed of vehicles of different types, which have all different road space requirements due to their respective size and performance characteristics [14].The first principle links the concept of passenger car equivalency to the level of service (LOS) concept.The second principle emphasizes the consideration of all factors that contribute to the overall effect of trucks on traffic stream performance.[14].Almost all studies have done so far agreed that to fully express traffic congestion, it is necessary to understand its four components or dimensions are namely; duration, extent, intensity, and reliability [15] & [16].

Time is an important factor to consider when acting on congestion since road networks do not operate at capacity all of the time. It follows that congestion is a temporal phenomenon, affecting some periods more than others and some not at all. Which periods are affected is linked to the temporal scale (daily, weekly, monthly, and/or yearly) and the timing of urban activities which is linked to decisions made by individuals and firms relating to the purpose of their trips[6].

3. METHODOLOGY

3.1 Descriptions of Study area

The study area is located in the capital city of Ethiopia which Addis Ababa, Yeka sub-city.

Addis Ababa lies at an altitude of 7,546 feet (2,300 meters) and a grassland biome located at 9° 1′ 48″ N 38° 44′ 24″ E. The city lies at the foot of Mount Entoto. From its lowest point, around Bole International Airport, at 2,326 meters (7,631 ft) above sea level in the southern periphery, the city rises to over 3,000 meters (9,800 ft) in the Entoto Mountains to the north. The area of Addis Ababa is 530.14 square kilometers [17].Addis Ababa city, the capital city of Ethiopia, covers 527 sq. km divided into 10 sub-cities and 116 woredas. The overall population of the city is estimated to be 3.385 million with an aggregate population density of 4,847.8 persons per square kilometer. This accounts for 3.4% of the country's population. Addis Ababa serves as the country's political and economic Centre. Addis Ababa's sub-cities are Akaki Kality, Nefas Silk- lafto, Kolfe Keraniyo, Kirkos, Gulele, Arada, Addis Ketema, Yeka, Bole, and Lideta[18].Yeka sub-city is located in the northeast part of Addis Ababa city. The total area of the Yeka sub-city is 85.98 km square and 4,284.9 people live in a one-kilometer square. Moreover, its entire population of the area is 368,418 people [19].

Addis Ababa, Yeka sub-city was including both Megenagna Diaspora square and Lamberat semen bus square. The Megenagna Diaspora intersection was one type of Yeka sub-cityroundabout that many vehicles were crosses the intersection at a different period. Megenagna was the business center and many users were crosses the intersection into different Addis Ababa sub-city and outer of the city for different types of works. The vehicles were approaches from three types of legs such as Lamberat, Kebena, and bole airport. The Megenagna Diasporaroundabouthas a 60m circular diameter. The Google Earth image of this intersection taken from Google earth was detail described in the following Figure 3.1.The Lamberat Semen Bus Terminal intersection was congested roundabout and it is very crucial because it connects northern parts of the country and which users are using for export and import activities. The intersection connected by four approaches legs were as Megenagna, Gurd shola, Kara, and Kotebe approach. Google Earth image of Lamberat Semen Bus Terminal intersection was taken from Google Earth can be seen in the following Figure 3.2.

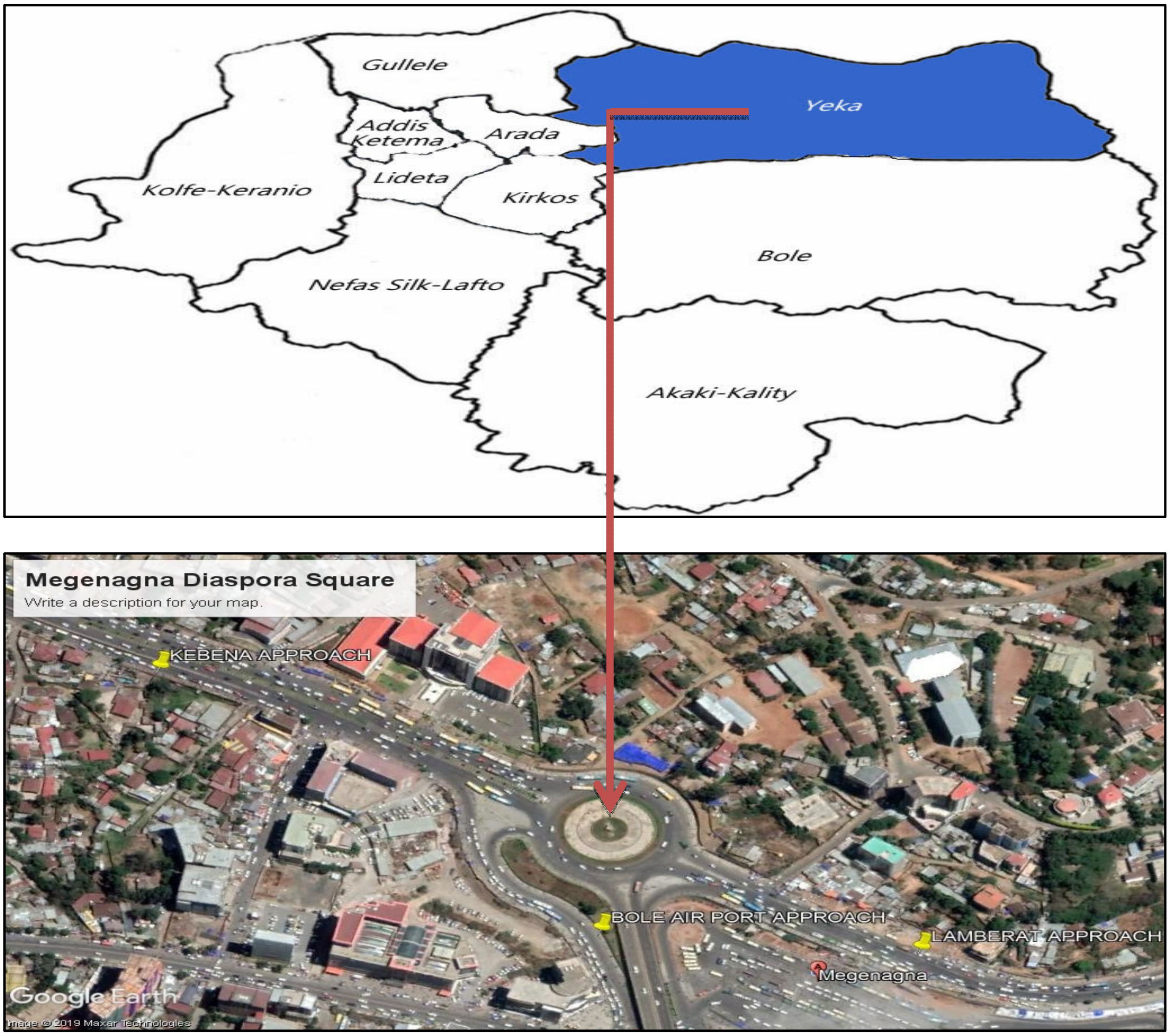

Figure 3.1: MapofMegenagna Diasporasquare [18]

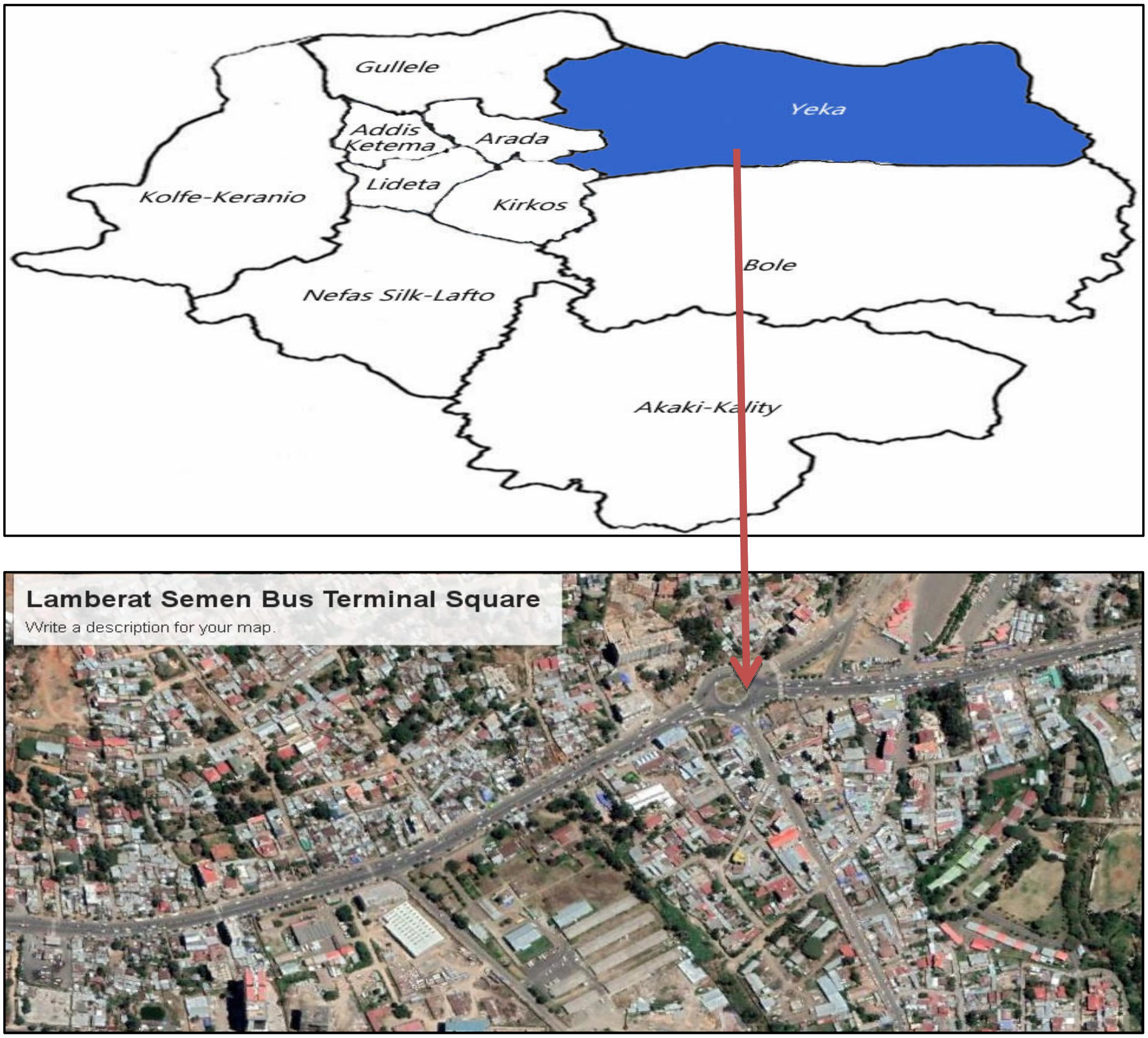

Figure 3.2: Mapof Lamberat Semen Bus Terminal square [18]

3.2 Research Method

The method used when collecting, processing, and analyzing the gathered data or information canbe either quantitative or qualitative research method.

I. **Quantitative research methods**: collect numerical data (data in the form of numbers) and analyze it using quantitative or statistical methods.

II. **Qualitative research methods**: collect qualitative data (data in the form of text, images,sounds) drawn from observations, interviews, and documentary evidence, and analyze itusing the qualitative data analysis method[20].

3.3 Method of Data Collection

The first preliminary stage was involving to visiting (reconnaissance) the study area for the analysis of congestion costs and assessing traffic congestion of selected study areas. The methods of took data were involving using different techniques and steps.

A. Primary data

The primary research data was collected through field data collection by the video camera, observation, questionnaires, field measurement, and interview.Such primary data was collected includes, travel time, traffic volume, vehicle occupancy, and other data was collected by interview. The primary data were collected using the following techniques:-

Direct observation; observation was used to understand the ongoing behavior and process of the traffic congestion at peak hours and the off-peak hour on the intersection of study areas of a sub-city. Field notes were used to record whatever important was observed in an unstructured manner to the study and in addition to the video camera.

Field measurements; Audit geometric features of the intersection for analysis of the level of service, different road geometric data were required. Accordingly, the following features were collected at an intersection: several lanes, circular radius, and lane width, the configuration of lanes, circulatory width, entry width, and width of the median.

Traffic volume counts; Video camera instruments setup on buildings' tops or floors were used for manual traffic volume count flow per 15-minute interval to determine the vehicular composition, average delay, average vehicle speed, and classifications of vehicles for selected routes directional traffic volume/flow per 15 min of interval.

Questionnaire;the structured questioner was distributed randomly for road users (car drivers, Bus drivers, Truck drivers, pedestrians, passengers, and other peoples).

Interview; researcher asked different persons about the traffic congestion condition of the study area in the form of an interview. The different persons participated in this interview was including that traffic police, passenger, vehicles driver, and other peoples living in that area.

B. Secondary Data

The secondary data was collected through the existing relevant documents and literature to review and analyze the issues related to the concerned objectives of the study. The secondary data included value of time, the fuel consumption of vehicles, and fuel cost which are required and gathered from different journal and website (secondary written material) and different organizations like; Addis Ababa City Road Authority and Addis Ababa Traffic Management Enterprise were the sources of secondary data for this study.

3.4 Sampling techniques andSampling size

The sampling technique used for this study wasthe following statistical equation to provide a sample size for different traffic conditions and level of confidence. This study wasused a samplesize for an infinite population of collecting travel time and number of each vehicle.

According to the travel time data collection Handbook, the sample size for manually transcript travel time data was given by the equation [21].

$$\boldsymbol{SamplesizeforTravelTimeofVehicles}\ (\boldsymbol{n}) = \frac{z^2 * cv^2}{e^2} \qquad (3.1)$$

The above statistical equation of handbook was usedto provide a sample size for different traffic conditions and level of confidence. Accordingly, confidence level with the usual recommended z value being 1.845 for congested traffic condition at 90% confidence interval and +10% errors with coefficient variation 25percent congested traffic andthe minimum sample size was calculated to be 18 for 15-30 minute time period counting [21]. Therefore, for 15 minute interval time, about 20 vehicles travel times were recorded for this study during data collection to enrich the accuracy.

I. Design Research Approach

The general overview of the research process was summarized by the following flow chart.

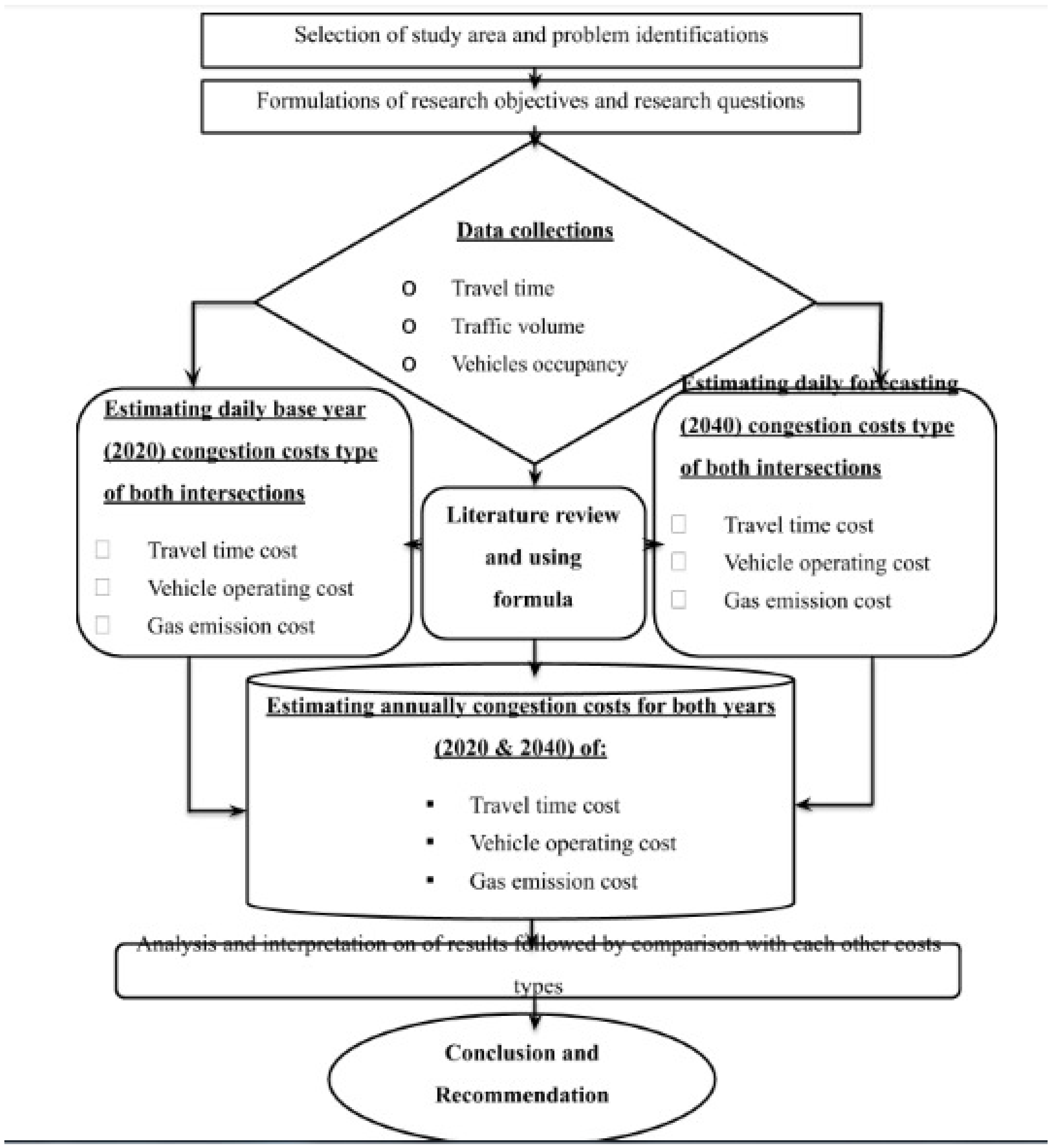

Figure 3.3: Flow chart of research design

II. Days and period for data recording

For the proper analysis of the required data, the variation of traffic volume of the day was considered. Monday and Friday have high traffic variation from the normal weekdays of Tuesday, Wednesday, Thursday, and Weekends (Saturday and Sunday) have low traffic volume. According to the Traffic volume count guide Traffic count during Monday and Friday may show exceptionally high volumes and are not normally used in the analysis, therefore, counts are usually conducted on Tuesday, Wednesday, and Thursday.Period recording traffic data was generally classified in three classes as shown below:

A. Morning Peak Period: it includes the time from **07:00 - 10:00 AM**,
B. Inter-peak Period or Mid-day period: the lowest traffic volume which includes from **11:00 AM - 02:00 PM** and
C. Evening Peak Period: includes from **04:30 PM - 07:30 PM**.

III. Value of Time

The adjustment factor for the average hourly earnings, the calculations needed to remain in 2020 prices (that no inflation) but researcher using wage growth associated with productivity.Thus the adjustment assumes that the average differential between the pace of wage growth and inflation growth (productivity) that occurred during the 4 the year 2016 to 2020 periods would continue during the twenty years to 2040. Thus the formula is essentially applying the average wage differential in the 2016 to 2020 period and applying this to obtain a projection of real wage growth over the following twenty years. In this study, the value of CPI adjustments was taken from the trading economics of Ethiopia consumer price index because there were data limitations to calculate the CPI and the researcher directly took the value of CPI (0.98)calculated [22].

In this research, the following formula was modified from the above forecasting value of travel time.

Adjustment factor of QES average hourly earnings of the 2040 year =

$$\left(\left(\frac{QESaveragehourlyearningsofthe2020year}{valueofCPI2020year}\right)^{\frac{1}{4}}\right)^{20} \quad (3.2)$$

IV. Traffic Volume Data

Traffic volume count data are very important to determine and understand the flow pattern in the facility, to determine the peak flow rates and peak periods, to assess the relationship between traffic volume and congestion.

Table 3.1: Summary of vehicles classification

Types of vehicles	Vehicles classification
Car	Passenger cars, minibusses up to 24-passenger seats, and taxis
Bus	Medium and large size buses above 24 passenger seats
Truck	Small and medium-sized trucks including tankers up to 7 tons load, Trucks above 7 tons load, Trucks with trailer or semi-trailer and Tanker Trailers.

V. Travel Time

To analysis traffic congestion and determine the economic cost of travel time, the acquisition of reliable data is critical and very important. The optimal travel time (sec/km) and travel time at capacity (sec/km) were calculated using the following formula:

Optimal travel time (sec/km) = Average travel time (sec/km) – average delay (sec/km)Travel time at capacity was estimated fromBureau of Public Roads (BPR) function relates travel times to traffic flows and the free flow time [23].

Travel time at capacity $= Optimaltraveltime * (1 + \beta * (\alpha)^{\rho})$ (3.3)

Average delay (sec/km) $= \frac{\text{Average travel time(sec)} - \text{Average free flow time(sec)}}{\text{Distance travelled(km)}}$

Time delay from capacity (sec/km) = Average travel time (sec/km) – travel time at capacity (sec/km)

Total time delay from capacity (hr.) = $\frac{\text{time delay from capacity (sec/km)}*\text{travel distance (km)}}{3600\,\frac{\text{sec}}{\text{hr.}}}$

Time delay from free flow (sec/km) = Average travel time (sec/km) – Optimal travel time (sec/km)

The total time delay from free flow (hr.) = $\frac{\text{Time delay from free flow (sec/km)} *\text{travel distance (km)}}{3600\,\frac{\text{sec}}{.}}$

VI. Traffic congestion costs analysis methods

Total congestion cost was made up of different costs, primarily of travel time delay costs and vehicle operating costs. In terms of travel time delay, it measures the delay costs imposed on others due to an extra motorist entering the road. The most widely used approach to estimate the associated cost is to impose the Value of Time (VOT) on the calculated delay due to congestion. The unobserved travel time at capacity operation is estimated by rearranging theUS Bureau of Public Roadsfunction and solving for *K*.The wellington report of Estimate of costs of road congestion was describe the value of the parameter were assumed to be α = 1, β = 0.2, ρ =4. The BPR function relates travel times to traffic flows and the free flow time [23].

$$\mathrm{Ta} = \alpha \mathrm{Tf} * (1 + \beta \left(\frac{\mathrm{D}}{\mathrm{K}}\right)^{\rho} \quad (3.4)$$

- ✓ Ta =Average travel time, Tf = the free flow time (optimal travel time) sec/km
- ✓ *D* = is demand (number of vehicle flow), *K* = capacity

A. Cost of extra time spent traveling (Estimating travel time congestion cost)

The principal cost of congestion is associated with the value of the extra time people spend traveling. This is calculated for each 15 minute period as [23].

$$Ci = (\mathrm{t} - \mathrm{tc}) \cdot \frac{\mathrm{TD}}{3600} \cdot \mathrm{oi} \cdot \mathrm{v} \qquad (3.5)$$

In due course, the above formula was modified and the following formula was finally used to compute congestion time travel costs of type "i" vehicles.

$$\boldsymbol{TTCi} = \mathbf{Dt} * \mathbf{Oi} * \mathbf{VOT} (3.5.1)$$

Where:-

- TTCi = Time travelers costs in-vehicle type "i" (time travel congestion cost)
- Dt = total time delay from capacity which is computed from distance travel in kilometer (km) multiply by time delay from capacity, VOT = Value of time for vehicle "i" types

B. Estimating of Vehicles operatingcosts

The increasing of travel time resulting from congestion was increasing the cost of operating [23].

$$\mathrm{Vi} = (\mathrm{t} - \mathrm{tc}) \cdot \frac{\mathrm{TD}}{3600} \cdot \mathrm{Fh} \cdot \mathrm{PF} \qquad (3.6)$$

The above formula was modifying as the following;

$\boldsymbol{VOCi} = \mathbf{Dt} * \mathbf{Va} * \mathbf{Fa} * \mathbf{PF}$(3.6.1)

The estimating vehicles operating cost in this study was using average speed (Va) km/hr anddiesel average fuel consumption (Fa) liters/100km of each vehicle. The fuel price of this research was including the fuel price(PF) of 2016, base year (2020), and forecasting year which was taken from Ethiopia's petrol price for both years (2016 &2020) and estimated for forecasting year by the following method. In this study, the fuel type used was diesel for each vehicle type.

$$\text{Adjustment factor of Diesel=}\left(\left(\frac{DieselvalueETBperliterofbaseyear(2020)}{DieselvalueETBperliterof\,(2016\,year)}\right)^{\frac{1}{4}}\right)^{20} \qquad (3.2.1)$$

C. Estimating of Gas emission costs

A vehicle's carbon emission rating is obtained from its fuel economy rating. This rating is then converted to take into account the type of fuel that the vehicle uses such as petrol and diesel. Here the following areconversion equations: [24].

$$\mathrm{Co_2}\,\frac{grams}{km} = premiumpetrol\frac{l}{100km} * 23.414$$

$$\mathrm{Co_2}\,\frac{grams}{km} = regularpetrol\frac{l}{100km} * 22.847$$

$$\mathrm{Co_2}\,\frac{grams}{km} = petrolaverage\frac{l}{100km} * 22.961$$

$$\mathrm{Co_2}\,\frac{grams}{km} = Diesel\frac{l}{100km} * 26.050$$

The carbon value of forecasting year (2040) was estimated from both year (2016 and 2020)adjustment factors.Themethodofadjustment factorvalue getting for forecasting (2040) wasdescribed as the following formula.

Adjustment factor of carbon $=\left(\left(\frac{carbonvalueETBpertonofbaseyear(2020)}{carbonvalueETBperton(2016\,year)}\right)^{\frac{1}{4}}\right)^{20}$ (3.2.1)

Carbon Emissions (CE) intones = Average CO2 grams/km*Average (km/h)*Total time delay

$\boldsymbol{CE} = \mathbf{Dt} * \mathbf{Va} * \boldsymbol{Co_{2av}}$(3.7)

Where:-

- CE = Carbon Emissions (CE) in tones, Va = Average speed (km/hour) of each vehicle" i"
- $Co_{2\,av}$ = Average carbon dioxide emission in gram per km, changed gram into tone divided by 1,000,000$\boldsymbol{GEC} = \mathbf{CE} * \boldsymbol{VOC}$(3.8)
- GEC = Gas Emission cost for types of vehicle "i", CE = Carbon Emissions (CE) intones
- VOC = Value of carbon in Ethiopian birr per ton (ETB/ton)

4. RESULT AND DISCUSSION

This chapter presented and describes that the key finding of the results from which the data gathered and discussions were done on different aspects of findings.

4.1 Response Rate of the Respondents

A structured questionnaire was prepared to gather additional information for accessing traffic congestion and analysis of costs. This structured questionnaire was used to take the perception of users that had the idea of traffic congestion on the intersection and how much delay was acceptable. A questionnaire respondent was distributed for different classes of road users. This was including the vehicle driver (car driver, bus driver, and truck driver), passenger, pedestrians, and another person. The questioner data was discussed and presented in an appropriate section in the analysis and result part of this research. The profile of the respondents showed that most of all aged stage was participants that means below 15, between 15 – 60 ages and above 60 ages.

4.2 Major Causes of traffic congestion

Traffic congestion is a multi-dimensional problem and an increase in traffic congestion is essentially a function of demand for road use increasing than capacity, combined with ineffective traffic management. So, this unbalance is caused by various factors that depend on the features of geometric design, the character of traffic flow, the behavior of road users, and other external factors. The other cause of traffic congestions of both intersections is identified by field observation, questionnaires, and interviews with road users (vehicles driver, passengers, and traffic police). The major causes of traffic congestion for both intersections are the Imbalance of traffic volume flow and road capacity, the problem of geometric design with road capacity, poor traffic management, and the problem of keeping traffic regulation and unnecessary parking on the intersections and near to intersections.

4.3 Hourly Traffic volume analysis

The hourly traffic volume recorded for one hour of both intersections that used for the analysis of traffic condition of the study area. The approaches traffic volumes into Megenagna Diaspora square at peak periods of time was turning from only three legs and the turning directions were includes right side, through and left side. But the traffic volume of Lamberat Semen bus terminal square was approaches from four legs with right, right north east (RNE), left, left north east (LNE), left south (LS) and through turning directions.

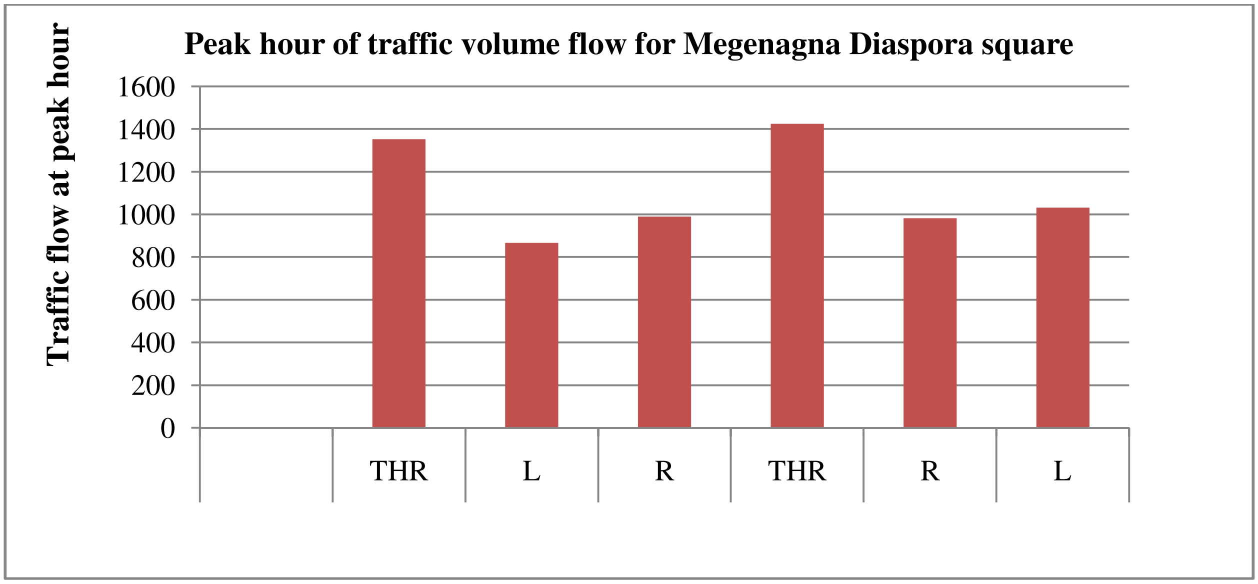

Figure 4.1: Hourly traffic volume Megenagna Diaspora square

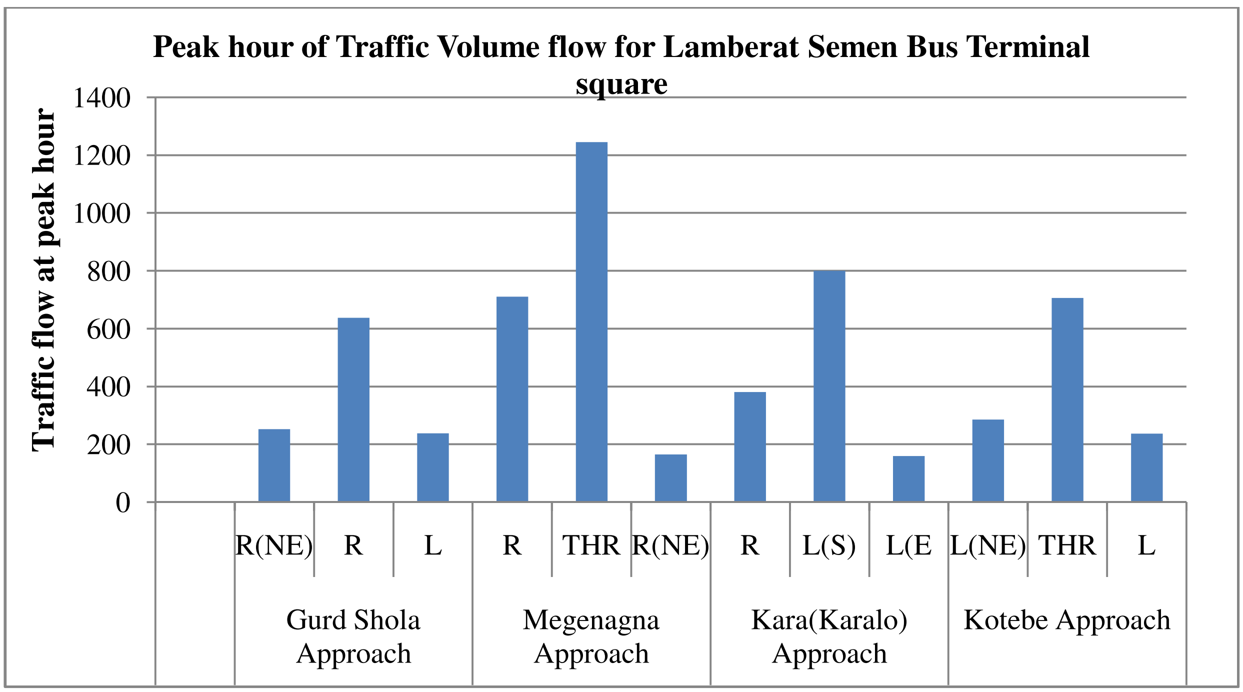

Figure 4.2: Hourly traffic volume Lamberat Semen Bus Terminal square

4.4 Level of service (LOS) analysis for both intersections

The results analyses of level of service were achieved by using all inputs data and the procedure analysis were achieved with the aid of software models (SIDRA version 5.1) for both selected roundabouts intersections described below. In SIDRA software the environment factor can be seen as a collection factor that includes everything at the Junction (intersections) environment of design type, visibility, grade, speed, driver response time and aggressiveness, amount of heavy vehicles, pedestrians and parking near to the intersections. The default values used in this research can be seen in the following Table 4.1.

Table 4.1: SIDRA software Default parameters

Parameters	Default values
Environment values	1.2
Lane utilization ratio (%)	100
Basic saturation flow (veh/hr.)	1900
Follow up headway	2.0 sec
Critical Gap	4.0 sec

4.5 Analysis LOS for Megenagna Diaspora Square by SIDRA software

The geometric design of Megenagna Diaspora square was measured on the field using a meter instrument and the traffic volume was recorded at peak hour by a video camera. Therefore, the analyzed level of service was depending on both geometric data and total traffic volume of vehicles flow at the peak hour of each direction approach legs. The analyzed level of service was F values at all approach legs except Lamberat and Kebena through turning. But the general analyzed the level of service for whole approach legs at the intersection was worst (F).

Table 4.2: Output data analyzed for LOS of average control delay per vehicle at Megenagna Diaspora square

Type of intersections	**Approach legs**	**Delays in second**			**Average delay(sec)**	**LOS**			**Value of Intersections**
		RT	TH	LT		RT	TH	LT	
	Lamberat	-	20.5	172.7	81.5	-	C	F	**F**

Megenagna Diaspora Square	Kebena	164	16.7	-	77.4	F	C	-	**F**
	Bole Airport	249.8	-	176.3	211.4	F	-	F	**F**
	Intersection				**120.5**	**F**			

The detailed output value described in Table 4.2 was including that the delays of all approach legs, average delays, and the level of service of each turning approach leg. Generally, the average delay of the intersection was 120.5 sec and the level of service was worst at the intersection.

4.6 Analysis LOS for Lamberat Semen Bus terminal square by SIDRA software

In the analysis LOS of Lamberat Semen Bus terminal, the first data was collected in the field using a meter instrument to measure geometric data and using a video camera to recording traffic volume at peak hour. To identify traffic congestion conditions of the intersection was done by analyzing the level of service using peak hour of traffic volume. Therefore the analyzed level of service at Lamberat semen bus terminal square for all approach legs was identified by using traffic turning. The level service analyzed for Megenagna and Kara approach was F values. But for the Kotebe approach analyzed was B turning through and F values in the left direction. The general level of service at the intersection was the worst (F) value.

Table 4.3: Output data analyzed for LOS of average control delay per vehicle at Lambert Semen Bus Terminal square

Type of intersections	Approach legs	Delays in second			Average delay(sec)	LOS			Intersection
		RT	TH	LT		RT	TH	LT	
Lamberat Semen Bus	Gurd Shola	1020	-	46.4	818.1	F	-	D	**F**
	Megenagna	221.3	51.6	-	127.1	F	F	-	**F**

Terminal Square	Kara	236.1	-	416.8	364.6	F	-	F	**F**
	Kotebe	-	11.9	64.9	35.4	-	B	F	**E**
	Intersection				**297**	**F**			

The above Table 4.3 shows as delays increased the level of service was worst. The delay value of Guard shola approach legs at through turning was high and the level of service analyzed was worst or F values. Generally, the average delays analyzed for Lamberat semen bus terminal intersection was 297 second and the worst level of service (F).

4.7 Analysis of total congestion costs at Megenagna Diaspora and Lamberat Semen Bus Terminal Square

The analysis of total congestion costs of Megenagna Diaspora and Lamberat semen bus intersections where includes total daily costs of the base year, total annual costs of the base year, total daily costs of forecasting, and total annual costs of forecasting year. The daily and annual total costs of both years were also containing that the total costs of vehicles (car, bus, and truck) analyzed for both intersections. So, the total costs of all vehicles were including travel time cost, vehicle operating cost, and gas emission cost which were lost due to congestion at both intersections. For more detailed information of total congestion cost analyzed for Megenagna Diaspora and Lamberat semen bus square as shown in Table 4.4 and Table 4.5 respectively.

Table 4.4: Total congestion costs of Megenagna Diaspora square

	Megenagna Diaspora square(roundabout)			
Types of vehicle	**Total Daily costs for the base year (2020)**	**Total Annually costs for the base year (2020)**	**Total Daily costs for forecasting year(2040)**	**Total Annually costs for forecasting year(2040)**
Car	281.07	70830.62	5873.14	1480032.43
Bus	3620.56	912380.26	64348.03	16215703.85

Truck	198.74	50081.98	5722.22	1442000.18
Total in ETB	**4,100.37**	**1,033,292.87**	**75,943.40**	**19,137,736.45**

Table 4.5: Total congestion costs of Lamberat semen bus terminal square

Types of vehicle	Lamberat Semen Bus Terminal Square(roundabout)			
	Total Daily costs for the base year (2020)	**Total Annually costs for the base year (2020)**	**Total Daily costs for forecasting year(2040)**	**Total Annually costs for forecasting year(2040)**
Car	238.38	60071.41	4875.15	1228536.89
Bus	3184.95	802607.65	56287.96	14184564.95
Truck	147.14	37078.34	4144.80	1044488.59
Total in ETB	**3,570.47**	**899,757.40**	**65,307.90**	**16,457,590.44**

The above Table 4.4 and Table 4.5 showed the total annual costs that were lost due to congestion of base year were 1,033,292.87 and 899,757.40 ETB at Megenagna Diaspora and Lamberat semen bus square respectively. And also the annual total cost of forecasting year for Megenagna Diaspora and Lamberat semen bus square 19,137,736.45 and16,457,590.44 ETB respectively.

4.8 Analysis of total annually congestion costs for the base year and forecasting year of both intersections

The annual congestion costs estimates for the base year and forecast year were based on the results of daily congestion costs. The analysis of total annual congestion cost was estimated using the assumption days of 252 for both base year and forecasting year. The annual total costs of both intersections were the sum of travel time cost, vehicle operating cost, and gas emission cost for both years (base year and forecasting). Therefore, the total estimated annual congestion cost of the base year for three types of vehicles at both intersections was **1,933,050.262** or **1.933** million ETB, and the forecasting year (2040) annual congestion cost was **35,595,326.89** or **35.595** million ETB. The annual congestion cost of forecasting was based on base year could estimate increases from **1.933** million ETB to **35.595** million ETB were described in the following Table 4.6.

Table 4.6: Annually congestion costs for both base year and forecasting year

Types of vehicle	Costs for both intersection in ETB	Annually costs of the base year (2020) =Daily *252 days	Annually costs of forecasting year(2040)=Daily forecasting *252 days
Car	Congestion time costs	124853.004	2140420.656
	Vehicle operating cost	4798.911125	19166.83552
	Gas emission cost	1250.116348	548981.8295
Bus	Congestion time costs	1701972.495	29177808.82
	Vehicle operating cost	10325.60163	41240.41952
	Gas emission cost	2689.819224	1181219.557
Truck	Congestion time costs	74237.0539	1272684.825
	Vehicle operating cost	10252.4878	40948.40313
	Gas emission cost	2670.773072	1172855.542
Total in ETB		**1,933,050.262**	**35,595,326.89**

The above Table 4.6 was shows that the annual congestion costs of three vehicles. From all parameters of annual costs which analyzed values shown in the above Table 4.6: the congestion time costs of the bus was highest than other vehicles (car and truck) for both annual years. Those annual congestion time costs of the base year and forecasting year of bus calculated whereas 1,701,972.495 and 29,177,808.82 ETB cost respectively.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study was discussed on assessing traffic congestion and cost analysis of selected two intersections of Addis Ababa, Yeka sub-city (Lamberat Semen Bus Terminal, and Megenagna Diaspora intersection). Based on the findings of the analysis in this study, the following points are concluded. The traffic police have to regulate the traffic condition at these two intersections since there were no traffic control devices. As this study, the major problem is related to the inadequate number of entry lanes, several circulatory lanes, high traffic flow, and unbalance approaches legs traffic flow as result the level of service(LOS) were worst or F values at both intersections. The annual total cost of Megenagna Diaspora intersections (roundabout) of the base year (2020) was 1,033,292.87 and Lamberat Semen Bus Terminal intersection was899,757.40 ETB per year and the total costs for the forecasting year of Megenagna Diaspora intersections was 19,137,736.45 and Lamberat Semen Bus Terminal intersection was16,457,590.44 ETB per year.

5.2 Recommendations

Traffic congestion was a serious problem in every social life of an urban area and to need properly addresses by police makers.

In this study, the data collection of traffic volume recorded was done only for two days due to resource (budget) limitations. So it is recommended that for the collection of traffic volume use modern electronics to minimize the error and use more than three days of traffic volume collections. The traffic volume recorded was including divided into three vehicles (car, bus, and truck) due to time limitations. Therefore it is recommended that to get the accurate value of data, collect the traffic volume of all vehicles separately.

The analyzed cost of the bus was very high at both intersections when compared with another two vehicles and society was lost more costs on this vehicle. So, the city administration should be considering this issue and formulate a method to improve traffic congestion in that area by shifting to other roads. Both intersections of this study have no enough parking in all approach legs and vehicles were use the roadway as parking. So, it is recommended that policymakers should take serious attention to minimize traffic congestion.

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