JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

FACULTY OF CIVIL ENGINEERING

HIGHWAY ENGINEERING STREAM

Investigation on the Causes of Traffic Delay along Adama to Wolenchity Road Segment

A Research Thesis Submitted to the School of Graduate Studies of Jimma University, Jimma Institute of Technology in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Highway Engineering)

By:

Bedada Germame

April, 2019

Jimma, Ethiopia

JIMMA UNIVERSITY
JIMMA INSTITUTE OF TECHNOLOGY
SCHOOL OF GRADUATE STUDIES
FACULTY OF CIVIL ENGINEERING
HIGHWAY ENGINEERING STREAM

Investigation on the Causes of Traffic Delay along Adama to Wolenchity Road Segment

A Research Thesis Submitted to the School of Graduate Studies of Jimma University, Jimma Institute of Technology in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Highway Engineering)

By:
Bedada Germame

Main advisor: Eng. Fekadu Fufa

Co-advisor: Engr. Anuar Negussie

April, 2019

Jimma, Ethiopia

DECLARATION

The undersigned, declare that the work which is being presented in this Research entitles **"INVESTIGATION ON THE CAUSES OF TRAFFIC DELAY ALONG ADAMA TO WOLENCHITY ROAD SEGMENT"** has been performed by myself in school of Civil and Environmental Engineering, Highway stream, under supervising main adviser and co-adviser

Name:

Bedada Germame __________ ____/______/____

Student signature date

This thesis has been submitted for examination with my approval as university adviser for the above mentioned title.

1. Dr. Eng. Fekadu Fufa ___________ ____/______/____

Advisor signature date

2. Eng. Anuar Negussie ___________ ____/______/____

Co-Advisor signature date

ACKNOWLEDGEMENT

Firstly and for all, my thanks favors to Almighty **God**, with his endless mercy and for giving me Peace and power to execute my research work.

Secondly, I would like to express my sincere gratitude to my Advisor Dr. Fikadu Fufa and my Co-Advisor Eng. Anuar Negussie (MSc) for their valuable guidance throughout the thesis work and their unlimited support.

I would like also to thank Adama Woreda road transport agency for allowing me to take all the necessary traffic data at the subject study road segment.

Furthermore, I wish to record my gratitude to the participants in my thesis, for their co- operation and helping me in acquiring the necessary data and for those who have willingly shared their precious time during the process of data recording, measuring and filling the questionnaires.

Lastly, my special thanks to my Wife Woynishet Bekele and my best friend Yazo Bekele for their support during data collections, again thanks to Ahmed Sali, Tufa Bose, Derege and Ifa for their support.

ABSTRACT

Slower vehicles can be passed only in the lane normally used by vehicles travelling in the opposite direction. Passing demand increases rapidly as traffic volumes increases, while passing opportunities in the opposite lane decline as the opposing volume increases. This results in the formation of platoons of vehicles in which drivers are subject to delay because of the inability to pass. Delay affects trade performance of a country in terms of cost, time, reliability, predictability and customer services.

The research study was focused on to investigate the causes of traffic delay at Adama to Wolenchity road segment. The methodology that has been employed for the study was a quantitative descriptive research design method. The data needed were; traffic volume data, spot speed data, travel time data, road condition data and survey questionnaire data depends on deriver provider's response. The traffic volume data was collected by using video camera for 12 hours starting from 6:00 AM to 6:00 PM at 15 minutes interval on Monday and Thursday, Spot speed data collection method was elevated video camera for 1 hour on 54m strip at Thursday daylight and travel time data was collected again by camera, Thursday at 1:00 pm - 2:00 pm with 200m distance measured by tape. Geometric layout data was measured by tape and questionnaire was distributed to drivers.

The volume of each vehicle category was converted to the same vehicle category using passengers' car unit (PCU) of each vehicle class. Data analysis and processing have been performed using micro soft excel and SPSS (Statistical Package for the Social Sciences) for spot speed in order to know the causes of traffic delay on segment. The result from travel time and spot speed has been indicated that the level of service D.

At last, the study identifies, the delay occur due to truck congestion, carts, narrow Adama-Wolenchity road segment, insufficient road lanes, poor drivers vision for other drivers, mixed of different traffic, town expansion and road surface problem reason and recommends shifting of heavy vehicles to other mode like rail way, restriction for heavy vehicles use expressway, illegal parking, for carts must use lateral clearance and increase the number of lanes of Adama-Wolenchity road segment. Finally proposed the design speed should be posted with 52km/hr based on traffic flow.

Key words: traffic delay, passenger car unit, peak period, road segment, travel time

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS/ ABBREVIATIONS

AACRA	Addis Ababa City Road Authority
AADT	Average Annual Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
CRRI	Central Road Research Institute
DEF	Daily Expansion Factor
ERA	Ethiopian Road Authority
FR	Flow Rate
GIS	Geographic Information system
HCM	Highway Capacity Manual
HD	Distance Headway
HT	Time Headway
HEF	Hourly Expansion Factor
HERS	Highway Economic Requirement System
HGV	Heavy Goods Vehicles
HRB	Highway Research Board
LOS	Level of Service
MB	Moving Bottleneck
MEF	Monthly Expansion Factor

PC	Passenger Car
PCE	Passengers Car Equivalency
PCU	Passenger Car Unit
PHF	Peak Hour Factor
PHV	Peak Hour Volume
SPSS	Statistical Package for the Social Sciences
SV	Slow Vehicle
TRB	Transport Research Board
UMR	Un-congested Maintenance and Repair
VC	Vehicle Classification
VOS	Vehicle Operation Coast
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background

As the number of motor vehicles and non motor vehicles of travel increases throughout the world, the exposure of the population to traffic delay also increases (Tapio, 2001). A two-lane road is defined as a road having one lane for use by traffic in each direction. Slower vehicles can be passed only in the lane normally used by vehicles travelling in the opposite direction. Passing demand increases rapidly as traffic volumes increase, while passing opportunities in the opposite lane decline as the opposing volume increases. This results in the formation of bottleneck of vehicles in which drivers are subject to delay because of the inability to pass(Ishai, 2009).

The mechanized development of vehicles during the past century has brought dramatic changes in transportation. It has provided the individual with greatly improved personal freedom of movement. It is difficult to estimate all the advantages accumulated by individuals, but it is certain that transportation had an enormous effect, whether measured in social or in economic terms (SC & HS Joubert, 2002).

The flow of traffic on any two-lane road shows a tendency of platoon formation. The ability of a driver to maintain a desired speed depends on the extent of platooning. The greater the number of vehicles caught up in platoons, the greater the frustration for drivers. The 1985 edition of the Highway Capacity Manual (TRB, 1985-1997) introduced this factor in the evaluation of two-lane roads.

Traffic delay was the additional travel time experienced by a drivers, passengers or pedestrians due to circumstances that impede the desirable movement of traffic. It is measured as the time deference between actual travel time and free-flow travel time (AASHTO Glossary), delay expressed or measured in time per vehicle and per person. For instance, Texas Transportation Institute (2005) stated, as it is a phenomena of a slow speed unlike other normal daytime. Equivalently Corpus Christi Metropolitan Planning Organization (2009) argued that delay is a manner in which journeys are taking long time than what would have been in a normally occurrences.

Traffic delay happens when time taken to transport goods and passenger from one point to another exceeds what is reason able under the circumstances and this problem has been an increasingly severe issue. Reasonable time is the amount of time which is meant for the transport of goods and passenger from the point of departure to the point of destination, considering normal conditions and using concrete means of transportation. A deviation from normal conditions can be force majeure or some other reason, not caused by the carrier (Gong et al., 2012). Time savings during transportation lead to a reduction in the resources required to perform a given volume of output (Adkins .1998).

Delay was becoming more serious problem on Adama-welenchity Road from time to time, such as population growth- in addition to natural growth, factor that immigrate people from different part of the city to the city in searching for livelihood. To sustain the Road, it is clear that these added portions of the society also need transport service to attain their day to day activities. However; the Road was unable to cope with the existing high transport services demand. In addition, inefficient land use planning, poor infrastructure, and absence of well traffic management were the major reasons for the problem of traffic delay. As a result, it is obvious that understand the present situation of vehicles traffic delay is very important area of consideration in order to make the right decision to solve the issue and thereby sustain continues traffic flow to contribute to the economic growth of the city is urgent on the top of everything. Therefore in order to address the traffic delay and prioritize traffic projects, public-sector, researchers and planners need to know the major causes and impact of delay on stakeholders. This is also important for fully understanding the benefit of transportation improvement projects and for justifying infrastructure investments.

1.2 Statement of the Problem

In the third world, the roads are narrow or incapable to accommodate a heavy traffic that slow the traffic flow, accompanied by in adequate provision for parking and loading and boarding facilities, sidewalk along the street, and mixed land use (Oluwoye, 2000). Traffic delay problems are manifesting in many of the major urban centers in Africa, these are indeed becoming a danger to free flow of traffic (Atomode, 2013). There are many rural Highway problem associated with traffic delay in Ethiopia, these are: inadequate road for vehicles or means of transport for goods, truck congestion, lack of conceptual understanding of how an intermodal system should operate, the inability of taking immediate actions for maintenance of roads, totally poor Highway handling and unavailable infrastructures are more problem, lack of coordination of Federal and Regional state Transportation agency was the great problem(Shewangizaw, 2009).

The main road from Ethiopia to Djibouti is passing through Adama to Welenchity Road segment, this has feet the effects of the greatly increased numbers of trucks, often overloaded trucks, passenger bus, are the one contributing factor for delay. Totally there are a lot of problems associated with the existing road. But illegal on-street parking habit is the major problems that lead to vehicles traffic delay on the Adama-Wolenchity road segment.

The above delay problem affects trades performance of the country in terms of cost, time, reliability and predictability and customer services also increasing fuel consumption- wastage. However there is no common agreement on the major causes of traffic delay. Hence in this study, the above discussion short coming is addressed, the other major factors affecting the traffic service quality in terms of delay is identified and the degree of the effect can be tested in detail through comprehensive study. Therefore, this research has been initiated to assess the causes of traffic delay on Adama-Wolenchity road segment. Otherwise, it could have significant effects on the overall development effort of the country.

1.3 Research Questions

1. How is traffic volume making traffic delay based on passenger car unit?
2. What is the spot speed of the vehicles at the road section of study area?
3. How to estimate the average travel time of the road segment?
4. How the road condition can be the cause of traffic delay?

1.4 Objectives of the study

1.4.1 General Objective

The main objective of this research was to make investigation on the causes of traffic delay along Adama to Welenchity road segment.

1.4.2 The Specific Objectives of the Study Include

- To determine the traffic volume with respect to passenger car unit.
- To evaluate the spot speed of the vehicles on the road section.
- To estimate the average travel time of traffic flow takes on the road segment.
- To check the road conditions of the segment.

1.5 Scope of the Study

The scope of the study is limited to Adama-Welenchity Road segment, located at 9°1′48″N 37°47′24″E and lies at an altitude of 2,369 m in Oromia, Geographically lies at Eastern part of Ethiopia. The study area was limited to cover around 24km. This study mainly uses the information of causes of traffic delay on Road segment. But not:

- determine drain age system
- Drivers characteristics
- Asphalt detail design.
- Pedestrian

1.6 Significance of the Study

It would be known that the output of this study should be added to the existing academic knowledge and enable to understand the subject matter as it paves the way for further investigation on the topic.

- It is identify all the causes of traffic delay on the road segment.
- It is provide information for Adama and Bosat Woreda transport office and for particular drivers.
- It gives information for Ethiopian Road Authority.

1.7 Limitation of the Study

Lack of related study from concerned body like: Adama and Bosat Woreda transport office and Ethiopian Road Authority. All data collection was very sensitive to professionals, such as volume data count from video, to differentiate vehicle types, questionnaire data from drivers and spot speed and travel time data recording from the road segment.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Overview of Traffic Movement on Two-lane and Delay

The flow of traffic on any two-lane road shows a tendency to platoon (queue or bunch) formation. Platoons are mostly caused by speed differentials between vehicles and limited passing opportunities (Shiomi, 2011). Overtaking is restricted by both traffic and road conditions. Sight distances are determined by the horizontal and vertical curvatures of the road. Drivers require suitable gaps in opposing traffic as well as clear sight distance before overtaking. The longer and the more frequent the gaps, the easier it is for vehicles to overtake. Overtaking therefore also depends on the extent of platoon in the opposing traffic stream (Kitamura, 2012). The effect of speed differential is most noticeable on grades where limitations on heavy vehicle performance have an effect not only on leader speeds but also on overtaking opportunities. With increasing traffic volume, the demand for overtaking increases, while the opportunities for overtaking (Gipps, 1976). Metropolitan Planning Organization (2009) argued that delay is a manner in which journeys are taking long time than what would have been in a normally occurrences.

Traffic study is the most prominent and basic issue to be considered for the development of a city and a nation. Developing countries are suffering serious transport problems as well. These are no longer just the luck of roads to connect distance rural areas with markets. Indeed, the new transport problems bear some similarities with those prevalent in the industrialized world: traffic delay, congestion, pollution, and so on. However, they have very distinctive futures deserving a specific treatment, fast urbanization and change, high demand for public transport, sound data and skilled personnel (Willumsen, 2004).

One of the most critical needs in traffic engineering is a clear understanding of how much traffic a given facility can accommodate and under what operating conditions. These important issues are addressed in traffic volume, road condition and cause of traffic delay analysis. Level-of-service analysis is a set of analytic procedures that relate demand or existing flow levels, geometric characteristics, and controls to measures of the resulting quality of operations. (A.A Traffic Analysis Report, 2015)

Different literatures and documentations state a lot about the distinctive features of studying the traffic condition of any roadway network in order to have a smooth and free movement of traffic. Having a free and smooth traffic flow in a country provides numerous benefits for the easy mobility and accessibility throughout the country and across nations. This can also create a significant role for the development of the country. Thus the study of traffic for a certain roadway network includes lots of traffic flow parameters to be studied and taken into consideration (yoshii, 2011).

Delay is defined as the increase of travel time over the normal expected travel time. The normal expected travel time is, however, a variable because a driver's perception of travel time may differ between peak periods and off-peak periods. In traffic engineering, delay is therefore defined as the increase of travel time over the travel time at optimum density (at which flow is a maximum) (Gerlaough, 1975).

As Tillotson, H. T. (1981) defined the word “delay” is so widely used that it may be assumed to be a simple concept which is well understood. It is taken to be a name for wasted time on a journey or it is better to define delay as unwanted journey time. This paper discusses the concept of traffic delay. In conclusion it is argued that delay should no longer be regarded as an objective quantity capable of direct measurement.

An increasingly important issue, as congestion levels increase more and more, the freeways become subject to rebuilding and restructuring when traffic cannot be re-routed (Yared, 2010).

Recently traffic delay has become the research agenda for a growing community of researchers particularly in developed countries. Directly or indirectly it has a relationship with on-street parking management, traffic volume, very slow speed, travel way of long vehicle and road way condition can affect peoples in various ways: long travel time vehicles more fuel conception (Haregewion, 2010).

2.2 Road Traffic Flow Characteristics

Road transport dominates other mode of transports in our world. The most common road transport modes are public transport: public buses, taxis that scheduled or non-scheduled or based on demand, individual’s motorized passengers (automobiles) and freight transport (trucks), and non-motorized "slow modes'" of transport, principally walking and cycling, animals and horse riding also (Winder and Morin, 2009) .

Non-motorized travel, such as walking, cycling and horse riding movements has a positive impact for reducing automobile trips on the road. However, in developing

Towns, infrastructures for non-motorized transport are inadequate and because of these passengers forced to use cars even for short trip (Litman, 2003). In addition, in developing Towns, high traffic volume is occurred during peak period in which large number of traveling is concentrated because "activities starts up in the early part of the day, so numerous journeys ... take the same time. A similar pattern occurred in the Afternoon when ... business activities end" (Ogundipe, 2007) and the portion of trips made by single occupant (small size) vehicles by commuters (Litman, 2003)

2.3 Characteristics of Mixed-Traffic Flow

The presence of a slow vehicle (SV) may cause a bottleneck for traffic stream with normal travel speed, which is moving with the running of that slow vehicle. SVs can be trucks, working vehicles, Bajaj, horse riding and even cars driving by cautious drivers (Tapio, 2001). These “moving bottlenecks (MBs)” make great contributions to the degradation of highway capacity and level of service, which has been confirmed by experimental findings. Hence, it is indispensable to incorporate the influence mechanism of MBs into practical traffic models. The existing studies on the influence mechanism of MBs can be classified into two categories. One is early studies on the exploration of characteristics of a MB and the other is subsequent studies on qualitative and quantitative influence of MBs on capacity. Early studies focused on exploring characteristics of MBs.

As its extensive research, Shiomi et al. developed a model of platoon formation behind a bottleneck and a model of speed transitions within a platoon, based on which could get the conclusion that a regulation relating to the maximum and minimum speed limitation would reduce the occurrence of traffic breakdown and improve the efficiency of expressways. Also, it was found that effect of MBs on capacity became more remarkable when the coupling effect of multiple MBs occurred and that increasing the maximum speed of SVs could reduce the effect of MBs on capacity. Accordingly, interactions between two MBs were analyzed by classifying them into three situations: no interaction, stop and go, and fully congested. However, these previous researches did not take both passing rate and probabilities of occurrence of various interactions among MBs into account to evaluate the impacts of MBs on traffic operation.

As for traffic information like traffic volume, travel time, travel speed and traffic condition, many researches without separately considering the influence of MBs on traffic operation had been conducted with considerable effectiveness. But for travel delay caused by SVs mixed in traffic stream, MBs are dominant elements. Hence, when one evaluates average travel delay in terms of MBs, the ignorance of passing rate will magnify that of influenced vehicles, and it is improper to develop statistically significant average travel delay model while probabilities of occurrence of various interactions among MBs are neglected. Therefore, both of the two factors should be considered to provide more accurate advice for traffic managements. The case of MBs with the same velocity is analyzed in the second section, and the third section presents case of MBs with different velocities (Daganzo, 2005).

2.4 Traffic Delay Causes and Time Taken

The patterns of time taken by delay causes in average peak-hour traffic delay were shown on this research. The problem of traffic wardens can be attributed to the absence of modern traffic management techniques at the road segment (Yi Jiang, 2001). The parking problems experienced include on-street parking, double parking, and parking to load and off -load which reduce the road space thereby impeding the free movement of vehicles (Adedimila, 1989). The parking problems found can be attributed to narrowness of the along roads which do not give room for side-kerbed parking. In addition, there is no provision for off-street parking in the city and as such vehicles have no alternative than to use the roads as parking space. Therefore gives room for indiscriminate on-street parking and parking to load and off-load. Other causes of delay identified include conflicts, construction works and rainfall which also account an average of 2 min constituting 1.7% of total delay time. (Atomode, 2013)

2.5 The Method Proposed by Journals about Traffic Volume, PCU, and Average Speed of Stream

Satyanarayana (2012) studied the effect of traffic volume, its composition and stream speed on passenger car equivalents. Method proposed by Chandra is used for developing the passenger car unit factors and found that for two axle trucks passenger car unit values are found to increase with an increase in compositional share of respective vehicle types in the traffic stream. The passenger car unit of two wheelers practically remains unaffected by its compositional share in the traffic stream. Compositional share of 2W at different locations were observed in the range of 31.69% to 34.23% whereas increase in PCU values are 1.1% only and it may be attributed due to high maneuverability. In slow moving traffic passenger car unit values of bullock carts are increasing with the decreasing in the compositional share in the stream.

V.T Hamizh Arasan and Krishnamurthy (2008) provided an insight into the complexity of the vehicular interaction in heterogeneous traffic. The passenger car unit estimates, made through microscopic of simulation, for the different types of vehicles of heterogeneous traffic, for a wide range traffic volume and roadway conditions indicate that the passenger car unit value of a vehicle significantly changes with change in traffic volume and width of roadway.

Marwah and Bhuvanesh (2000) suggested level of service classification for urban Heterogeneous traffic. They considered journey speed of cars, journey speed of motorized two wheelers, concentration, and road occupancy to define LOS.

Central Road Research Institute (CRRI), (1988) New Delhi to determine the passenger car unit value for different types of vehicles comprises of linear regression of the speed of cars with volume of different categories of vehicles. The method suggests collection of large amount of data on speed of cars under traffic volume and composition and fitting multiple linear regression equations.

Ramanayya (1988) developed a computer simulation model relating average speeds of the traffic stream, the traffic volume and composition of traffic stream. The model could recognize eight different categories of vehicles in the stream and it could be run for any combination of slow and fast moving vehicles. Traffic stream models, relating speed of vehicle type with flow and percentage of slow moving vehicles, were developed for each vehicle type. The models, so derived are given in the following equations.

$$\left.\begin{aligned} V_{car} &= 101.42 - 21.48 \log Q - 30.38P \\ V_{bus} &= 95.12 - 20.75 \log Q - 30.39P \\ V_{truck} &= 92.8 - 21.81 \log Q - 19.61P \\ V_{auto} &= 85.0 - 18.35 \log Q - 30.02P \\ V_{motorcycle} &= 85.9 - 16.7 \log Q - 23.41P \end{aligned}\right\} \quad (2.1)$$

Where,

V= average speed (km/hr),

Q= average traffic flow (veh/hr),

P= percentage of slow moving vehicles in the traffic stream.

The above relationships indicate that proportion of slow moving vehicles has negative effect on speed of a vehicle type. Using the above relationships, design vehicle units (DVU) were derived in terms of western passenger car.

Tanaboriboon and Aryal (1990) studied the effect of vehicle size on capacity of multilane highway in Thailand. All vehicles moving on the road were classified in to three major categories; small, medium and large. Headway was observed for different combinations of leading and trailing vehicles and the basic capacity was determined by considering the reciprocal of the average minimum time headway adopted by small vehicle. Medium sized vehicles were not found to have affected the lane capacity in any way, but the presence of large vehicle, had an adverse impact on the traffic stream. The average headway was found to have increased with an increase in the percentage of large vehicles in stream. This in turn, led to reduction in capacity of the traffic lane.

Parker (1996) observed that knowledge of traffic composition plays an important role in determining capacity. It was found that the percentage of heavy goods vehicles (HGVs) within traffic stream has a major effect on capacity due to length, limited maneuverability, lower desired speed and engine power to weight ratio. As the presence of HGV's in the traffic stream increases, the capacity reduces in term of throughout of vehicle per hour.

Arkatkar (2011) studied the effect of variation of traffic volume, road width, magnitude of upgrade and its length on PCU value; by using traffic-flow simulation model HETEROSIM. Field data collected on traffic flow characteristics are used in calibration and validation of the simulation model. The validated simulation model is then used to derive PCU values for different types of vehicles and it indicate that the model is capable of replicating the heterogeneous traffic flow on mid-block sections of intercity roads, for different roadway conditions, to a satisfactory extent.

The Highway Capacity Manual advises that in the absence of field measurements, reasonable approximations for the PHF may be made as follows: 0.95 for congested conditions, 0.92 for urban areas, and 0.88 for rural areas. General guidelines for determining future peak hour factors can be found in the Development Review Guidelines, and are summarized as follows: 0.85 for Minor Street inflows and outflows, 0.90 for Minor Arterials, 0.95 for Major Streets, unless better information is available.

2.6 Traffic Volume Study

Traffic volume studies were conducted to collect data on the number of vehicles that pass through on a highway facility during a specified time period. This Time period varies from as little as 15 minutes to as much as a year depending on the anticipated use of the data. Road segment volume studies had been taken to determine vehicle classifications, the number of vehicles passing through movements at segment. These data are used mainly in determining causes of traffic delay based on volume of vehicles. In this study the data collected not directional movement. The data collected for both approaching legs at the same time for 12 hours at 15 min interval. It has the most basic of all traffic parameters and the one most often used in planning, design, control, operation and management analysis of road(from ERA manual). Three basic variables-volume, speed, and density; can be used to describe traffic conditions on any roadway. Since speed and density were usually experienced on highway segment or for uninterrupted-flow conditions.

Volume or traffic flow was a parameter common to both uninterrupted- and interrupted-flow characteristics, but speed and density apply primarily to uninterrupted flow. Some parameters related to flow rate, such as spacing and headway, are also used for both types of flow characteristics; other parameters, such as saturation flow or gap, are specific to interrupted flow (Highway Capacity Manual 2000). Thus, the research work primarily focuses on volume, speed and travel time.

2.6.1 Peak Hour Volume and Flow rate

Peak Hour Volume: - is the maximum number of vehicles that pass a point on a highway during a period of 60 consecutive minutes. PHVs are used for:

a) Functional classification of highways
b) Design of the geometric characteristics of a highway, for example, number of lanes, intersection signalization, or channelization
c) Capacity analysis
d) Development of programs related to traffic operations, for example, one-way street systems or traffic routing
e) Development of parking regulations

The peak hour volume would be the sum of four peak volume of passenger car units for the given hour. The peak hour volume is normally given in terms of passenger car units, since changing all vehicles into pcu makes these volume calculations more representative of what was actually going on.

Flow rate: - is the equivalent hourly rate at which vehicles pass over a given point or section of a lane or roadway during a given time interval of less than 1 hour, usually 15 minute. Peak flow rates and hourly volumes produce the peak-hour factor (PHF). (Sanchari, 2013)

2.6.2 Peak Hour Factor

It is simply the ratio of total hourly volume to four times the peak fifteen-minute volume. For example, during the peak hour, there will probably be a fifteen-minute period in which the traffic volume is denser than during the remainder of the hour. That is the peak fifteen minutes, and the volume of traffic that uses the approach lane, during those fifteen minutes is the peak fifteen-minute volume. The peak hour factor is given below.

$$PHF = \frac{\text{Hourly Volume(V)}}{\text{peak flow rate within hour}} \tag{2.2}$$

The peak hour volume is just the sum of the volumes of the four 15 minute intervals within the peak hour (Nicholas J. et al., 2009).

If 15-min periods are used, the PHF may be computed by Equation:-

$$\mathrm{PHF} = \frac{\mathrm{V}}{4 * \mathrm{V15mi}} \tag{2.3}$$

Where

PHF= peak-hour factor,

V= hourly volume (veh/h),

V15 = volume during the peak 15 min of the peak hour (veh/15 min).

When the PHF is known, it can convert a peak-hour volume to a peak flow rate by Equation:-

$$\mathrm{v} = \frac{\mathrm{V}}{\mathrm{PHF}} \tag{2.4}$$

Where

v= flow rate for a peak 15-min period (veh/h),

V = peak-hour volume (veh/h), and

PHF= peak-hour factor

The flow rate then can be computed simply as 4 times the maximum 15-min count.

Peak-hour factors in urban areas generally range between 0.80 and 0.98. Lower values signify greater variability of flow within the subject hour, and higher values signify little flow variation. Peak-hour factors over 0.95 are often indicative of high traffic volumes, sometimes with capacity constraints on flow during the peak hour (Nicholas, 2009).

2.6.3 Passenger Car Unit (PCU)

The Passenger Car Unit (PCU) or Passenger Car Equivalent (PCE) is the universally adopted unit of measure for traffic volume or capacity. Thus, the traffic flow with any vehicular composition can be expressed in terms of its equivalent Passenger Car Unit (Satyanarayana (2012)). Many studies have been performed to determine reasonable values for PCE under different road and traffic conditions. In the HCM 2000 the definition of PCE is given as “The number of passenger cars displaced by a single heavy vehicle of a particular type under specified roadway, traffic, and control conditions”.

The PCU value of a passenger car was identified as 1.0 because of ease maneuverability in any directions. Each vehicle type was given a single PCU equivalent to represent its relative disturbance to the flow under the prevailing traffic condition. Sometimes a set of PCU values is assigned to a particular type of vehicle to represent the various disturbances in its presence in different traffic situations (Chitturi, and Benekohal, 2008).

Passenger car unit analysis is important because it considers different characteristics like width, length and height that cause serious variations in the traffic stream. Due to this difference each type of vehicle has distinct effect on the traffic steam. Therefore the PCU is important because it compare the effect of different vehicle with respect to single car (H.C.M. Iqbal, and Zahurul, 2009).

*2.6.*4 Average Annual Daily Traffic (AADT)

It is the average of 24-hour counts collected every day of the year. AADTs are used in several traffic and transportation analyses:

a. Estimation of highway user revenues

b. Computation of crash rates in terms of number of crashes per 100 million vehicles

c. Establishment of traffic volume trends

d. Evaluation of the economic feasibility of highway projects

e. Development of freeway and major arterial street systems

f. Development of improvement and maintenance programs

Average Daily Traffic (ADT) is the average of 24-hour counts collected over a number of days greater than one but less than a year. ADTs may be used for:

a. Planning of highway activities

b. Measurement of current demand

c. Evaluation of existing traffic flow

2.6.5 Adjustment of Periodic Counts

Expansion factors, used to adjust periodic counts, are determined either from continuous count stations or from control count stations, expansion factors from continuous count stations. Hourly, Daily, and Monthly expansion factors can be determined using data obtained at continuous count stations.

Hourly expansion factors (HEFs) are determined by the formula

$$\mathrm{HEF} = \frac{\text{total volume for 24−hr period}}{\text{volume for particular hour}} \qquad (2.5)$$

These factors are used to expand counts of durations shorter than 24 hour to 24-hour volumes by multiplying the hourly volume for each hour during the count period by the HEF for that hour and finding the mean of these products.

Daily expansion factors (DEFs) are computed as

$$\mathrm{DEF} = \frac{\text{average total volume for week}}{\text{average volume for particular day}} \qquad (2.6)$$

These factors are used to determine weekly volumes from counts of 24-hour duration by multiplying the 24-hour volume by the DEF.

Monthly expansion factors (MEFs) are computed as

$$\mathrm{MEF} = \frac{\text{AADT}}{\text{ADT for particular month}} \qquad (2.7)$$

The AADT for a given year may be obtained from the ADT for a given month by multiplying this volume by the MEF.

Table2. 1 hourly expansion factor for a rural primary road table

Hour	volume	HEF	Hour	volume	HEF
6:00-7:00 am	294	42	6:00-7:00 pm	743	16.62
7:00-8:00 am	426	29	7:00-8:00 pm	706	17.49
8:00-9:00 am	560	22.05	8:00-9:00 pm	606	20.38
9:00-10:00 am	657	18.8	9:00-10:00 pm	489	25.26
10:00-11:00 am	722	17.1	10:00-11:00 pm	396	31.19
11:00-12:00 pm	667	18.52	11:00-12:00 am	360	34.31
12:00-1:00 pm	660	18.71	12:00-1:00 am	241	51.24
1:00-2:00 pm	739	16.71	1:00-2:00 am	150	82.33
2:00-3:00 pm	832	14.84	2:00-3:00 am	100	123.5
3:00-4:00 pm	836	14.77	3:00-4:00 am	90	137.22
4:00-5:00 pm	961	12.85	4:00-5:00 am	86	143.6
5:00-6:00 pm	892	13.85	5:00-6:00 am	137	90.14
Total daily volume= 12350					

Table2. 2Daily expansion factors

Day of week	Volume	DEF
Sunday	7895	9.515
Monday	10714	7.012
Tuesday	9722	7.727
Wednesday	11413	6.582
Thursday	10714	7.012
Friday	13125	5.724
Saturday	11539	6.510
Total weekly volume=75122		

Table2. 3Monthly expansion factors

Month	ADT	MEF
January	1350	1.756
February	1200	1.975
March	1450	1.635
April	1600	1.481
May	1700	1.394
June	2500	0.948
July	4100	0.578
August	4550	0.521
September	3750	0.632

(Source: Nicholas J. Garber)

2.7 Spot Speed Studies

Distribution of speeds of vehicles in a stream of traffic at a particular location on a highway Involves recording of speeds of sample of vehicles at fixed location, results are time, traffic and environment specific applications include (but not limited to):

- Establish speed zones, speed limits and passing restrictions
- Evaluate performances of traffic control devices if there
- Determine and evaluate the adequacy of highway geometric characteristics

Before discussing these procedures, it is first necessary to define certain significant values that are needed to describe speed characteristics. They are:

1. Average Speed which is the arithmetic mean of all observed vehicle speeds or which is the sum of all spot speeds divided by the number of recorded speeds. It was given as $\bar{U} = \sum \frac{fi * ui}{\sum fi}$ (2.8)

Where

$\bar{U}$_ Arithmetic mean

fi _ number of observations in each speed group

ui _ Midvale for the *i*th speed group

N _ number of observed values

The formula also can be written as $\bar{U} = \sum \frac{Ui}{N}$

Where

*Ui*_ speed of the *i*th vehicle

N _ number of observed values

2. Median Speed which was the speed at the middle value in a series of spot speeds that was arranged in ascending order. 50 percent of the speed values will be greater than the median; 50 percent will be less than the median.

3. Modal Speed which was the speed value that occurs most frequently in a sample of spot speeds.

4. The **i^{th} -percentile Spot Speed** which is the spot speed value below which *i* percent of the vehicles travel; for example, 85th-percentile spot speed is the speed below which 85 percent of the vehicles travel and above which 15 percent of the vehicles travel.

5. Pace which is the range of speed—usually taken at 10-mi/h intervals—that has the greatest number of observations. For example, if a set of speed data includes speeds between 30 and 60 mi/h, the speed intervals will be 30 to 40 mi/h, 40 to 50 mi/h, and 50 to 60 mi/h, assuming a range of 10 mi/h. The pace is 40 to 50 mi/h if this range of speed has the highest number of observations.

6. Standard Deviation of Speeds which is a measure of the spread of the individual speeds. It is estimated as $S = \frac{\sqrt{\sum_1^1 (Ui-^{-})2}}{N-1}$ (2.9)

Where

S _ standard deviation

Ū_ arithmetic mean

u_j _ *j*th observation

N _ number of observations

However, speed data are frequently presented in classes where each class consists of a range of speeds. The standard deviation is computed for such cases as

$$S = \frac{\sqrt{\sum_1^1 fi(Ui-\bar{u})2}}{N-1} \quad (2.10)$$

Where

Ui _ midvalue of speed class *i*

fi _ frequency of speed class *i*

2.7.1 Time of Day and Duration of Spot Speed Studies

The time of day for conducting a speed study depends on the purpose of the study. In general when the purpose of the study is to establish posted speed limits, to observe speed trends, or to collect basic data, it is recommended that the study be conducted when traffic is free-flowing, usually during off-peak hours. However, when a speed study is conducted in response to citizen complaints, it is useful if the time period selected for the study reflects the nature of the complaints. The duration of the study should be such that the minimum number of vehicle speeds required for statistical analysis is recorded. Typically, the duration is at least 30min and the sample size is at least 40 vehicles (Nicholas J. Garber. 4th Edition).

2.8 Travel Time and Delay Studies

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.

2.8.1 Applications of Travel Time and Delay Data

The data obtained from travel time and delay studies may be used in any one of the following traffic engineering tasks:

- Determination of the efficiency of a route with respect to its ability to carry traffic
- Identification of locations with relatively high delays and the causes for those delays
- Performance of before-and-after studies to evaluate the effectiveness of traffic operation improvements
- Determination of relative efficiency of a route by developing sufficiency ratings or congestion indices
- Determination of travel times on specific links for use in trip assignment models
- Compilation of travel time data that may be used in trend studies to evaluate the changes in efficiency and level of service with time
- Performance of economic studies in the evaluation of traffic operation alternatives that reduce travel time

2.8.2 Definition of Terms Related to Time and Delay Studies

Let us now define certain terms commonly used in travel time and delay studies:

1. **Travel time** is the time taken by a vehicle to traverse a given section of a highway.
2. **Running time** is the time a vehicle is actually in motion while traversing a given section of a highway.
3. **Delay** is the time lost by a vehicle due to causes beyond the control of the driver.
4. **Operational delay** is that part of the delay caused by the impedance of other traffic. This impedance can occur either as side friction, where the stream flow is interfered with by other traffic (for example, parking or no parking vehicles), or as internal friction, where the interference is within the traffic stream (for example, reduction in capacity of the highway).

5. Stopped-time delay is that part of the delay during which the vehicle is at rest.

6. Fixed delay is that part of the delay caused by control devices such as traffic signals. This delay occurs regardless of the traffic volume or the impedance that may exist.

7. Travel-time delay is the difference between the actual travel time and the travel time that will be obtained by assuming that a vehicle traverses the study section at an average speed equal to that for an uncongested traffic flow on the section being studied.

2.8.3 Methods Requiring a Test Vehicle

This category involves three possible techniques: floating-car, average-speed, and moving-vehicle techniques.

Floating-Car Technique:

In this method, the test car is driven by an observer along the test section so that the test car "floats" with the traffic. The driver of the test vehicle attempts to pass as many vehicles as those that pass his test vehicle. The time taken to traverse the study section is recorded. This is repeated, and the average time is recorded as the travel time. The minimum number of test runs can be determined using an equation similar to Eq. 4.5, using values of the t distribution rather than the z values. The reason is that the sample size for this type of study is usually less than 30, which makes the t distribution more appropriate. The equation is

$$N = (ta * óA/d)2 \quad (2.11)$$

Where

N _ sample size (minimum number of test runs)

s _ standard deviation (mi/h)

d _ limit of acceptable error in the speed estimate (mi/h)

ta _ value of the student's t distribution with (1 _ a/2) confidence level and (N _ 1) degrees of freedom

a _ significance level

The limit of acceptable error used depends on the purpose of the study. The following limits are commonly used:

- Before-and-after studies: 1.0 to 3.0 mi/h
- Traffic operation, economic evaluations, and trend analyses: 2.0 to 4.0 mi/h
- Highway needs and transportation planning studies: 3.0 to 5.0 mi/h

Average-Speed Technique:

This technique involves driving the test car along the length of the test section at a speed that, in the opinion of the driver, is the average speed of the traffic stream. The time required to traverse the test section is noted. The test run is repeated for the minimum number of times, determined from Eq. 4.8, and the average time is recorded as the travel time. In each of these methods, it is first necessary to clearly identify the test section. The way the travel time is usually obtained is that the observer starts a stopwatch at the beginning point of the test section and stops at the end. Additional data also may be obtained by recording the times at which the test vehicle arrives at specific locations which have been identified before the start of the test runs.

A second stopwatch also may be used to determine the time that passes each time the vehicle is stopped. The sum of these times for any test run will give the stopped-time delay for that run. Alternatively, the driver alone can collect the data by using a laptop computer with internal clock and distance functions. The predetermined locations (control points) are first programmed into the computer. At the start of the run, the driver activates the clock and distance functions; then the driver presses the appropriate computer key for each specified location. The data are then recorded automatically. The causes of delay are then recorded by the driver on a tape recorder.

Moving-Vehicles Technique:

In this technique, the observer makes a round trip on a test section like the one shown in Figure 3.1, where it is assumed that the road runs north to South. The observer starts collecting the relevant data at section X-X, drives the car northward to section Y-Y, then turns the vehicle around and drives southward to section X-X again.

2.8.4 Cost of Drivers Wasted Travel Time

Wasted travel time imposes significant costs on drivers, including, increased fuel consumption, added variability of trip times, and reduced mobility. Most estimates of congestion costs (both nationwide and for individual metropolitan regions) have focused on direct costs, including loss of time and excess fuel costs accrued to vehicle users. The principal categories of congestion cost considered in this study are:

- **Travel Time Cost:** The most prominent cost of traffic congestion is the delay associated with lower travel speeds, start-and-stop traffic flows, and in extreme cases, gridlock. These delays represent an opportunity cost of time -- time that could be spent both at work and for leisure.

- **Unreliability Cost:** This represents the cost assumed by drivers in having to deal with travel times made unpredictable by congestion. Travelers cope to some extent by leaving early for a destination in anticipation of delays, but they also sometimes suffer the inconveniences from arriving late.
- **Vehicle Operating Cost (VOC):** Traffic congestion leads to higher vehicle operating costs, primarily as a result of increased fuel use due to idling or starts and- stop traffic flows, both of which consume more fuel than driving at steady speeds.
- **Vehicle Operating Costs:** Vehicle operating costs (VOC) are generally the most recognized congestion user costs because they typically involve the out-of-pocket expenses associated with owning, operating, and maintaining a vehicle. The cost components of VOC measured in this analysis include: fuel consumption, oil consumption, maintenance and repairs, tire wear, as well as vehicle depreciation. Figure 4 illustrates the structure and logic of the estimation of vehicle operating costs. The method used to estimate consumption rates as a function of speed, as well as unit prices of these components, is based on both the UMR for fuel consumption in addition to the Federal Highway Administration's Highway Economic Requirements System (HERS) for other components.

To assess the effects of traffic congestion on vehicle operating costs, this study utilized data and information from several sources in order to develop vehicle operating cost usage rates in the current congested state and compared those rates to an un-congested highway system. In doing so, vehicle operating costs for five cost components were analyzed: fuel consumption, oil consumption, tire wear, vehicle depreciation, and maintenance and repair costs. These consumption components were calculated for both autos and trucks on arterials as well as freeways.

Generalized cost per vehicle-mile of travel, C, is defined as the sum of cost components:

C = Time Cost + Vehicle Operating Cost + Reliability Cost

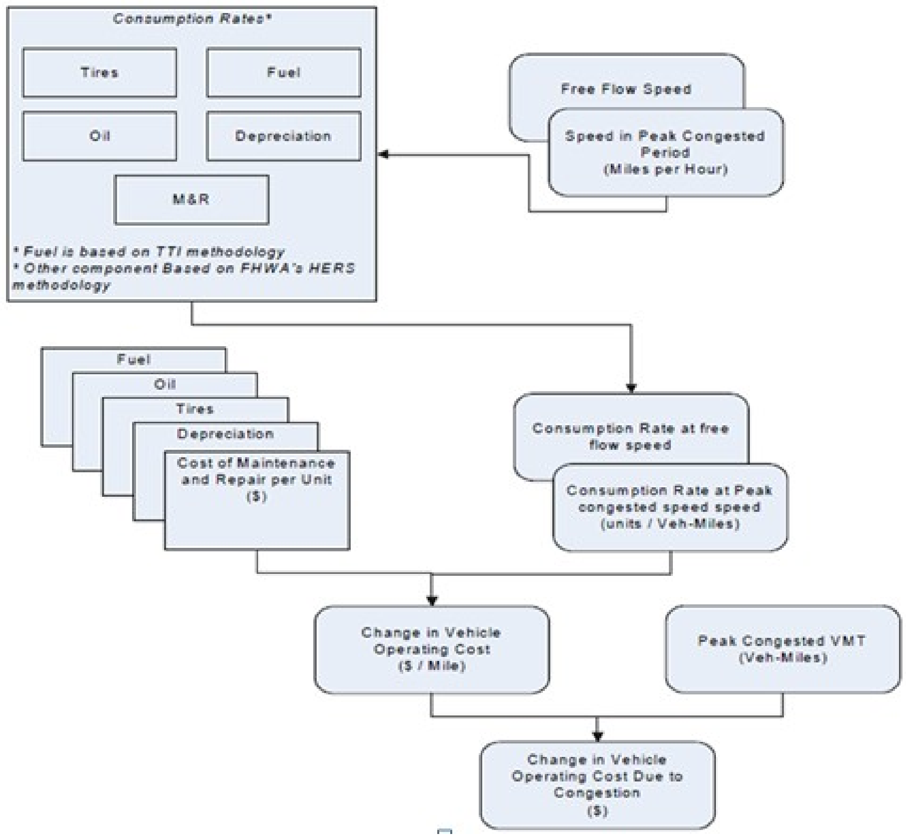


Figure2. 1.Structure and Logic Diagram for Vehicle Operating Cost

(Source: Assessing the Full Costs of Wasted travel time on Surface Transportation Systems and Reducing Them through Pricing February 2009)

2.9 Primary Elements of Traffic Flow)

The primary elements of traffic flow are flow, density, and speed. Another element, associated with density, is the gap or headway between two vehicles in a traffic stream. The definitions of these elements follow.

Flow (q) is the equivalent hourly rate at which vehicles pass a point on a highway during a time period less than 1 hour. It can be determined by:

$$q = \frac{n*3600veh/h}{T} \tag{2.12}$$

Where

n = the number of vehicles passing a point in the roadway in T sec

q = the equivalent hourly flow

Density (k) sometimes referred to as concentration is the number of vehicles traveling over a unit length of highway at an instant in time. The unit length is usually 1 mile (mi) thereby making vehicles per mile (veh/mi) the unit of density (Nicholas J. G.).

Speed (u) is the distance traveled by a vehicle during a unit of times? It can be expressed in miles per hour (mi/h), kilometers per hour (km/h), or feet per second (ft /sec). The speed of a vehicle at any time t is the slope of the time space diagram for that vehicle at time t. Vehicles 1 and 2 in Figure 6.1, for example, are moving at constant speeds because the slopes of the associated graphs are constant. Vehicle 3 moves at a constant speed between time zero and time t3, then stops for the period t3 to (the slope of graph equals 0), and then accelerates and eventually moves at a constant speed. There are two types of mean speeds: time and space mean speed **Time mean speed** is the arithmetic mean of the speeds of vehicles passing a point on a highway during an interval of time. The time mean speed is found by (Nicholas J. Garber).

$$\ddot{u} = 1\frac{1}{n}\sum_{i=1}^{n} ui \qquad (2.13)$$

Where

n = number of vehicles passing a point on the highway

ui = speed of the i^{th} vehicle (ft /sec)

Space mean speed ( ) is the harmonic mean of the speeds of vehicles passing a point on a highway during an interval of time. It is obtained by dividing the total distance traveled by two or more vehicles on a section of highway by the total time required by these vehicles to travel that distance. This is the speed that is involved in flow-density relationships. The space mean speed is found by (Nicholas J. Garber).

$$\bar{U}s = \frac{n}{\sum_{i=1}^{n}(1/ui)} = \frac{nL}{\sum_{i=1}^{n} ti} \qquad (2.14)$$

Where

u_s= space mean speed (ft /sec)

n = number of vehicles

ti _=the time it takes the ith vehicle to travel across a section of highway (sec)

u_i = speed of the ith vehicle (ft /sec)

L =length of section of highway (ft)

The time mean speed is always higher than the space mean speed. The difference between these speeds tends to decrease as the absolute values of Speeds increase.

It has been shown from field data that the relationship between time mean speed and space mean speed can be given as (Nicholas J. Garber). Traffic flow theory is mostly concerned with three major characteristics of traffic: speed, time intervals and distance intervals between vehicles. Traffic flow can be studied on two levels, namely the microscopic or macroscopic approaches. (Joubert, 2002)

2.9 Microscopic Approach

The microscopic approach considers traffic as a mixture of individual or discrete vehicles. Three basic characteristics may be identified, namely microscopic speed, time headways and distance headways (HCM, 2000)

2.10 Macroscopic Approach

The macroscopic approach considers traffic as a stream or fluid continuum (hydrodynamic analogy). Three basic characteristics may be identified, namely macroscopic speed, flow and density (or concentration). These characteristics are meaningful only as averages over a length of a road and a time period

Time Headway

Time headway (Ht) is defined as the time interval between the fronts or rears of two successive vehicles measured at a fixed point along the road.

Distance Headway

Distance headway (Hd) is defined as the distance interval between the fronts or rears of two successive vehicles measured at a given moment in time.

2.11 Directional and Lane Distribution

In addition to the distribution of vehicle types, two other traffic characteristics affect capacity, service flow rates, and level of service: directional distribution and lane distribution. Directional distribution has a dramatic impact on two-lane rural highway operation, which achieves optimal conditions when the amount of traffic is about same in each direction. Capacity analysis for multilane highway focuses on a single direction of flow. Nevertheless, each direction of the facility usually is design to accommodate the peak traffic flow rate in the peak direction. Typically, morning peak occurs in one direction and evening peak traffic occurs in the opposite direction. Lane distribution also is a factor on multilane facilities. Typically, the shoulder lane carries less traffic than other lanes (H.C.M 2000).

Roadway conditions include geometric and other elements. In some cases, these influence the capacity of a road; in others, they can affect a performance measure such as speed, but not the capacity or maximum flow rate of the facility. Roadway factors include the following:

- Number of lanes,
- The type of facility and its development environment,
- Lane width,
- Shoulder widths and lateral clearances,
- Design speed,
- Horizontal and vertical alignments and
- Availability of exclusive turn lanes at intersections.

The horizontal and vertical alignment of a highway depends on the design speed and the topography of the land on which it is constructed. In general, the severity of the terrain reduces capacity and service flow rates. This is significant for two-lane rural highways, where the severity of terrain not only can affect the operating capability of individual vehicles in the traffic stream, but also can restrict opportunities for passing slow-moving vehicles (H.C.M 2000).

2.12 The concept of level of service

Defined by (TRB, 1985-1997) as a qualitative measure of describing operating conditions within a traffic stream, six levels of service are defined ranging from, A (best) to F (worst):

a) Level-of-service A represents free flow. Individual drivers are virtually unaffected by the presence of other vehicles on the road. Freedom to select a desired speed is extremely high and drivers can expect not to be delayed more than 30% of the time. Average speeds of at least 88 km/h can be maintained on specific grades.

b) Level-of-service B represents a region of stable traffic flow but the presence of other vehicles on the road begins to be noticeable. Freedom to select a desired speed is relatively unaffected but there is a slight decline in the freedom to overtake and drivers could be delayed up to 45% of the time. Average speeds of 80 km/h can be maintained on specific grades.

c) Level-of-service C is also in the range of stable flow, but individual drivers are now beginning to be significantly affected by other vehicles. Overtaking requires substantial vigilance on the part of drivers and percentage time delay may increase up to 60%. On specific grades, average speeds may be reduced to 72 km/h.

d) Level-of-service D represents the onset of unstable flow when the two opposing directions of traffic essentially begin to operate separately as overtaking becomes extremely difficult. The percentage of time vehicles are delayed approaches 75%. Average speeds on specific grades can be reduced to as low as 65 km/h indicating a generally poor level of comfort and convenience.

e) Level-of-service E represents operating conditions at or near the capacity level. The average percentage of time vehicles are delayed exceeds 75%. On specific grades, speeds can be reduced to as low as 40 m/h.

f) Level-of-service F defines forced or breakdown flow. Traffic demand exceeds the capacity of the road and operations are characterized by stop-and-start waves. Some basic relationships between speed, percentage time delay and flows are shown in Figures 2.2 and 2.3 for ideal traffic and roadway conditions. Many of the procedures in the Highway Capacity Manual (TRB, 1985 1997) are applicable to so-called "ideal conditions". In principle, an ideal condition exists when no further improvements will increase the capacity or level of service of a facility.

The capacity of two-lane roads under these ideal conditions is 2800 passenger car units per hour total, in both directions (TRB, 1985-1997). This is less than the about 2000 passenger car units per hour per lane which may be accommodated on multilane uninterrupted flow facilities and is explained by the impact of opposing vehicles on passing maneuvers which restricts the ability of traffic to efficiently fill gaps in the traffic stream. In most capacity analyses prevailing conditions are not ideal and computations of capacity and level of service must include adjustments to reflect this. The Highway Capacity Manual (TRB, 1985 1997) takes various aspects such as lane and shoulder widths, design speed and vehicle type into account:

a) Lane widths can have a significant impact on traffic flow. Narrow lanes cause vehicles to travel closer to each other laterally and drivers generally need to slow down and to observe longer spacing, resulting in a decrease in level of service.

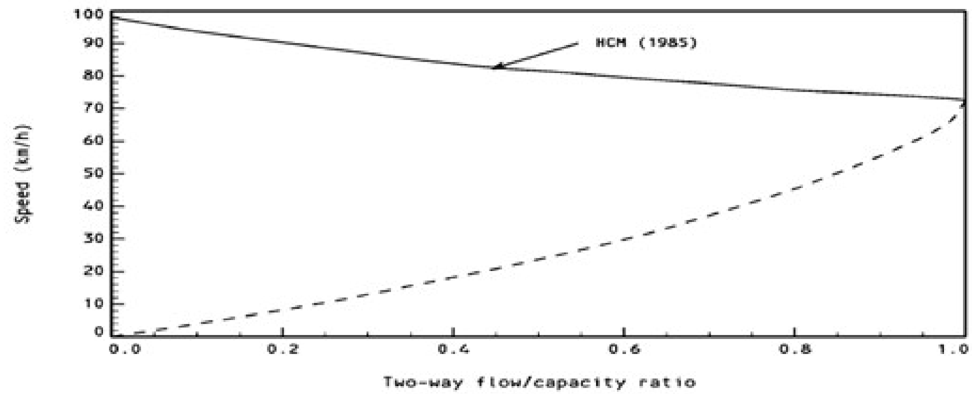
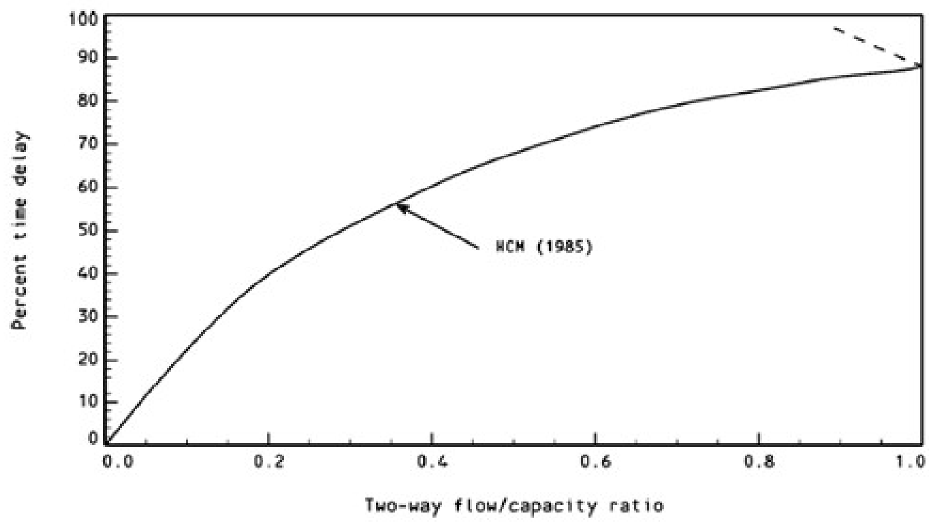


Figure2. 2 Speed-flow relationships for two-lane roads



(Source SC Van AS 2002)

Figure2. 3 Percentage time delay/flow relationship

b) Shoulder widths and lateral obstructions may cause drivers to "shy away" from obstructions resulting in the same behavior as with narrow lanes. On many two-lane roads, shoulders are used for the passing of slow vehicles and narrow shoulders may then negatively affect flow.

c) Restrictive design speed affects level of service because drivers are forced to drive at reduced speeds and to be aware of poorer sight distances and harsher vertical and horizontal alignments reflected by restricted design speeds.

d) Frequency of no passing zones on a two-lane highway is an important factor having a significant effect on platoon forming. A no passing zone is defined by the Highway Capacity Manual as any marked zone or any section of road with a passing sight distance of 450 meter or less. The average percentage of no passing zones in both directions along a road is used in the capacity analysis.

e) Unbalanced directional distribution may cause capacity to decline resulting in lower speeds and a higher percentage time delay. Optimum conditions occur when the split of traffic is about 50/50 (50 percentage in each direction).

f) Vehicle type composition is an important factor influencing operations. Heavy vehicles are longer than passenger cars and therefore occupy more roadway space. They have poorer operating capabilities than passenger cars, particularly with respect to acceleration, deceleration, and the ability to maintain desired speeds on upgrades. (Hoban C.J., 1984).

Table2. 4 Level of service criteria

Level of service criteria

Level of Service	Density Range for basic Freeway Section (pc/mi/ln)	Density Range for Multilane Highways (pc/mi/ln)
A	$\geq 0 \leq 11$	$> 0 \leq 11$
B	$> 11 \leq 18$	$> 11 \leq 18$
C	$> 18 \leq 26$	$> 18 \leq 26$
D	$> 26 \leq 35$	$> 26 \leq 35$
E	$> 35 \leq 45$	$> 35 \leq (40\text{-}45)^{+}$
F	> 45	$> (40\text{-}45)^{++}$

$^{+, ++}$ *Depending on FFS*

(Source: The Highway Capacity Manual (HCM 2000))

2.13 Rural Roads

Papenfus, (1992) developed a stratification system for rural roads based on trip purposes identified from normal weekly traffic patterns. The following trip purposes were identified as: - Additional peak hour traffic on Mondays to Fridays occurring during peaks over and above the traffic during midday. These peaks occur mainly as a result of commuter trips or business trips.

- Weekend traffic that results in an increase in traffic on Friday afternoons. This coincides with traffic returning on Sunday afternoons and Monday mornings. This traffic is a result of long-distance migrant trips or recreational traffic over weekends.
- Basic traffic that remains after the above-mentioned additional traffic is deducted.

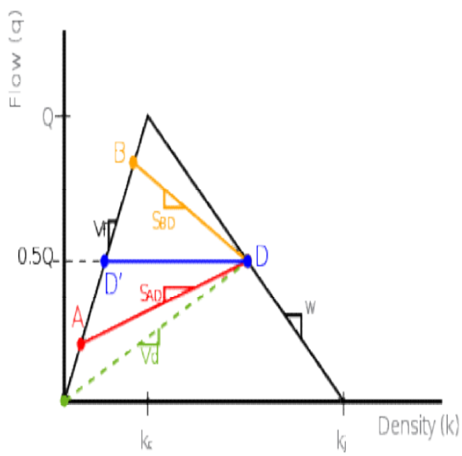
A stratification system for rural areas should ideally also include a trip purpose that allows for holiday and other exceptional traffic. In practice, it is difficult to observe the contribution of such traffic on any particular road. Papenfus (1992) have, however, shown that some relationship exists between weekend traffic day and holiday traffic and, although this relationship is not perfect, it can be used in the identification of holiday routes. A stratification system can therefore be based on the relative degree to which additional peak hour and weekend traffic occurs.

2.14 theoretical and graphical represent of traffic bottleneck

A **traffic bottleneck** is a localized disruption of vehicular traffic on a street, road, or highway. As opposed to a traffic jam, a bottleneck is a result of a specific physical condition, often the design of the road, or sharp curves. They can also be caused by temporary situations, such as vehicular accidents (Gazis, 1994).

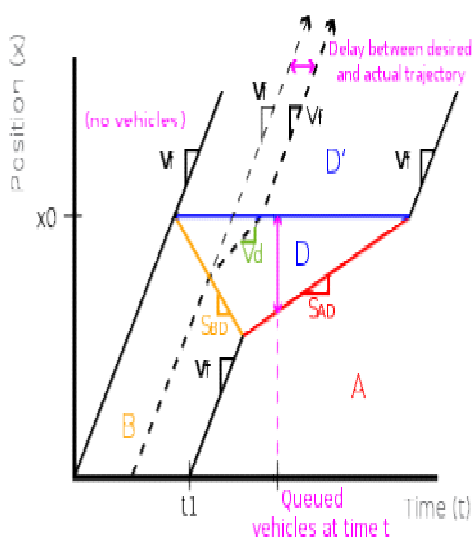
Traffic bottlenecks are caused by a wide variety of things:

- Construction zones where one or more existing lanes become unavailable (as depicted in the diagram on the right)
- Accident sites that temporarily close lanes
- Narrowing a low-capacity highway road Terrain (e.g., uphill sections, very sharp curves)
- Poorly timed traffic lights
- Slow vehicles that disrupt upstream traffic flow upstream (also known as a "moving bottleneck")
- Rubbernecking; for example, vehicles safely pulled to the shoulder by a police car often result in passing drivers to slow down to "get a better look" at the situation.



Consider a stretch of highway with two lanes in one direction. Suppose that the fundamental diagram is modeled as shown here. The highway has a peak capacity of Q vehicles per hour, corresponding to a density of k_c vehicles per mile. The highway normally becomes jammed at k_j vehicles per mile. Before capacity is reached, traffic may flow at *A* vehicles per hour, or a higher *B* vehicles per hour. In either case, the speed of vehicles is v_f (or "free flow"), because the roadway is under capacity. Now, suppose that at a certain location x_0, the highway narrows to one lane. The maximum capacity is now limited to *D*', or half of *Q*,

Figure 2.4 example of flow/density make bottleneck (source: Munoz, 2002)



Since only one lane of the two is available. State *D* shares the same flow rate as state *D'*, but its vehicular density is higher.

Using a time-space diagram, we may model the bottleneck event. Suppose that at time t_0, traffic begins to flow at rate *B* and speed v_f. After time t_1, vehicles arrive at the lighter flow rate *A*. Before the first vehicles reach location x_0, the traffic flow is unimpeded.

Figure 2.5 example of position/time make bottleneck(source: Juran, 2009)

However, downstream of x_0, the roadway narrows, reducing the capacity by half—and to below that of state *B*. Due to this, vehicles will begin queuing upstream of x_0. This is represented by high-density state *D*. The vehicle speed in this state is the slower v_d, as taken from the fundamental diagram. Downstream of the bottleneck, vehicles transition to state *D'*, where they again travel at free-flow speed v_f. Once vehicles arrive at rate *A* starting at time t_1, the queue will begin to clear and eventually dissipate. State *A* has a flowrate below the one-lane capacity of states *D* and *D'*.

2.14.1Moving bottleneck

Figure 2.6 A slow tractor creates a moving bottleneck. **Figure 2.7** trucks make bottle

(Source: Munoz, 2002)

For this example, consider three lanes of traffic in one direction. Assume that a truck starts traveling at speed v, more slowly than at the free-flow speed vf. As shown on the fundamental diagram below, speed qu represents the reduced capacity (two-thirds of Q, i.e., 2 out of 3 lanes available) around the truck.

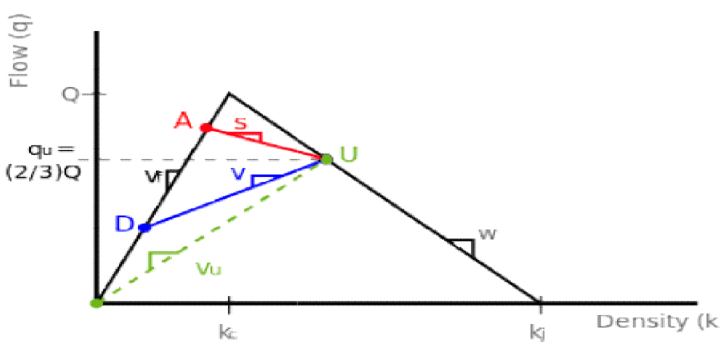


Figure 2.8 the queuing upstream of the truck make bottleneck (source: Juran, 2009)

State A represents normal approaching traffic flow, again at speed vf. State U, with flow rate qu, corresponds to the queuing upstream of the truck. On the fundamental diagram, vehicle speed vu is slower than speed vf. But once drivers have navigated around the truck, they can again speed up and transition to downstream state D. While this state travels at free flow, the vehicle density is less because fewer vehicles get around the bottleneck.

CHAPTER THREE

MATERIALS AND RESEARCH METHODS

3.1 Study Area Description

The studies were conducted at the road from Adama to Welenchity road segment, with a total length of 24 kilometers. The Road was a two-way highway and highest in the country. The road segment between Adama to Welenchity was the main route of the Ethiopians import and export corridor. Furthermore, more fertile land which was suitable for agriculture is located along the route especially large scale farmers of teff and other plants peasants, also molasses are in habited at the sides of the road. In general, the road connects the capital city of the Ethiopia to other city like Dire Dawa, Harar, Jigjiga and Afar and neighboring countries i.e. Djibouti as well as recreation centers, and to the main agricultural potential area. The road traverses through two towns; Adama and Welenchity. Due to these facts, the road is considered as the most vital route in terms of economic and traffic volume. Again Adama to Welenchity road segment comprises all types of vehicles which travel between town and cross route.

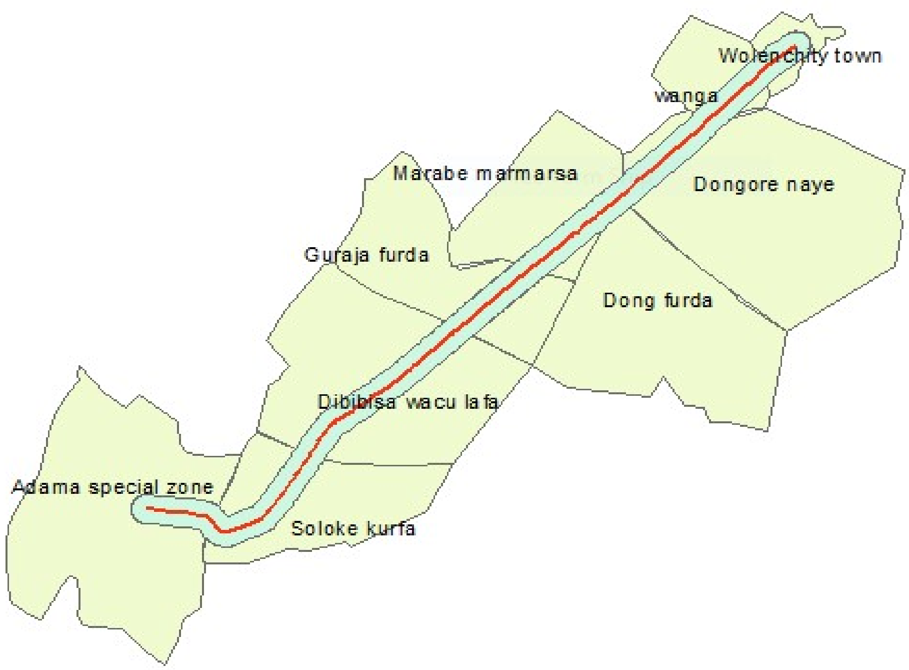


Figure3. 1 Digitized study area and road buffered (source: GIS 10.1 digitize)

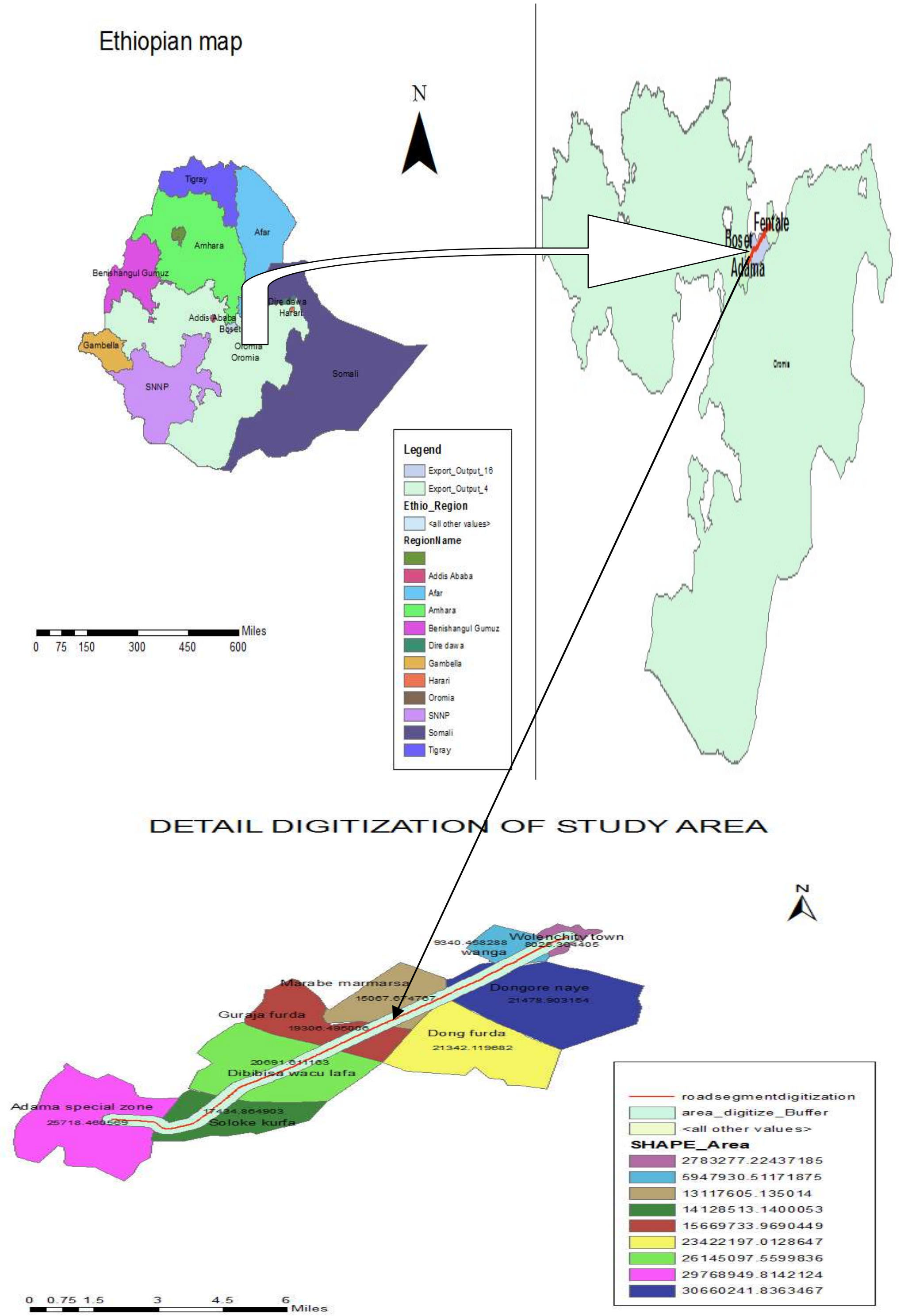


Figure3. 2 Location of the study area (source: GIS 10.1 digitize).

3.2 Materials

The materials used for accomplishment of the thesis work are:

- Video camera – for to record the actual movement of the vehicles on the road segment
- Laptop computer- for to store necessary data and analysis.
- Tape or mater- for to measure the road condition and road section.
- Mobile phone – for stopwatch
- Using flag man for spot speed record data, note book etc.

3.3 Study Period

The study period of the research work was from May 2018-October 2018 for the different activities including thesis writing.

3.4 Study Variables

Research variables are including:

- Dependent variables: - cause of delay.
- Independent variables are: traffic volume, spot speed, and Vehicle classification, travel time, level of service, road condition.

3.5 Research Design

The quantitative descriptive research design used for the purpose of this study which enable the research to interpret the finding adequately and accurately. Consequently, the research works consisted the relevant data collection, intensive data analysis by some suitable tools and describe the effect of road traffic flow, road condition data and questionnaire with the relationship of what the causes of traffic delay. Below is the flow chart of the research work.

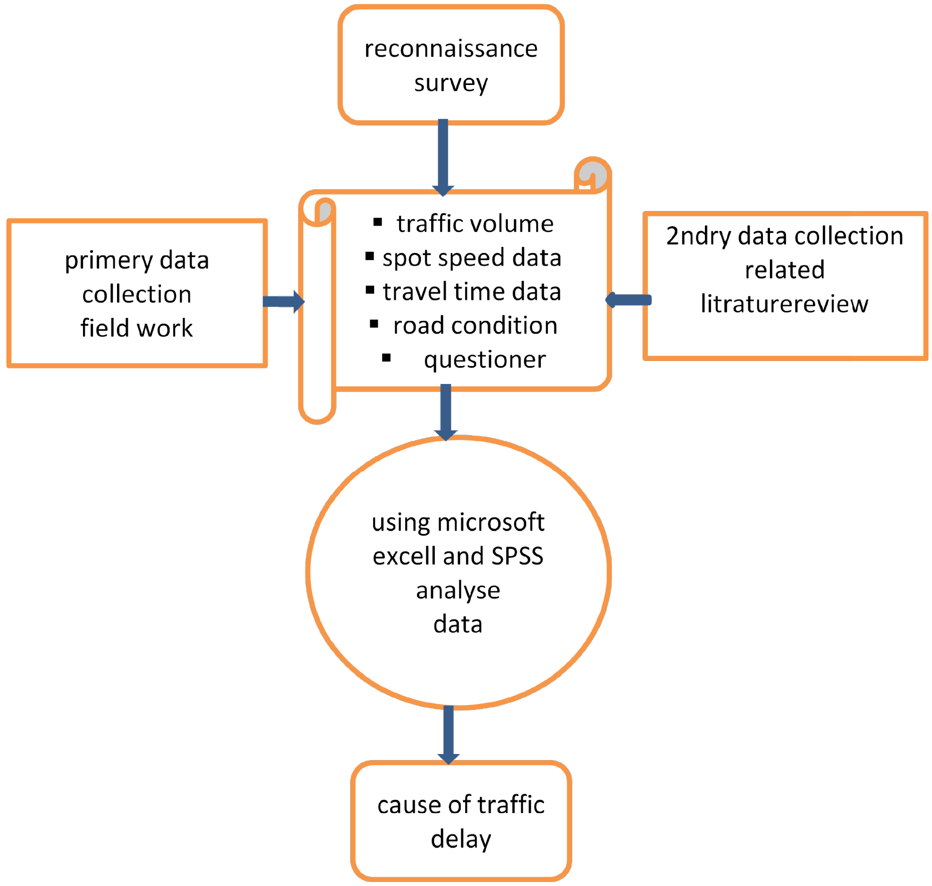


Figure3. 2 Sequential research work procedures.

3.6 Data Collection Methods

In order to attain research work ethical considering before starting any data collection formal letters from Jimma Institute of Technology and an official permission was obtained. Then the data used as inputs were obtained from:

1. Motorized and non motorized mixed traffic flow data in both legs of the road.
2. Spot speed data.
3. Travel time data.
4. Road condition data.
5. Questionnaire data

3.6.1 Reconnaissance Survey

Reconnaissance Survey was performed to observe the rough flow conditions, safety and operating conditions. The researcher visited the site to evaluate and inspection improvements to the segment by considering three perspectives.

1. Segment perspective: This deals with operational performance, geometric configuration, movements types with slow or speed, and pavement markings.
2. User perspective: visibility of road marking, driver ability, decision making, level of service, and conflicts for all user types.
3. System perspective: impacts of upstream/downstream segment influence of adjacent driveways, location relative to other facility types.

3.6.2 Primary Source of Data

Primary data involve the collection of original data using deferent data collection methods. Both qualitative and quantitative data gathering methods were used in the form of questionnaire and video camera record. The survey questionnaires were presented to drivers using Adama-Welenchity road segment to have the opinion on cause of delay.

3.6.3 Secondary Source of Data

In addition to gathering needed documents related to cause of traffic delay from related documents such as: books, international journals studies and police document that related were reviewed to assess the current condition of cause of traffic delay and its effects to strengthen the analysis, to have an understanding on what has been done in the past and current situation.

3.7 Data Analysis

The collected data needs to be calculated and analyzed in order to describe the existing conditions of traffic delay; it is expressed in terms of numbers or words. To figure out the rest of assessment the data is analyzed using Microsoft office excel and SPSS software, for traffic volume data, spot speed data and vehicle composition. Again ArcGIS10.1 is used for digitizing roads and study area. Therefore, for the data analyses purposes, SPSS software and Microsoft office excel were used in this study which are discussed as follows and was utilized for the analysis.

3.7.1 Statistical Package for the Social Sciences (SPSS)

Statistical Package for the Social Sciences (SPSS) is the most widely used software for the statistical analysis of quantitative data. In this study, the SPSS software was used in order to analyze the spot speed data. But volume data and vehicle composition was analyzed by Microsoft Excel which is used to assess the causes and effects of traffic delay. The questionnaires were designed in such a way that the appropriate parameters are incorporated and were addressed to acquire the opinions from truck, car and bus drivers(Kalkidan, 2017). Therefore, the results obtained from the analysis of the data using the above methods are presented in the next chapter.

Traffic studies may be grouped into three main categories: (1) inventories, (2) Administrative studies, and (3) dynamic studies. Inventories provide a list or graphic display of existing information, such as street widths, parking spaces, transit routes, traffic regulations, and so forth. Administrative studies use existing engineering records, available in government agencies and departments.

Dynamic traffic studies involve the collection of data under operational conditions and include studies of traffic volume, spot speed, travel time and delay. Since dynamic studies are carried out by the traffic engineer to evaluate current conditions and develop solutions, they were described in detail in literature review.

3.8 Data Collection Time and Method

Data acquisition and field investigation provides an understanding of the physical and operational characteristics of the study road segment and identify factors that contribute to its deficiencies. Field survey of traffic data for volume, spot speed, travel speed, road condition and survey questioner were conducted from September 10-24/2018. While the secondary data were collected from different relevant bodies, such as Adama Woreda Transport Agency office, Books, Internet and some related thesis.

3.9 Method of Volume Data Collection

There are two manual data collection methods, direct and indirect, for this particular study. The traffic volume data was collected by using video camera for 12 hours starting the morning 6:00 AM to the evening 6:00 PM at 15 minutes interval Observer should be positioned where they have a clear view of traffic and are safely away from the edge of the road way. Observer recorded the traffic stream flow carefully as shown to appendix (5) also by using tally manual counting from the video at 15 min interval for both approaching legs. The vehicles were counted in category as carts, bicycle and motor cycle at one group, Car, pick up and minibus again as the same, bajaj, L/bus, single and dual rear axle truck, 4axle truck and articulated large truck. The raw data of traffic volume counted at Monday and Thursday for both approach were summarized in Annex-1.

The PCU values of vehicle types are summarized in the following table based on movement types.

Table3. 1 PCU Factor

type of vehicle	bajaj	Carts, cycle and motorcycle	Minibus, car and pickup	L/bus	Single and dual rear Truck	Large trucks and articulated truck
PCU	0.8	0.5	1	3	2.25	3

(Source: H.C.M, Iqbal, and Zahurul, 2009)

Using the above factors, each vehicle classes converted to the total pcu for each 15min intervals in the peak hour traffic condition as shown on appendix (1-4).

3.10 Method of Vehicle Classification (VC)

Vehicle classification records volume with respect to the type of vehicles, for example, passenger cars, two-axle trucks, or three-axle trucks. VC is used in:

a) Design of geometric characteristics, with particular reference to turning-radii requirements, maximum grades, lane widths, and so forth
b) Capacity analyses, with respect to passenger-car equivalents of trucks
c) Adjustment of traffic counts obtained by machines
d) Structural design of highway pavements, bridges, and so forth

3.11 Method of Spot Speed Data Collection

Depends on the intended purposes of collected data, for example Basic data collection

- Locations that represent different traffic conditions on a highway or highways

Speed trend analysis:

- Straight, level sections of rural highways

To observe spot speed trends, collect basic data time of day when traffic is free flowing –off peak hours (Nicholas J. Garber)

Spot speed data collection method

- Automatic method which is elevated video camera.
- Record travel times within a small strip of 54m.
- Location: Mid-block
- Duration: for 1 hour at Thursday

3.11.1 Sample Size for Spot Speed Studies

The calculated mean (or average) speed is used to represent the true mean value of all vehicle speeds at that location. The accuracy of this assumption depends on the number of vehicles in the sample. The larger the sample size, the greater the probability that the estimated mean is not significantly different from the true mean. It is therefore necessary to select a sample size that will give an estimated mean within acceptable error limits. Statistical procedures are used to determine this minimum sample size.

3.11.2 Determining Spot Speed Sample Size

As part of a class study, a group of data collected data total of 160 spot speed samples at a location and determined from this data that the standard variation of the speeds was 9.95 km/h. If the sample required that the confidence level be 95% and the limit of acceptable error was 1.6 km/h, determine whether this sample satisfied the project requirement.

Solution: to determine the minimum sample size to satisfy the project requirements.

$$N = (Z\sigma/d)^2 \tag{3.1}$$

Where

Z =1.96 (from Table 4.1 Garber book page 104)

s =9.95

d = 1.6

The result was discussed in chapter four

3.12 Method of Travel Times Field Measurement and Delay Calculation

A reliable way of measuring travel times is the license matching procedure, which often serves as a standard for evaluating other methods. Observers record the license numbers of vehicles and the times at which they enter and leave a test section. The difference of the values for a particular license number is the travel time for that vehicle. This technique produces the true travel times of vehicles traversing the test section, because the variations in individual driving habits are accounted for. Only total travel times are measured, however, and stopped times and running times, along with the locations and causes of delays were obtained.

The procedure was also times consuming as license numbers must be matched and travel times computed. A variation of the license matching process is the arrival-output method, in which only the times are recorded for vehicles entering and leaving the test section. The average travel time for the route was the difference of the average vehicle entrance time and the average vehicle exit time. This technique was applicable where all vehicles pass through the entire test section: that is, there are no points of access or egress along the roadway. The data collections were made on weekdays, Thursday in daylight between the hours of 1:00 p.m. - 2:00 p.m., and during clear and dry weather conditions. The travel time data and delay calculation was attached on appendix 13.

3.12.1 Travel time moving-vehicles technique:

In this technique, the observer record entry and exit vehicles on a test section for 45min like the one shown in Figure 3.4, where it is assumed that the road runs north to South. The observer starts collecting the relevant data at section X-X, drives the car northward to section Y-Y, again record the vehicle drives southward to section X-X.

The following data are collected as the test vehicle makes the round trip:

- The time it takes to travel north from X-X to Y-Y (Tn), in minutes
- The time it takes to travel south from Y-Y to X-X (Ts), in minutes
- The number of vehicles traveling north in the opposite lane while the test car is traveling north (Nn)

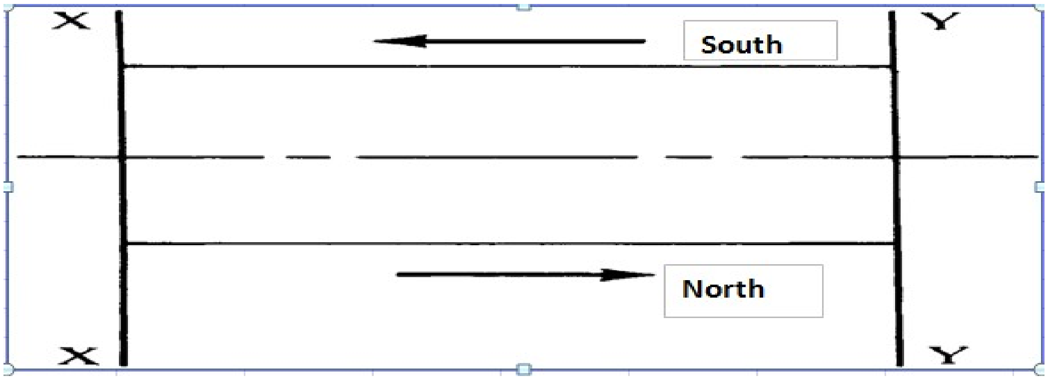


Figure3. 4 Test Site for Moving-Vehicle Method (source Nicholas J. Garber)

- The number of vehicles that overtake the test car while it is traveling south from Y-Y to X-X that is, traveling in the south bound direction (Os)
- The number of vehicles that the test car passes while it is traveling south from Y-Y to X-X that is, traveling in the south bound direction (Ps)
- The volume (Vs) in the south bound direction can then be obtained from the expression

$$\mathrm{Vs} = \frac{(\mathrm{Nn}+\mathrm{Os}-\mathrm{Ps})60}{\mathrm{Tn}+} \qquad (3.2)$$

Where

(Nn + Os - Ps) is the number of vehicles traveling southward that cross the line X-X during the time (Tn +Ts). Note that when the test vehicle starts at X-X, traveling northward, all vehicles traveling southward should get to X-X before the test vehicle, except those that are passed by the test vehicle when it is traveling southward. Similarly, all vehicles that pass the test vehicle when it is traveling southward will get to X-X before the test vehicle. The test vehicle will also get to X-X before all vehicles it passes while traveling westward. These vehicles have, however, been counted as part of Nn or Os and therefore, should be subtracted from the sum of Nn and Os to determine the number of southbound vehicles that cross X-X during the time the test vehicle travels from X-X to Y-Y and back to X-X. These considerations lead to similarly, the average travel time in the southbound direction is obtained from

$$\frac{\dot{\mathrm{T}}\mathrm{s}}{60} = \frac{\mathrm{Ts}}{60} - \frac{\mathrm{Os}-\mathrm{Ps}}{\mathrm{Vs}} \qquad (3.3)$$

$$\dot{\mathrm{T}} = \mathrm{Ts} - \frac{60(\mathrm{Os}-\mathrm{Ps})}{\mathrm{Vs}}$$

And calculate the volume in the northbound direction similarly.

$$Vn = \frac{(Ns+On-Pn)60}{Tn+Ts} \tag{3.4}$$

If the test car is traveling at the average speed of all vehicles, it will most likely pass the same number of vehicles as the number of vehicles that overtake it. Since it is probable that the test car will not be traveling at the average speed, the second term of corrects for the difference between the number of vehicles that overtake the test car and the number of vehicles that are overtaken by the test car.

Finding Volume and Travel Time Using Moving-Vehicle Technique The data were obtained in a travel time study on a section of highway using the moving-vehicle technique. Determine the travel time and volume in both directions at this section of the highway.

3.13 Methods of road condition data collections (shown on appendix 14)

1. Taking measurement with tape
2. Taking photo with camera
3. Visual inspection

3.14 Interviews method:

The interviewing method was carried out by obtaining information from people who drives on the study site regarding their travel times, their experience of delays, and so forth. Since the result depends entirely on the information given by them

3.15 Purpose of Reconnaissance Survey for Question provide

The main objective of reconnaissance survey was examining the general characteristics of the area for the purpose of determining the feasible rout or routes for further detailed investigations. Data collected should be adequate to examine the feasibility of all the different segments in questions. The survey should also help in determining any deviations necessary in the basic geometric standards had been adopted for the highway facility.

3.16 The Drivers Response Provide and sampling technique.

This section presents the drivers Providers response on the causes of traffic delay at traveling time on segment, at entrance and exit of Wolenchity and Adama town. Finally effects of delay on drivers in chapter four it clearly discussed. Concerning the sampling technique for the questioner, simple random sampling technique is used to select a participant from each group in which each element have an equal chance of selection, though random selection does not always produce a sample that is representative of the population. Therefore, the samples were selected randomly. The respondents for drivers provide were trucks, cars and bus drivers rather than other drivers. This is because it was believed that the other drivers are not use all the length of the segment response to the questionnaire relative to these drivers. On the other hand, semi-structured interviews were also conducted which is done by directly approaching the appropriate personnel to get a detailed explanation of the current situation.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 General traffic volume

The total traffic volume at Monday and Thursday for both approaches was summarized in the Table below.

Table4. 1 Total Traffic Volume in PCU for both Approaches

Adama to Wolenchity road segment			
Monday		Thursday	
South approach	North approach	South approach	North approach
3534.3	3587.2	3762.7	4140.5

From above table the collected data at Thursday north approach was the highest and the volume at Monday south direction was the least. Totally the traffic flow volume at Thursday was more than the Monday. Because of this may be the cause of Thursday was the middle day and local market day for both towns. So the cause of delay here, there was more movement at Thursday and after changed to passenger car unit large volume was considered. the reason of this two days selected was as researcher reconnaissance and familiar within that area, the marketing day for both towns was at Thursday and Monday, more movements seen at those days rather than the other days. So they can represent the other days.

The following figure shows summarized factored vehicles sum of two days traffic data from both approach.

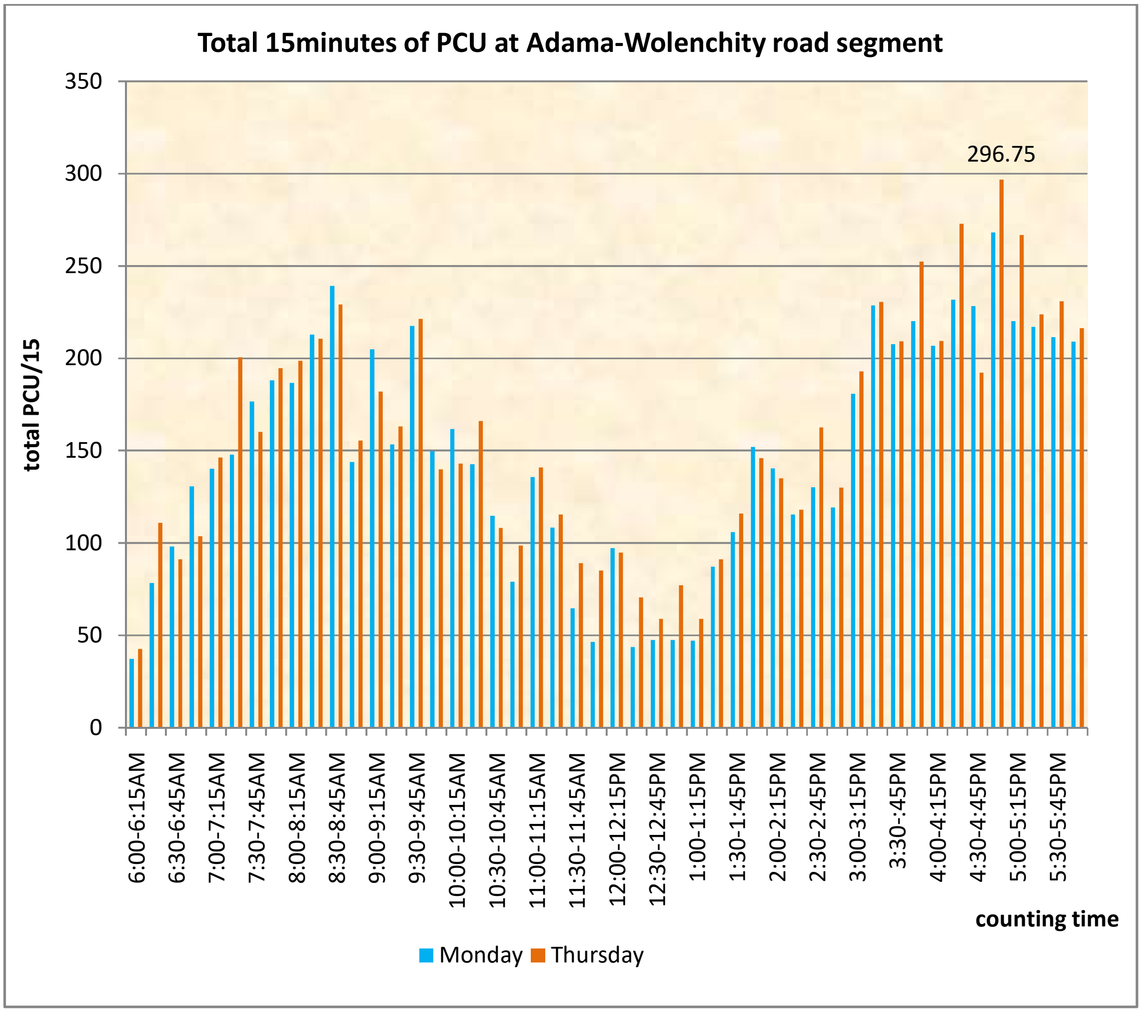


Figure4. 1 Total passenger car unit per 15minutes at road segment

Based on observation taken at the study area, the above figure (4.1) shows that the total pcu per15min at Adama to Wolenchity road segment within the observation of the days were taken for both days at Monday and Thursday the two peak hours are 8:00-9:00 am and 4:15-5:15 pm. The highest 297 passenger car unit per 15 minutes on segment was observed on Thursday at 4:45 to 5:00 in the afternoon which justified that the traffic delay really occurs at the afternoon times.

On the other hand, the lower counts of passenger car unit per 15 minutes were observed relatively on Monday at 6:00-6:15 in the morning than that of Thursday. This may be because of these day was not more local marketing day as compare with Thursday or may be near to the resting day (Sunday).

Additionally, average passenger car unit for two days with respect to 15min interval time described using bar graphs for both approach in the following figure.

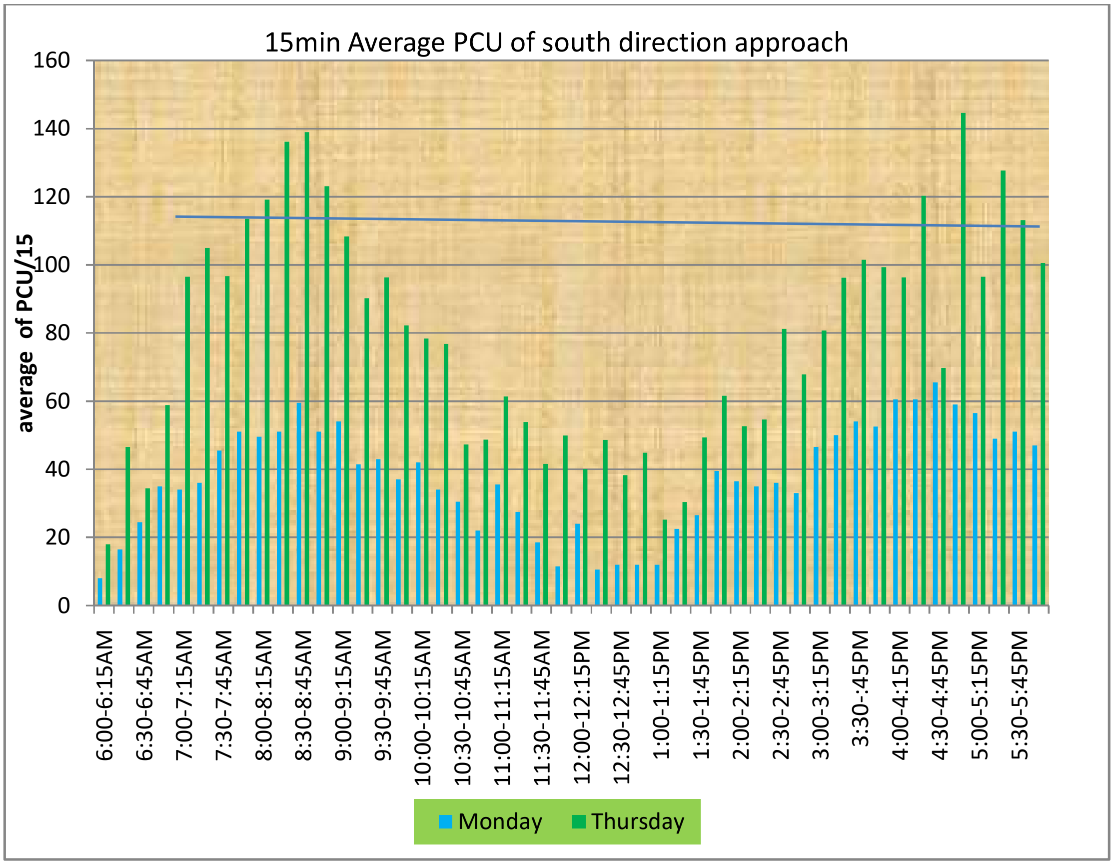


Figure4. 2 Shows avg. passenger car unit/15min from south direction at road segment

As the above figure (4.2) shows the values along the y-axis shows that two days average 15minutes vehicle movements and the x-axis represents 15minutes counting periods of the movement. The peak hour of 15 minutes volumes of south approach was observed in the morning and afternoon. The peak hour volume of south approaches was obtained by summing up the largest four 15 minute volumes of the intervals within the peak hours. The peak hour factor (PHF) was found by dividing the peak hour volume to four times the peak 15 minute volume and the actual flow rate was also calculated by dividing the peak hour volume to the PHF or simply by multiplying the peak 15 minute volume by four. It has been shown on appendix (6). PHF = 0.90. Therefore; the values signify greater variability of flow within the subject hour based on the actual data. The movement of traffic flow within 15min interval was small gap at south direction rather than north.

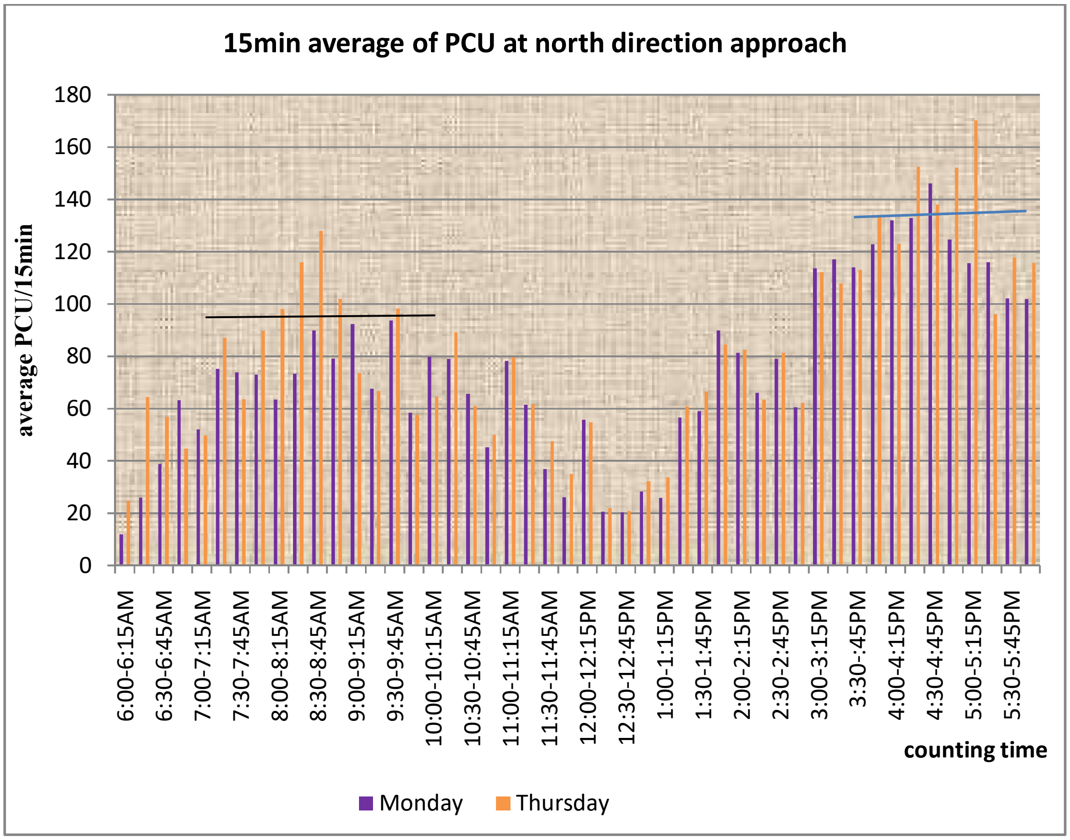


Figure4. 3 Total 15min pcu vs counting times at the north direction

As figure 4.3 the peak hour of 15 minutes volumes of north approach has been observed in the morning and afternoon. This approach has different from south peak 15minutes volumes (V15min.), hourly volumes (V), peak hour factors (PHF), and actual (design) flow rates as shown on appendix (7).

Peak Hour Factor (PHF) = 0.89 which was some lower than south direction and again some gap of traffic flow than south approach. In urban areas generally the peak hour factor range between 0.80 and 0.98 lower values signify greater variability of flow within the subject hour, and higher values signify less flow variation. PHFs over 0.95 are often indicative of high traffic volumes sometimes with capacity constraints on flow during the peak hour (H.C.M 2000). From this range the traffic flow on this segment was high as urban. Again this range has been also used for some rural area near town.

4.1.1 Calculating AADT Using Expansion Factors

The data shown below are collected on a Thursday during the month of September.

6:00 –7:00 a.m.	352	12:00 –1:00 p.m.	322
7:00 –8:00 a.m.	704	1:00 –2:00 p.m.	415
8:00 –9:00 a.m.	842	2:00 –3:00 p.m.	546
9:00 –10:00 a.m.	757	3:00 –4:00 p.m.	886
10:00 –11:00 a.m.	52	4:00 –5:00 p.m.	972
11:00 –12:00 a.m.	442	5:00 –6:00 p.m.	940

- Estimate the 24-hr volume for Thursday using the factors given

$$= \frac{(352 * 42.00 + 704 * 29.0 + 842 * 22.05 + 757 * 18.80 + 528 * 17.10 + 442 * 18.52 + 322 * 18.71 + 940 * 13.85)}{12}$$

$= \mathbf{12,065.47}$

- Adjust the 24-hr volume for Thursday to an average volume for the week using the factors given

$$\text{Total 7} - \text{day volume} = 12{,}065.47 * 7.012$$

Average 24 $-$ hr volume $= \frac{12{,}065.47 * 7.012}{7} = \mathbf{12,086.15}$Veh/day

$\mathbf{AADT} = 12{,}086.15 \times 0.632 = \mathbf{7638}.45$Veh/day on every month of a year

The expansion factor was shown in literature review on table (2.1 and 2.2) based on that the AADT was calculated. Because of using the factor from this manual was, no arranged data dealing with this segment. The ERA was collected trucks and large bus data only, again local data such as Adama Woreda and Zone Transport office only collected passenger car data so no fulfill data, for example no collected data on bajajs, carts and bicycles. Again the data on this manual was balanced with collected volume data on Thursday.

As the result of AADT shows the traffic volume was not balanced with in the existed road segment. Because the traffic flows has been increase from year to year based on the environmental current demand. So as traffic flow increases the traffic delay was formed. From this decision the cause of traffic delay was the increase of traffic flow from year to year.

4.2 Vehicle classification

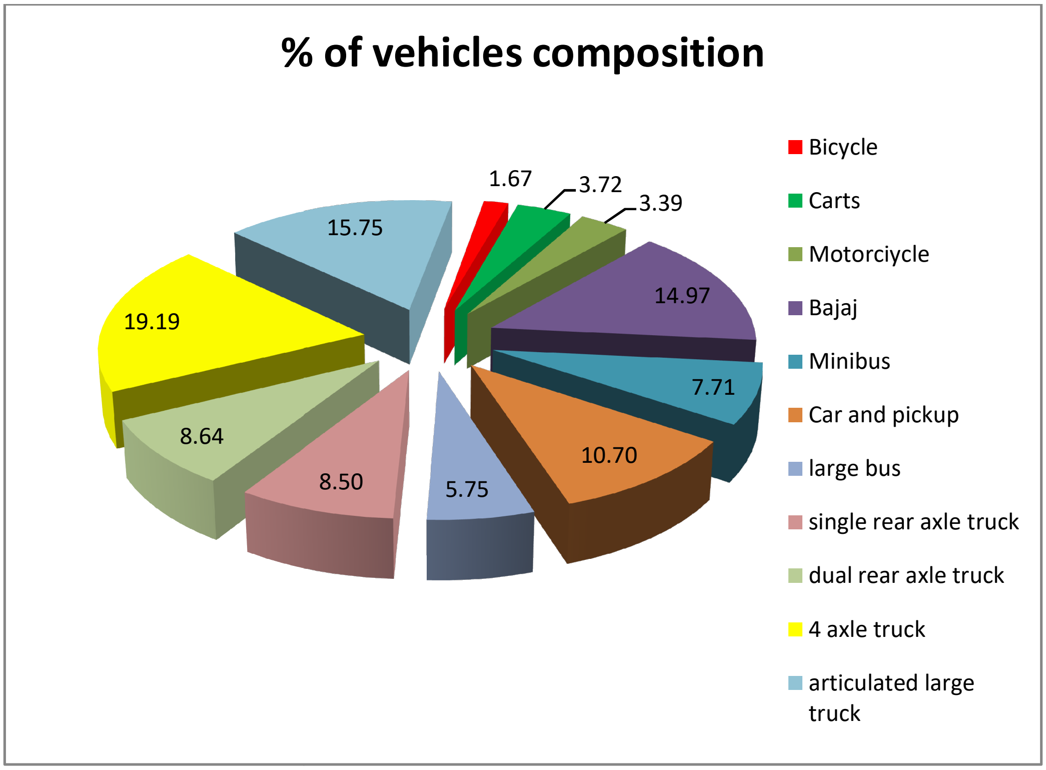


Figure4. 4 Average vehicles percent composition of pcu on road segment

From total % of vehicles composition result there was a mixed heterogeneous vehicles types using the same road segment make traffic delay, this road more occupied by 4 axle truck and articulated large trucks (28.24 and 20.40%) respectively. They were larger than passenger car and occupy more roadway space and they have poorer operating capability than passenger car, particularly with respect to acceleration, deceleration and the ability to maintain speed. The inability of heavy vehicles to keep pace with passenger car in many situations creates large gaps in the traffic stream which are difficult to fill by passing maneuvers. So the delay is formed.

Bicycles are the smallest percent (1.67%) from the total composite vehicle on the segment. From this result the presence of carts again the causes of traffic delay.

4.3 The Spot Speed Collected Data Results and Discussion

The minimum number of spot speeds collected to satisfy the sample requirement is 144. Since the data collected 160 samples, that satisfied the sample requirements. Therefore the collected data for spot speed from field was enough for determining the speed of road segment.

$$\text{Standard deviation } SD = \sqrt{\frac{\sum (Si - Sm)^2}{n - 1}} = 9.95$$

$$\text{Time mean speed } TMS = \frac{\sum S}{n} = \frac{4892.84}{160} = 30.58 Km/hr$$

$$\text{Space mean speed } SMS = \frac{d}{\frac{\sum t}{n}} = \frac{54m}{\frac{1172}{160}s} * 3.6 = 26.56 Km/hr$$

From the results observed that the time mean speed **TMS** for vehicles traveling at different speeds was always greater than the space mean speed **SMS**.

Frequency distribution

Minimum value = 7.65 Km/hr.

Maximum value = 55.23 Km/hr.

Range = 47.58 Km/hr.

Class range for 20 classes = 47.58 Km/hr/20 = 2.38 Km/hr.

Class range for 8 classes = 47.58 Km/hr/8 = 5.94 Km/hr.

Appropriate class range = 5 Km/hr.

Table4. 2 Speed Data Class

speed class	mid value (ui)	Frequency (fi)	frequency Percent	Cumulative Percent	$f_i u_i$
7-11.9	9.5	12	7.5	7.5	114
12-16.9	14.5	14	8.8	16.3	203
17-21.9	19.5	24	15.0	31.3	468
22-26.9	24.5	23	14.4	45.6	563.5
27-31.9	29.5	20	12.5	58.1	590
32-36.9	34.5	22	13.8	71.9	759
37-41.9	39.5	26	16.3	88.1	1027
42-46.9	44.5	11	6.9	95.0	489.5
47-51.9	49.5	6	3.8	98.8	297
52-56.9	54.5	2	1.3	100.0	109
Total	320	160	100.0		4620

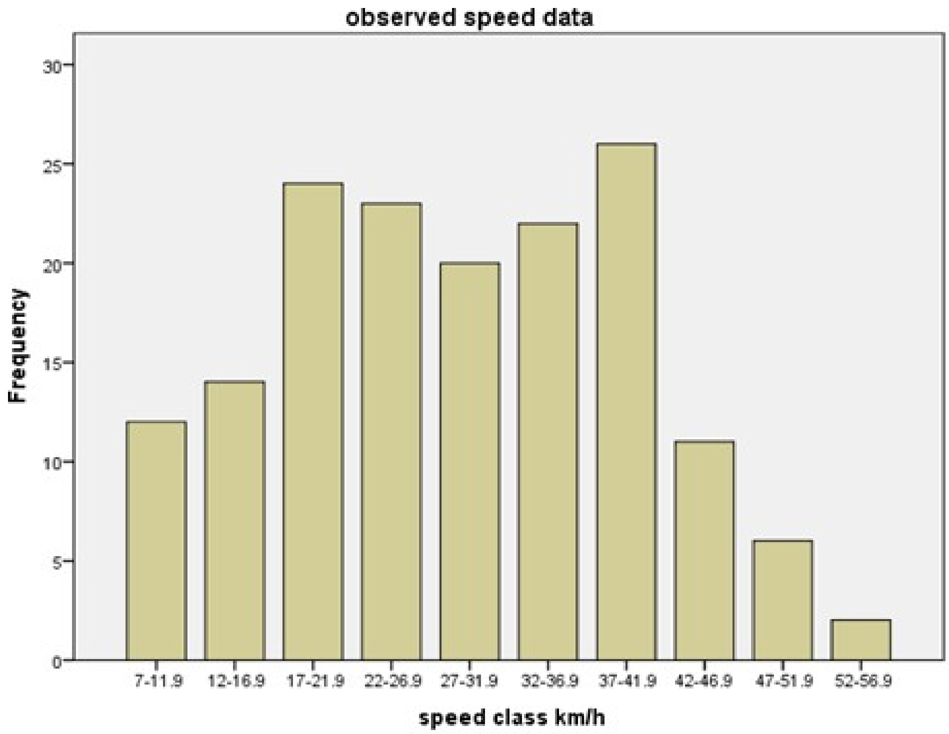


Figure4.5 Frequency histogram

- The mode or modal speed was obtained from the frequency histogram as the result shows from the figure mode=39.4 km/h. It also may be obtained from the frequency distribution curve shown in Figure 4.6 where the speed corresponding to the highest point on the curve was taken as an estimate of the modal speed. So from result the spot speed of Adama-Wolenchity road segment was 39.4km/hr. here it shows traffic delay because of congestion of heavy vehicles and narrowness of the road width no chance of passing for other passenger car. Again speed class 52-56 km/hr was very small this shows majority of the traffic flow had been travel within delay time.

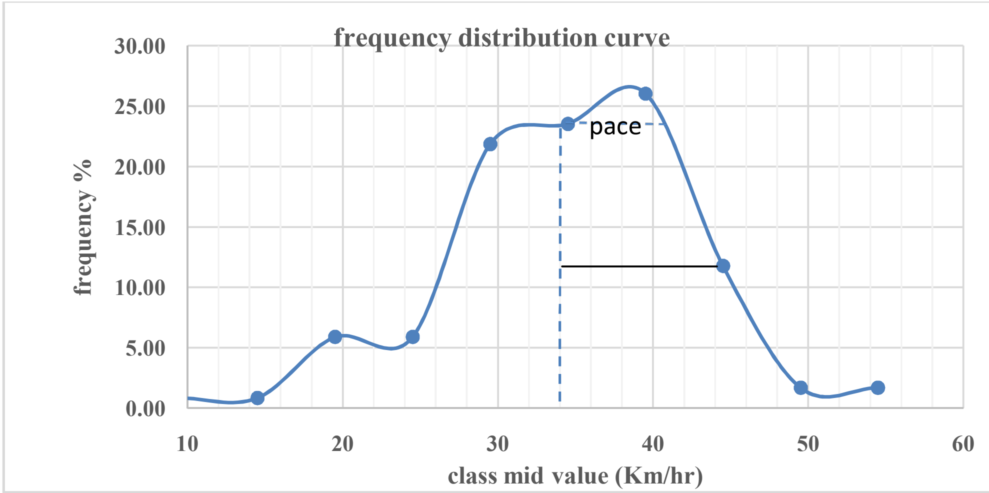


Figure4. 6 Frequency distribution curve

- As the above figure shows the pace was obtained from the frequency distribution curve which was 34 to 44 km/hr this is the range of the traffic flow on Adama-Wolenchity road were travel within this interval. The pace 34 to 44 km/hr were the range of speed that has the highest number of observations shown. The most frequency of speed was shown in range of 37-41.9 which was 26% which had the largest observation. So as to be the rural road this speed shows the traffic delay existed here on study area. Because of deference traffic types uses these road specially which have slow peed such as: carts, single and rear axle trucks, 4axle and articulated large trucks, large buses and non motor cycles.

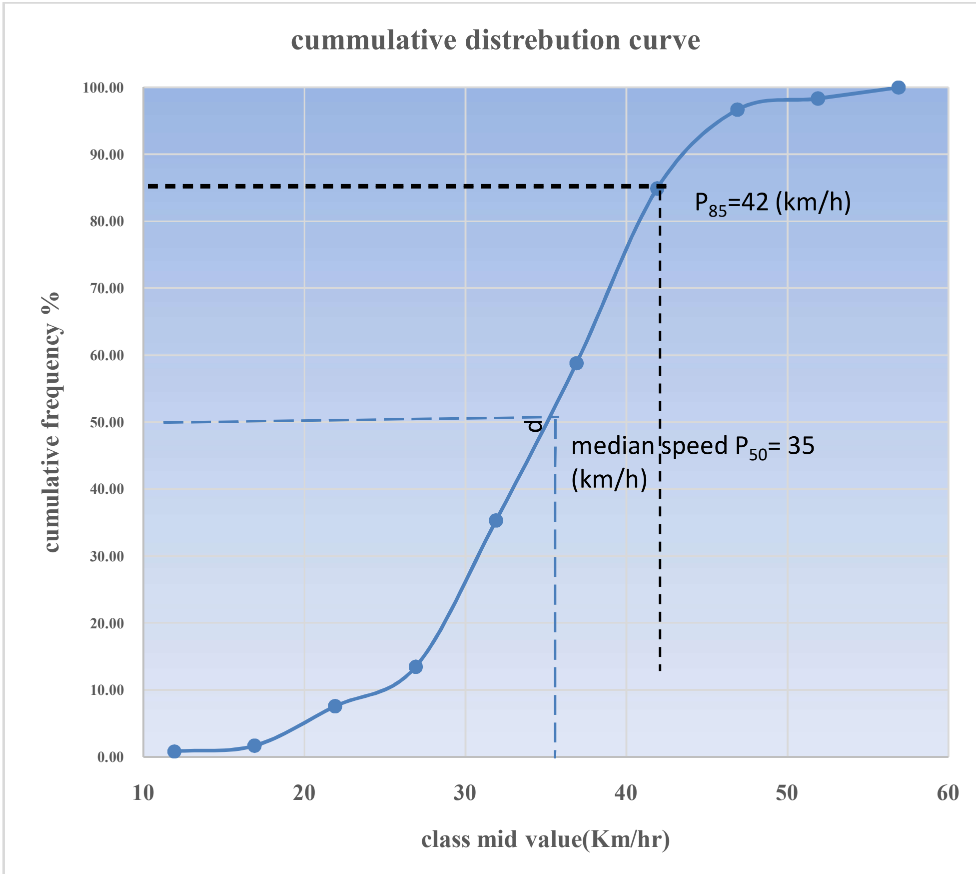


Figure4. 7 Cumulative frequency distribution

- The median speed is obtained from the cumulative frequency distribution curve (Figure 4.7) as 35 km/h, the 50th-percentile speed.
- 85th-percentile speed is obtained from the cumulative frequency distribution curve as 42 km/h.

*85th percentile was used in evaluating/recommending posted speed limits based on the assumption that 85% of the drivers are traveling at a speed they perceive to be safe. In other words, the 85th percentile of speed is normally assumed to be the highest safe speed for a roadway section.

Therefore, the recommended speed limit was 42 Km/hr. As a general guide, the design speed should be 10 Km/hr higher than the 85th percentile speed value (Nicholas J. Garber). Therefore, Design speed = 42 km/hr + 10 km/hr = 52 Km/hr. from these result what concluded that the highest safe should be posted speed is 52km/hr but from collected data the highest point speed on this section was 39.4km/hr so there have been delay here. From field observation and sample size the causes of traffic delay were mixed of different vehicles and large vehicles in given time.

Table4. 3 Data from travel time study using the moving-vehicle technique

Run direction	Travel Time (min)	No. of vehicle traveling in opposite direction	No. of vehicles that overtook test vehicle	No. of vehicles overtaken by test vehicle
Northward				
1	35.65	2	1	0
2	42.34	3	0	0
3	40.94	2	0	1
4	39.08	4	0	1
5	41.91	4	1	1
6	43.35	4	0	2
7	44.00	3	2	1
8	42.99	1	0	0
9	43.50	2	1	0
10	43.53	3	1	1
11	44.96	3	1	1
Average	41.03	2.82	0.64	0.73
Southward				
1	40.71	3	2	1
2	38.67	2	0	0
3	42.91	4	0	1
4	43.94	1	1	1
5	44.80	3	1	0
6	42.95	5	0	0
7	44.72	1	0	0
8	44.58	2	0	1
9	45.00	3	0	0
Average	43.21	2.67	0.39	0.44

Mean time it takes to travel northward (Tn) = 41.03 min

Mean time it takes to travel southward (Ts) = 43.21min

Average number of vehicles traveling westward when test vehicle is traveling northward (Nn) =2.82

Average number of vehicles traveling eastward when test vehicle is traveling southward (Ns) =2.67

Average number of vehicles that overtake test vehicle while it is traveling southward (Os) =0.39

Average number of vehicles that overtake test vehicle while it is traveling northward (On) =0.64

Average no. of vehicles the test vehicle passes while traveling southward (Ps) = 0.44

Average no. of vehicles the test vehicle passes while traveling northward (Pn) =0.73

Find the volume in the southbound direction by using equation (3.2):

$$\mathrm{Vs} = \frac{(2.82 + 0.39 - 0.44)60}{41.03 + 43.21} = \mathbf{1.97}\mathrm{veh/h}$$

Calculate the volume in the northbound direction using equation (3.4).

$$\mathrm{Vn} = \frac{(2.67 + 0.64 - 0.73)60}{41.03 + 43.21} = \mathbf{1.84}\mathrm{veh/h}$$

- Find the average travel time in the southward direction using equation (3.3).

$$\dot{\mathrm{T}}\mathrm{s} = 43.21 - \frac{60(0.39 - 0.44)}{1.97} = \mathbf{44.74}\mathrm{min}$$

- Again find the average travel time in the northward direction

$$\dot{\mathrm{T}}\mathrm{n} = \mathrm{Tn} - \frac{60(\mathrm{On} - \mathrm{Pn})}{\mathrm{Vn}}$$

$$\dot{\mathrm{T}}\mathrm{n} = 41.03 - \frac{60(0.64 - 0.73)}{1.84} = \mathbf{43.94}\mathrm{min}$$

Therefore the overall travel speed between the origin and destination points of travel was invariably lower than the desired running speed.

As seen from the results of appendix 13 table calculated delay value have varied within the gap high, medium and low delay. It shows there had been a mixed deferent traffic flow on the study section. So the cause of traffic delay was mixed deferent traffic flow. Again the causes of traffic delay during data collection were illegal parking vehicles; there are animals on the road, poor driver vision for other drivers, in sufficient road width and lane. From table 4.3 result on both directions in the given time the traffic volume was low because to finish the segment in the given time the vehicles were delayed.

The result of average travel time was also shows delay when compare with estimated actual travel time and as drivers interviewed result. Estimated Actual travel time was checked by researcher by using free time vehicle travel. The estimation of actual travel time was around 34min and the interviewed is approximately 32min. but from calculation result 44.74min to south direction and 43.94min to north direction. These may be the cause of road problem, the presence of vertical curve, turning of heavy vehicles to the express way.

4.4 Determining Level of Service

From calculated result of level of service on appendix (15) **LOS = "D".** After changed to passenger car unit all vehicle types, which means the segment has been serving near its flow with low speed. But before changed to passenger car unit level of service of the road segment was **LOS= "C".** This implies relatively stable flow condition on segment. As the result shows after changed to passenger car unit the traffic volume was increased this was because the road segment was more occupied by heavy vehicles so this vehicles make the traffic delay on the road.

4.5 Geometric Layout of Roadway Data

Collected data on geometric layout of roadway from field are tabulated in table below.

Table4. 4 Collected data on geometric layout of roadway

Approach legs	Asphalt width (m)	Asphalt width from side mark to side	Shoulder width(m)	Lane width (m)	Distance b/n bridge and asphalt	Height of asphalt edge(cm)	Number of lane
South approach	7.23	6.66	2.3	3.68	3.9	1.2	1
North approach	7.23	6.66	3	3.5	3.9	1.6	1

From this table as collected data shows from both approaches, totally the geometric layout of the road was insufficient as above collected volume data. This road had been constructed around 34 years as researcher interviewed the environmental person who knows the history of this highway. So this segment was not as rural highway based on the expansion of towns. There was more settlement near to the road as researcher reconnaissance. The cause of traffic delay was insufficient of the geometric layout of the road segment.

4.5.1 Surface Condition observation

By qualitative observation of road surface conditions the following results are detected. Potholes, formation of ruts, damages of shoulder and edge of the road

Potholes

There are more potholes on the study road segment surface. As observed result, potholes existed at entrance and exit of both Wolenchity and Adama town again at the middle of the road segment as example. The causes of traffic delay on this segment were again the existence of potholes, formation of Ruts and the damage of edge of the road segment.

- **Flexible Pavement Fail by Formation of Ruts.**

Figure4. 8 Photo shows the surface of the road segment.

Again due to the road surface problem traffic has been delay. For example as shown on the figure 4.8 the road surface of Adama-Wolenchity road has formation of ruts. Therefore the surface of the road was not suitable for travel as speed needed they travel by selecting the surface or occupies the opposite direction, because of that the traffic forced to become delay. So the other cause of traffic delay was the road fail by formation of ruts.

- **Considerable Damage to Shoulder and Edge of Highways**

Figure4. 9 Photo shows the damaged shoulder and edge of road segment

As shown on the above figure the road shoulder and edge was damaged at many section of the segment. So during passenger car stopped for passenger, it must stop up on asphalt and also carts no option to depart the road. Because of this the road makes bottleneck. No option of passing, the opposite lane occupied by other traffic. On this the causes of traffic delay was damaged shoulder and elevated edge of the road. Totally the road was not suitable for traffic to go away from asphalt.

4.6 Survey Questionnaire

4.6.1 Causes of traffic delays at travelling time as evaluated by driver's response.

The results of the questionnaires related to the causes of traffic delays during traveling time which are responded by drivers are summarized below to determine the contribution of during traveling time operations to traffic delays on segment. For this specific question all 30 participants responded.

Table4. 5 Driver response frequencies on the causes of traffic delay during traveling

		Responses N	Percent of Cases, %
	Road surface problem	10	33.3
	More carts use road	12	40
	More bajaj	14	46.7
	Truck congestion	14	46.7
	Narrow Adama-Wolenchity road	22	73.3
	There is animals on the road	5	16.7
	Poor drivers vision for other drivers	15	50
	Bureaucracy	7	23.3
	Poor road administration and Management	7	23.3
	Overloaded truck	8	26.7
Consequence	Traffic accident	18	60
	Traffic delay	20	66
	Customer takes Long travel time	12	40
	Freight delay for import and export	16	53.3
	Takes long time for cross the road	11	36.7
	lack of the public service	7	23.3

Note: N stands for number of respondents.

As it can be observed from Table 4.5 above, the majority of drivers (73.3%) responded that narrow Adama-Wolenchity road was the main cause of traffic delay during travel time; 50-66% of respondents agreed that, Poor drivers vision for other drivers, Traffic accident, Traffic delay, Freight delay for import and export are the causes of traffic delays during travel time. 40-46.7% of respondents agreed that, more carts use road, more bajaj, customer takes long travel time are the causes of traffic delays during travel time. while 33.3-36.7% of the respondents agreed that Road surface problem, Takes long time for cross the road are the causes of traffic delay. Only 16-26.7% of the respondents stated that there were animals on the road, Poor road administration and Management, overloaded truck, lack of the public service was the causes of traffic delay.

Figure4. 10 Photo shows during t raveling time at the middle of the road segment

As shown from the above figure the Adama to Wolenchity road segment was congested with heavy vehicles from both approaches. Totally this road was not the road of trucks, because it was very narrow and as to be between these nearer towns there were more movement, marketing area, especially Adama was the developed town, which had more industry and busy within the movement, when this truck added delay was formed. So here the cause of delay was truck congestion.

4.6.2 Traffic delay due to problems related to entrance and exit of Wolenchity town evaluated by drivers.

The responses of drivers with regards to entrance and exit of welenchity town problems are summarized in Table4.6 below to determine which problems need attention. A total of 30 drivers were approached with questionnaire and twenty six, 26 (86.7%) of them responded.

Table4. 6 drivers‟ response frequencies on the causes of traffic delay at entrance & exit of welenchity town

		Responses N	Percent of Cases, %
Causes of traffic delays at entrance & exit of welenchity	Illegal on-street parking habit	20	76.9
	Many informalities of truck stop	14	53.8
	Informal passenger on the road	12	46.2
	Insufficient space for stop	11	42.3
	Unsuitable parking design for different	5	19.2
	Poor sight distance for passing	9	34.6
	Poor traffic control	10	38.5

Note: N stands for number of respondents.

As shown in the above Table 4.6 the drivers‟ opinion on the entrance &exit of welenchity town problems that can cause traffic delay.53.8-76.9% of respondents stated that many informalities of trucks stop, Maximum traffic flow, Illegal on-street parking habit and other information was the main cause of traffic delay at the entrance and exit of welenchity town. More than 40% of the respondents (42.3-46.2%) agreed that insufficient space for stop, Informal passenger on the road was the cause of traffic delay at entrance and exit of welenchity town and 34.6-38.5% of the respondents agreed that Poor sight distance for passing, Poor traffic control at the entrance and exit of Wolenchity town was the cause of traffic delays. While, 19.2% of respondents‟ states that Unsuitable parking design for different types of trucks were the causes of traffic delay at entrance and exit of welenchity town

4.6.3 Causes of traffic delay at entrance and exit of Adama town as evaluated by the drivers

The responses of the drivers regarding, entrance and exit of Adama town contribution to traffic delay is summarized in this section to determine which problem mainly contributes to traffic delay on the segment. A total of 30 drivers were approached with questionnaire and twenty eight, 28 (93.3%) of them responded.

Table4. 7 drivers‟ response frequencies on the causes of traffic delay at Adama end.

		Responses N	Percent of Cases, %
Causes of traffic Delay at Adama entrance	More truck turn to express way	6	21.4
	More taxi turning	13	46.4
	The carts stop on the road	4	14.3
	Steep upgrades	15	53.6
	Down grade operation	4	14.3
	More bajaj turning	8	28.6

Note: N stands for number of respondents.

As shown on Table 4.7 above, it was noted that 53.6% of the respondents mentioned that the main cause of traffic delay was Steep upgrades at Adama entrance and 46.4% agreed that more taxi turning was the cause of traffic delay at Adama entrance. Above twenty percent (21.4-28.6%) of respondents agreed that more truck turn to expressway and more bajaj turning is the main cause of traffic delay at the Adama entrance; While 14.3% stated that the carts stop on the road and downgrade operations were the causes of traffic delay.

4.6.4 Response of drivers regarding the effect of delay to drivers

Effects of delay were assessed in terms of driver behavior and the responses are summarized as follows. A total of 30 drivers were approached with questionnaire and all of them responded.

Table4. 8 drivers‟ response on the Effects of delay on drivers

		Responses N	Percent of Cases, %
Effects of Delay to Drivers	Delay cause anger	26	86.67
	Delay causes tediousness	22	73.33
	Delay cause fatigue	21	70.0
	Drivers get restless due to delay	19	63.33
	Delay reduces performance	23	76.67
	Delay reduce work motivation	27	90.0
	Delay change drivers driving behavior	23	76.67
	Delay cause waste of time	28	93.33
	Delay cause fuel- conception	15	50.0
	Delay cause accidents	19	63.33
	Delay causes complexity of reaction	24	80.0
	Delay cause extravagancy	27	90.0
	Delay forces drivers to drive day and night	8	26.67

Note: N stands for number of respondents.

Table4.8 above shows that more than 85% of truck drivers respond that delay can cause them extravagancy, waste of time, anger and it can reduce their work motivation and 75-80% stated that delay can change their driving behavior, complexity of reaction and it can also reduce their performances by causing tediousness. According to 63.33%-70.0% of the drivers, delay cause fatigue, can make them restless and it can even cause accidents,

50.0% of drivers agreed that delay can cause fuel-conception and only 26.67% of the respondents said that Delay forces drivers to drive day and night.

Generally, Drivers believe that delay has an adverse effect to the drivers and customer by increasing the travel time cost and vehicle operating cost. In addition, to that they believe delay has an effect to the unreliability cost.

4.6.5 Survey Findings

The survey findings are summarized in this section with causes of delays totally on Adama to Wolenchity road segment based on respond of drivers.

Table 4.9 below presents rank of driver's response regarding causes of delay at Adama to Wolenchity road segment.

Table4. 9 Rank of causes of delay on Adama-Wolenchity road segment as response

Causes and Consequences of Delay	N	Percent of Cases, %
Traffic delay	22	73.3
Narrow Adama-Wolenchity road	20	66.7
Traffic accident	18	60
Freight delay for import and export	16	53
Poor drivers vision for other drivers	15	50
Track congestion	14	47
Customer takes long travel time	12	40
Road surface problem	10	33
Poor sight distance for passing	9	30
Over loaded truck	8	27
Poor road administration and management	7	23

Note: N stand for number of respondents

The Adama-Wolenchity road segment has a distance of 24Km. Having recently been rehabilitated, the first only 1 km from the city was in good condition, while the remainder of the road on segment is narrow, formation of ruts damaged edges of the road and pot-holed. In this study, the majority (73.3%) of respondents claimed that the Adama-Wolenchity road is totally there was traffic delay. In this regard, 67% of respondents stated that it's the narrowness of the road and illegal parking habit that causes delays while 60% agreed that its traffic accident and the large number of trucks on Adama Wolenchity road that cause delays. On the other hand, 53-40% of drivers state that Freight delay for import and export; Poor drivers vision for other drivers, Track congestion, and Customer takes long travel time on Adama-Wolenchity road segment are the source of delay on the road respectively. At last, 33-23% of the respondents state that Road surface problem, Poor sight distance for passing, over loaded truck, and Poor road administration and management on Adama-Wolenchity road segment is the other causes of delays respectively.

Concerning the effects of delay to trucks, cars and bus drivers, Table 4.14 above shows that in addition to waste of time and money, delay can affect the driving behavior, motivation and performance of the driver. Above 85% of drivers agreed that delay can cause waste of time and extravagancy and it can also reduce work motivation. While 75-80% of drivers respond that delay can cause anger, it can reduce performance and In this regard, 50-70% drivers‟ expressed drivers believe that delay has an adverse effect to the drivers as tediousness, fatigue, restlessness, fuel-conception and accidents as a consequence of delay and only 26% of the respondents agree on the effect of delays it forces them to drive day and night Hence directly or indirectly they agreed that delay can change their driving behaviors.

CHAPTER FIVE

CONCLUSION AND RECUMMENDATIONS

5.1 CONCLUSION

Based on the collected data and analysis made, the study concludes the following points:

- The total average of two days traffic volume from both approach was 3862.5 before changed to passenger car unit, after changed to passenger car unit the total average volume from both approach was 7512.35 this shows the road segment was occupied by heavy vehicles. The % age of vehicles composition results also shows the number of trucks was more and makes delay. The AADT value shows the traffic flow is increase from year to year based on expansion of both towns.
- From spot speed data collection the median speed was 35km/hr, the pace was 34 and 44km/hr, the mode or modal speed was 39.4km/hr and the 85th-percentile speed was 42km/hr. As a general guide, the design speed should be 10 Km/hr higher than the 85^{th} percentile speed value (Nicholas J. Garber). So the highest safe speed should be posted was 52km/hr but from collected data the highest point speed on this section is 39.4km/hr these was because of mixed of different traffic.
- From calculated delay there was a mixed deferent traffic flow on the study section. The result of average travel time was also shows delay when compared with estimated actual travel time and as drivers interviewed result. The actual travel time was around 34min and the interviewed was approximately 32min. but from calculation result 44.74min to south direction and 43.94min to north direction. These were the causes of road problem, the presence of vertical curve, turning of heavy vehicles to the express way and overloaded trucks.
- The LOS of segment was “D” which means the segment has been serving near its flow with low speed, but data before change to pcu shows, LOS “C” which implies relatively stable flow condition on segment. Insufficient road width, potholes, formation of ruts and damage edge of road was cause of traffic delay on road surface
- Adama-Wolenchity road segment was uncomfortable or inconvenient, which as a result cause delay to traffic. Truck congestion, poor sight distance for passing and poor driver’s vision for other drivers was also the main cause of traffic delay. Delay can affect driving behavior, motivation and performance of drivers.

5.2 RECOMENDATION

Based on the field survey and collected data hereunder are the recommendations in order to decrease traffic delay at Adama-Wolenchity road segment.

- Ethiopian government, as the infrastructure provider, better invest its resources wisely on road, railway, and other infrastructures and Shifting of heavy traffic to other modes of transport like the railways. This is because progress is driven by improvement in infrastructure.
- The ERA and regional transport agency should be now as: Adama town expansion caver the Adama-Wolenchity road and more movement area, traffic flow increase from year to year, traffic volume and road segment width was imbalanced. So they must extend express way stopped at the end of Adam to Wolenchity.
- Traffic regulations principles around the road segment that may include: restriction for heavy vehicles only use express way at the entrance of Adama, restricting heavy vehicles illegal parking at Wolenchity town exit and restricting for carts must be use lateral clearances this can have decrease traffic delay.
- Increasing the number of lanes of Adama to Wolenchity road segment, strengthening or increasing the thickness of the existing pavement through overlay or reconstruction should be done.
- The immigrate peoples from different part of the city to the city in searching for livelihood was make problem here, this added portion of the society also need transport service to attain their day to day activities. However; the Road is unable to cope with the existing high transport services demand. Poor infrastructure and absence of well traffic management are the major reasons for traffic delay. So the regional state should be assigning to the federal government this area.
- the researcher proposed that based on the traffic flow the design speed should be posted with 52km/hr, the passenger cross should be marked at entrance of both town and reapplying the faded pavement markings, damaged shoulder and edge of the road.
- Following the Literature review and the case of Adama-Wolenchity road segment, the other cause of delay can be recommended for further study.

REFERENCE

Adeolalu A. (1977). Traffic accident and road safety are inverse relationship between each other.

Adedimila S. A. (1989). Towards Improving Traffic Flow in Lagos.

Adkins, W. A., Ward, G. & W. F. McFarland (1967). Value of Time Savings of Commercial Vehicles: Washington, D.C.

Akcelik (2004): speed-flow models for uninterrupted traffic facility.

Arkatkar, S.S. (2011). “Effect of Intercity Road Geometry on Capacity under

Heterogeneous Traffic Conditions Using Microscopic Simulation Technique”.

Atomode, I. J. (2013). Traffic delay problems and characteristics at urban road intersection,

Central Road Research Institute, (1988). “Capacity of Roads in rural Areas”,Project

Sponsored by Ministry of Surface Transport.

Chitturi, M.V. and Benekohal, R.F., (2008). “Passenger Car Equivalents for heavy vehicles in work zones” 87th TRB Annual Meeting and Publication in TRR.

Daganzo CF, Laval JA (2005). Moving bottlenecks: A numerical method that converges in flows. The case of Ilorin Nigeria research

Department of Transportation, Federal Highway Administration, (1992). Traffic Monitoring Guide. U.S. Washington, D.C.

Elsevier, B. V. (2014). Traffic delays estimation in two-lane highway reconstruction,

Englewood Cliffs, NJ, (1994). Manual of Transportation Engineering Studies. Institute of Transportation Engineers,

Gazis DC, R. H. (1992).The moving and ‘phantom’ bottlenecks.

Golias, J.C. (2003). “Examining Sensitivity of Impact of Taxi Traffic on Capacity and Delays at Urban Road Sections”.

H.M. Iqbal, M. and MD. Zahurul, I. (2009). Passenger Car Equivalency of through vehicle at signalized intersection in Dhaka Metropolitan City, Bangladesh.

Juran, I. Prashker JN, Bekhor S, Ishai.I. (2009). A dynamic traffic assignment model for the assessment of moving bottlenecks talia

Joel Marcuson P.E. (2010). Highway Capacity: Manual. Jacobs Engineering. U.S.A.

Kalkidan Waktole. (2017). Assessing Freight Transport Performances in Relation to Delays in Ethiopia.

Kifle A. (1997): The Management of Commercial Road Transport in Ethiopia, Addis Ababa, Ethiopia.

Litman, (2003): infrastructures for non-motorized transport are in adequate.

Lum, K. M., Fan, H.S.L., Lam, S. H. and Olszewski, P. (1998), " Speed-Flow Modeling

of Arterial Roads in Singapore", Journal of Transportation Engineering.

Marwah, B. R. and Singh, B. (2000). "Level of service classification for urban

Heterogeneous traffic: A case study of Kanpur metropolis." Transportation Research.

Muñoz, JC. (2002) Moving Bottlenecks: A Theory Grounded on Experimental Observation

Nicholas J. et al., 2009. Traffic and highway engineering. Fourth edition; University of Virginia

Ogunsanya, A. A. (1983): Contribution of Freight Vehicles to Urban Traffic Delays: The Case of Lagos, Nigeria. The Nigerian Geographical Journal,

Oluwoye J.O., 2000. An investigation of the factors of the design of roads. That Affect Planning For Traffic Safety in the Third World. South African Transport Conference. South Africa.

Ogunsanya, A. A. (1984): Traffic Congestion in an Urban Centre: The Case of Ilorin, Nigeria.

Osama masaud (2014): detection and classification of vehicle.

Ortuzar and Willumsen, (2004) Modeling Transport, 3rd Edition, England

Parker, M.T. (1996), "The Effect of Heavy Goods Vehicles and Following Behavior on Capacity at Motorway Sites".

QingMiao, Bruce X Wang & Teresa M Adams (2011): Assessing the Value of Delay to Truckers and Carriers. Texas.

Ramanayya, T.V. (1988): "Highway Capacity under Mixed Traffic Conditions", Traffic Engineering and Control.

Satyanarayana PVH, (2012): "effect of traffic volume, composition and speed on rural highways in Visakhapatnam".

Shewangizaw Dagmawi (2009): Assessment of the impact of logistic performance on trade in Ethiopia.

Shiomi Y, Yoshii T, Kitamura R (2011): Platoon-based traffic flow model for estimating breakdown probability at single-lane expressway bottlenecks.

Tanaboriboon,Y. and Aryal Roshan (1990): "Effect of Vehicle Size On Highway Capacity in Thailand", Journal of Transportation Engineering.

Winder and Morin, (2009): the most common road transport modes are public transport.

TRB (Transportation research board), 1985-1997, Highway Capacity Manual, National Research Council, Special Report 209, Washington D.C.

Tillotson, H. T. (1981)): The Concept of traffic Delay

V. T Hamizh Arasan and K. Krishnamurthy (2008): "Study of the Effect of Traffic Volume and Road Width on PCU Value of Vehicles using Microscopic Simulation".

World Bank.(2002).Cities on the Move: A Worlds Bank Urban Transport Strategy review

Yi Jiang, (2001): estimation of traffic delay and vehicle queues at freeway work zone .

Yared Haregewoin, 2010. Impact of Vehicle Traffic Congestion in Addis Ababa.

APPENDIXES

Appendix 1 Monday PCU north direction data

time	bicycle, carts and motorcycle	bajaj	minibus, car and pickup	large bus	single and dual rear axle track	large and articulated trucks	sum	
6:00-6:15AM	0	0	3	0	0	9	12	
6:15-6:30AM	0	0.8	5	0	2.25	18	26.05	
6:30-6:45AM	0.5	1.6	6	0	6.75	24	38.85	140.05
6:45-7:00AM	0.5	2.4	7	3	11.25	39	63.15	
7:00-7:15AM	1.5	0.8	4	6	6.75	33	52.05	
7:15-7:30AM	0.5	2.4	7	3	11.25	51	75.15	
7:30-7:45AM	2.5	2.4	6	6	9	48	73.9	274.1
7:45-8:00AM	3.5	4	7	6	13.5	39	73	
8:00-8:15AM	4	3.2	9	6	11.25	30	63.45	
8:15-8:30AM	4.5	4.8	7	3	18	36	73.3	
8:30-8:45AM	6	2.4	11	6	22.5	42	89.9	305.8
8:45-9:00AM	5.5	6.4	14	3	11.25	39	79.15	
9:00-9:15AM	2.5	4.8	13	6	18	48	92.3	
9:15-9:30AM	1	3.2	11	0	13.5	39	67.7	
9:30-9:45AM	2	2.4	12	6	20.25	51	93.65	312.15
9:45-10:00AM	1	4	10	3	22.5	18	58.5	
10:00-10:15AM	2	5.6	7	9	29.25	27	79.85	
10:15-10:30AM	1.5	4	3	6	22.5	42	79	
10:30-10:45AM	1	4.8	5	6	15.75	33	65.55	269.6
10:45-11:00AM	0.5	3.2	4	3	13.5	21	45.2	
11:00-11:15AM	1.5	4	6	6	24.75	36	78.25	
11:15-11:30AM	0.5	4	6	12	18	21	61.5	
11:30-11:45AM	1	3.2	2	0	6.75	24	36.95	202.8
11:45-12:00AM	0	1.6	2	3	4.5	15	26.1	
12:00-12:15PM	0.5	2.4	4	6	15.75	27	55.65	
12:15-12:30PM	1	1.6	0	3	0	15	20.6	
12:30-12:45PM	0	1.6	3	3	6.75	6	20.35	124.9
12:45-1:00PM	0.5	0.8	3	6	9	9	28.3	
1:00-1:15PM	0	3.2	1	0	6.75	15	25.95	
1:15-1:30PM	0.5	2.4	5	9	15.75	24	56.65	
1:30-1:45PM	0.5	4.8	2	6	15.75	30	59.05	231.55
1:45-2:00PM	1.5	6.4	7	21	18	36	89.9	
2:00-2:15PM	1.5	5.6	6	15	20.25	33	81.35	
2:15-2:30PM	1	8.8	9	9	11.25	27	66.05	
2:30-2:45PM	1	7.2	7	18	15.75	30	78.95	286.85
2:45-3:00PM	0.5	4	8	9	18	21	60.5	
3:00-3:15PM	1.5	7.2	12	30	18	45	113.7	
3:15-3:30PM	1	5.6	8	21	24.75	72	132.35	
3:30-:45PM	0	8.8	10	15	20.25	60	114.05	482.95

3:45-4:00PM	1	5.6	9	12	20.25	75	122.85	
4:00-4:15PM	1	9.6	13	18	24.75	51	117.35	
4:15-4:30PM	0.5	7.2	18	12	20.25	75	132.95	
4:30-4:45PM	0.5	8	10	9	22.5	96	146	520.9
4:45-5:00PM	0	5.6	5	3	27	84	124.6	
5:00-5:15PM	0.5	6.4	12	12	24.75	60	115.65	
5:15-5:30PM	0	4	10	9	18	75	116	
5:30-5:45PM	0	5.6	11	6	13.5	66	102.1	435.55
5:45-6:00PM	0	4.8	7	3	9	78	101.8	
							3587.2	

Appendix 2 Monday PCU south direction data

time	bicycle, carts and motorciycle	bajajs	minibus, car and pickup	large bus	single and dual rear axle track	large and articulated trucks	sum	
6:00-6:15AM	0	0	2	0	2.25	21	25.25	
6:15-6:30AM	0	0.8	2	0	4.5	45	52.3	
6:30-6:45AM	0.5	4	6	0	6.75	42	59.25	204.3
6:45-7:00AM	1	11.2	8	12	2.25	33	67.45	
7:00-7:15AM	1.5	4.8	10	24	9	39	88.3	
7:15-7:30AM	1	6.4	6	9	20.25	30	72.65	
7:30-7:45AM	3.5	7.2	11	18	9	54	102.7	378.7
7:45-8:00AM	1.5	12	13	30	13.5	45	115	
8:00-8:15AM	3	8	8	21	20.25	63	123.25	
8:15-8:30AM	1.5	7.2	7	12	24.75	87	139.45	
8:30-8:45AM	2.5	8.8	12	6	27	93	149.3	476.8
8:45-9:00AM	3	4	6	3	15.75	33	64.75	
9:00-9:15AM	2.5	8.8	9	6	20.25	66	112.55	
9:15-9:30AM	1	4.8	10	0	15.75	54	85.55	
9:30-9:45AM	2.5	2.4	8	12	18	81	123.9	413.2
9:45-10:00AM	1.5	3.2	7	6	13.5	60	91.2	
10:00-10:15AM	2	5.6	6	9	11.25	48	81.85	
10:15-10:30AM	1	4.8	4	6	9	39	63.8	
10:30-10:45AM	1.5	3.2	7	3	13.5	21	49.2	228.6
10:45-11:00AM	2	4	3	0	6.75	18	33.75	
11:00-11:15AM	1.5	4.8	7	0	11.25	33	57.55	
11:15-11:30AM	1.5	2.4	4	6	9	24	46.9	
11:30-11:45AM	2	3.2	3	0	4.5	15	27.7	152.5
11:45-12:00AM	1	0.8	2	0	4.5	12	20.3	
12:00-12:15PM	1.5	2.4	4	0	6.75	27	41.65	
12:15-12:30PM	0.5	0	3	0	4.5	15	23	
12:30-12:45PM	0	1.6	3	0	4.5	18	27.1	111.1
12:45-1:00PM	1	0.8	1	0	4.5	12	19.3	

1:00-1:15PM	0.5	1.6	1	0	9	9	21.1	
1:15-1:30PM	0.5	3.2	5	0	6.75	15	30.45	
1:30-1:45PM	1	2.4	6	3	13.5	21	46.9	160.5
1:45-2:00PM	1.5	4.8	7	3	15.75	30	62.05	
2:00-2:15PM	1	5.6	6	6	13.5	27	59.1	
2:15-2:30PM	2	4.8	9	3	6.75	24	49.55	
2:30-2:45PM	1.5	7.2	5	3	13.5	21	51.2	218.7
2:45-3:00PM	3	4.8	6	6	9	30	58.8	
3:00-3:15PM	2.5	3.2	8	3	11.25	39	66.95	
3:15-3:30PM	3.5	8	6	0	15.75	63	96.25	
3:30-:45PM	3	12	11	0	13.5	54	93.5	354
3:45-4:00PM	1	4.8	12	3	22.5	54	97.3	
4:00-4:15PM	2.5	5.6	13	3	20.25	45	89.35	
4:15-4:30PM	2	4.8	11	3	18	60	98.8	
4:30-4:45PM	4.5	8	9	3	24.75	33	82.25	414
4:45-5:00PM	5	5.6	10	0	27	96	143.6	
5:00-5:15PM	1.5	7.2	11	0	24.75	60	104.45	
5:15-5:30PM	1	5.6	6	0	22.5	66	101.1	
5:30-5:45PM	0.5	9.6	10	0	20.25	69	109.35	
5:45-6:00PM	0.5	4.8	9	3	27	63	107.3	
							3534.3	

Appendix 3 Thursday PCU north direction data

time	bicycle, carts and motorciycle	bajajs	minibus, car and pickup	large bus	single and dual rear axle track	large and articulated trucks	sum	PCU
6:00-6:15AM	0	3.2	2	0	13.5	6	25	
6:15-6:30AM	1	2.4	10	0	9	42	64	191
6:30-6:45AM	1.5	1.6	8	3	6.75	36	57	
6:45-7:00AM	1.5	0.8	5	3	4.5	30	45	
7:00-7:15AM	5	0	11	0	6.75	27	50	
7:15-7:30AM	9.5	1.6	7	3	18	48	87	291
7:30-7:45AM	5.5	4.8	6	0	11.25	36	64	
7:45-8:00AM	6	4	4	6	15.75	54	100	
8:00-8:15AM	6	3.2	14	6	11.25	39	89	
8:15-8:30AM	4.9	5.6	16	3	18	27	95	357
8:30-8:45AM	8.5	2.4	5	6	20.25	56	118	
8:45-9:00AM	5	4	9	3	11.25	33	85	
9:00-9:15AM	4	5.6	10	6	18	30	94	
9:15-9:30AM	3.5	4.8	6	0	13.5	39	77	347
9:30-9:45AM	2.5	6.4	12	6	20.25	51	98	
9:45-10:00AM	1.5	1.6	11	3	22.5	18	68	
10:00-10:15AM	2	5.6	12	9	9	27	65	
10:15-10:30AM	2.5	2.4	7	6	29.25	42	89	275
10:30-10:45AM	1	3.2	2	6	15.75	33	71	
10:45-11:00AM	0.5	4	8	3	13.5	21	50	
11:00-11:15AM	1.5	2.4	9	6	24.75	36	80	
11:15-11:30AM	0.5	3.2	7	12	18	21	62	225
11:30-11:45AM	1	4.8	11	0	6.75	24	48	
11:45-12:00AM	1	1.6	10	3	4.5	15	35	
12:00-12:15PM	2	0	4	6	15.75	27	55	
12:15-12:30PM	1	0	3	3	0	15	22	130
12:30-12:45PM	0.5	1.6	3	3	6.75	6	21	
12:45-1:00PM	0	3.2	5	6	9	9	32	
1:00-1:15PM	1	4	7	0	6.75	15	34	
1:15-1:30PM	1.5	5.6	5	9	15.75	24	61	247
1:30-1:45PM	2	4.8	8	6	15.75	30	67	
1:45-2:00PM	0.5	4	5	21	18	36	85	
2:00-2:15PM	2.5	4.8	7	15	20.25	33	83	
2:15-2:30PM	0	7.2	9	9	11.25	27	63	289
2:30-2:45PM	1	9.6	7	18	15.75	30	81	
2:45-3:00PM	1.5	4.8	8	9	18	21	62	
3:00-3:15PM	3	7.2	9	30	18	45	112	
3:15-3:30PM	2.5	8	6	21	24.75	72	134	507
3:30-:45PM	1	6.4	5	15	20.25	60	108	

3:45-4:00PM	0	4.8	11	42	20.25	75	153	
4:00-4:15PM	0.5	8.8	7	21	24.75	51	113	
4:15-4:30PM	2	3.2	13	39	20.25	75	152	540
4:30-4:45PM	1.5	5.6	9	9	22.5	75	123	
4:45-5:00PM	0.5	7.2	5	24	31.5	84	152	
5:00-5:15PM	1	3.2	10	12	36	108	170	
5:15-5:30PM	1.5	2.4	6	9	20.25	57	96	500
5:30-5:45PM	0.5	5.6	3	6	24.75	78	118	
5:45-6:00PM	1	4	2	3	15.75	90	116	
	104.4	195.2	359	429	774	1934	3926.55	
	52.2	156.16	716	1287	1741.5	5802	4140.5	

Appendix 4 Thursday PCU south direction data

time	bicycle, carts and motorciycles	bajajs	minibus, car and pickup	large bus	single and dual rear axle track	large and articulated trucks	sum	
6:00-6:15AM	0	0	3	0	0	15	18	
6:15-6:30AM	0.5	0	4	0	9	33	46.5	
6:30-6:45AM	0.5	2.4	3	0	4.5	24	34.4	160
6:45-7:00AM	1.5	4.8	6	6	13.5	27	58.8	
7:00-7:15AM	0.5	8.8	13	18	20.25	36	96.55	
7:15-7:30AM	1	7.2	7	30	29.25	39	113.5	
7:30-7:45AM	1.5	6.4	10	24	24.75	30	96.65	413
7:45-8:00AM	2.5	8	9	21	13.5	51	105	
8:00-8:15AM	1	10.4	11	36	6.75	54	119.2	
8:15-8:30AM	1.5	7.2	18	18	31.5	60	136.2	
8:30-8:45AM	1	12	12	9	27	78	139	485
8:45-9:00AM	0.5	8	6	6	15.75	54	90.25	
9:00-9:15AM	1.5	9.6	5	6	20.25	66	108.4	
9:15-9:30AM	1	5.6	11	9	15.75	54	96.35	
9:30-9:45AM	0.5	4.8	9	15	33.75	60	123.1	410
9:45-10:00AM	1.5	3.2	7	6	22.5	42	82.2	
10:00-10:15AM	1	2.4	6	3	18	48	78.4	
10:15-10:30AM	0	1.6	4	12	20.25	39	76.85	
10:30-10:45AM	1.5	3.2	5	3	13.5	21	47.2	253
10:45-11:00AM	0.5	2.4	3	6	6.75	30	48.65	
11:00-11:15AM	1.5	5.6	4	3	11.25	36	61.35	
11:15-11:30AM	1.5	2.4	5	9	9	27	53.9	
11:30-11:45AM	0.5	1.6	2	3	4.5	30	41.6	207
11:45-12:00AM	1	2.4	6	3	4.5	33	49.9	
12:00-12:15PM	1.5	0.8	4	0	6.75	27	40.05	
12:15-12:30PM	0.5	1.6	3	3	4.5	36	48.6	
12:30-12:45PM	0.5	3.2	3	6	4.5	21	38.2	172
12:45-1:00PM	1	2.4	1	3	4.5	33	44.9	
1:00-1:15PM	3	3.2	1	0	9	9	25.2	
1:15-1:30PM	2	1.6	5	0	6.75	15	30.35	
1:30-1:45PM	3.5	2.4	6	3	13.5	21	49.4	168
1:45-2:00PM	4	4.8	7	0	15.75	30	61.55	
2:00-2:15PM	5	5.6	6	0	9	27	52.6	
2:15-2:30PM	7	4.8	9	3	6.75	24	54.55	
2:30-2:45PM	1.5	7.2	5	3	13.5	51	81.2	257
2:45-3:00PM	3	4.8	6	6	18	30	67.8	
3:00-3:15PM	5	3.2	8	3	22.5	39	80.7	
3:15-3:30PM	3.5	8	6	0	15.75	63	96.25	
3:30-:45PM	5.5	12	12	0	18	54	101.5	379

3:45-4:00PM	1	4.8	14	3	22.5	54	99.3	
4:00-4:15PM	2.5	5.6	11	3	29.25	45	96.35	
4:15-4:30PM	3.5	4.8	16	0	36	60	120.3	
4:30-4:45PM	4.5	8	10	3	11.25	33	69.75	432
4:45-5:00PM	5.5	12.8	7	3	20.25	96	144.6	
5:00-5:15PM	3	8	12	0	13.5	60	96.5	
5:15-5:30PM	0.5	10.4	14	3	33.75	66	127.7	
5:30-5:45PM	0.5	9.6	7	0	27	69	113.1	440
5:45-6:00PM	0	13.6	6	0	18	63	100.6	
	91.5	263.2	348	291	756	2013	3763	

Appendix 5 photo shows volume data recording

Appendix 6 percentages of total sum and average vehicles

Monday

typis of vehicle	north	south	total	% of vehicle
Bicycle	25	33	58	1.60
Carts	49	66	115	3.17
Motorciycle	43	64	107	2.95
Bajaj	254	301	555	15.31
Minibus	154	146	300	8.28
Car and pickup	194	187	381	10.51
large bus	119	75	194	5.35
single rear axle truck	149	134	283	7.81
dual rear axle truck	175	155	330	9.11
4 axle truck	346	373	719	19.84
articulated large truck	285	297	582	16.06
Sum			3624	100.00

Thursday value

typis of vehicle	north	south	total	% of vehicle
Bicycle	42	26	68	1.73
Carts	83	83	166	4.23
Motorciycle	75	74	149	3.80
Bajaj	245	329	574	14.64
Minibus	148	134	282	7.19
Car and pickup	212	214	426	10.87
large bus	143	97	240	6.12
single rear axle truck	159	199	358	9.13
dual rear axle truck	185	137	322	8.21
4 axle truck	342	387	729	18.60
articulated large truck	321	285	606	15.46
Sum			3920	100.00

Appendix 7 peak hour volume calculation for south and north approaches

Peak hour volume calculation for south direction approach based on vehicles counted data are:

Peak hourly volume (PHV) = average of morning and afternoon is sum of two peak 15minutes= 87.35+87.85+100.55+88.65=364.4pcu

Peak 15minuts volume (Vp15min) = maximum 15minute volume =100.55pcu.

Peak Hour Factor (PHF) = PHV/ (4*Vp15min.) = 364.4/ (4*100.55) = 0.90

Flow rate (FR) = 4*100.55 = 402.2 pcu/hr = design flow rate

Similarly, for the north approaches:

PHV=111.5+116.5+126+98.5=452.5pcu

Maximum 15minute volume=126pcu

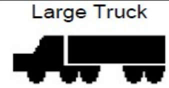
Peak Hour Factor (PHF) = 452.5/ (4*126) = 0.89

Flow rate (FR) = 4*126 = 504 pcu/hr

Appendix 8 % of vehicle composition data and vehicle classification

typis of vehicle	Thursday	Monday	average	% of vehicle composition
Bicycle	68	58	63	1.67
Carts	166	115	140.5	3.72
Motorciycle	149	107	128	3.39
Bajaj	574	555	564.5	14.97
Minibus	282	300	291	7.71
Car and pickup	426	381	403.5	10.70
large bus	240	194	217	5.75
single rear axle truck	358	283	320.5	8.50
dual rear axle truck	322	330	326	8.64
4 axle truck	729	719	724	19.19
articulated large truck	606	582	594	15.75
			3772	100

Vehicle classification as per AACRA (January 2003)

Category	Cars	Light	Medium	Heavy	Articulated
Axles	2	2	3	4	>4
Tyres	4	6	10	14	>14
Length	<3 m	3m – 7.5m	3m – 7.5m	>7.5m	>7.5m
GVW	<3.5T	3.5T-12T	>12T	>12T	>12T
Includes	Cars  Utility  Minibus  4WD 	Bus  1 Axle Truck 	2 Rear Axle Truck 	4 Axle Truck 	Large Truck 

Appendix 9 Total entering vehicles from south directions at Thursday

time	bicycle, carts and motorcycle	Bajaj	minibus, car, and pickup	large bus	single and dual rear axle	large trucks and articulated	Sum
12:00-1:00AM	3	20	18	15	7	47	131
1:00-2:00 AM	15	38	41	19	23	56	261
2:00-3:00 AM	20	35	41	14	39	92	333
3:00-4:00 AM	15	24	32	8	30	87	284
4:00-5:00 AM	13	22	20	6	18	42	177
5:00-6:00 AM	12	14	16	2	12	28	132
6:00-7:00 PM	6	10	11	0	9	24	93
7:00-8:00 PM	7	15	19	2	20	25	191
8:00-9:00 PM	14	28	26	6	19	34	254
9:00-10:00PM	20	35	37	2	28	70	303
10:00-11:00 PM	28	30	43	3	40	78	414
11:00-12:00 PM	7	34	36	1	42	86	353

Appendix 10 Total entering vehicles from north directions at Thursday

time	bicycle, carts and motorcycle	Bajaj	minibus, car, and pickup	large bus	single and dual rear axle	large trucks and articulated	Sum
12:00-1:00AM	6	8	21	4	3	36	78
1:00-2:00 AM	19	19	33	7	18	140	236
2:00-3:00 AM	38	27	38	10	23	98	234
3:00-4:00 AM	34	33	29	5	19	110	230
4:00-5:00 AM	35	32	18	11	17	76	189
5:00-6:00 AM	16	9	12	2	16	65	120
6:00-7:00 PM	13	6	9	6	7	78	119
7:00-8:00 PM	17	22	32	14	11	59	155
8:00-9:00 PM	15	34	27	18	18	126	238
9:00-10:00PM	11	75	30	21	22	174	333
10:00-11:00 PM	8	43	19	19	20	169	278
11:00-12:00 PM	5	30	23	9	23	180	270

Appendix 11 Spot speed data obtained from Adama-Wolenchity road, on fixed section

car No.	speed (km/h)	car No.	speed (km/h)	car No.	speed (km/h)	car No.	speed (km/h)
1	17.82	41	41.81	81	37.89	121	24.7
2	21.32	42	43.78	82	36.13	122	21.71
3	45	43	29.72	83	31.1	123	22.28
4	32.13	44	31.76	84	30.38	124	19.87
5	20.33	45	36.2	85	45.74	125	16.99
6	29.77	46	39.04	86	23.97	126	13.64
7	39.04	47	35.8	87	28.42	127	23.72
8	37.17	48	32.19	88	31.56	128	20.56
9	34.29	49	40.33	89	34.59	129	14.8
10	31.82	50	29.06	90	42.91	130	20.84
11	26.49	51	37.67	91	41.19	131	22.25
12	35.87	52	31.71	92	42.35	132	20.41
13	38.65	53	40.42	93	46.4	133	23.8
14	31.76	54	35.47	94	33.81	134	18.58
15	34.96	55	52.83	95	46.84	135	17.35
16	34.47	56	21.39	96	38.42	136	22.75
17	27.34	57	37.24	97	37.03	137	20.41
18	32.03	58	25.75	98	34.47	138	10.55
19	30.61	59	32.56	99	45.31	139	15.98
20	38.65	60	36	100	36.34	140	12.1
21	27.19	61	44.59	101	25.28	141	22.4
22	16.12	62	39.59	102	24.15	142	20.77
23	36.4	63	30.86	103	18.95	143	18.5
24	39.84	64	38.88	104	28.93	144	15.72
25	40.58	65	46.29	105	31.87	145	16.43
26	30.96	66	37.53	106	37.89	146	18.51
27	30.14	67	36.89	107	46.96	147	17.01
28	21.39	68	38.12	108	19.25	148	16.03
29	31.82	69	37.75	109	33.34	149	24.73
30	31	70	37.03	110	7.65	150	19.92
31	50.76	71	33.75	111	28.42	151	10.46
32	37.31	72	41.63	112	29.72	152	9.35
33	50.1	73	42.17	113	26.74	153	11.07
34	39.04	74	33.69	114	30.06	154	23.48
35	55.23	75	36.54	115	21.35	155	20.09
36	38.42	76	37.97	116	25.92	156	14.68
37	45.96	77	37.75	117	35.78	157	15.92
38	27.5	78	39.51	118	23.44	158	18.07
39	36.4	79	31.41	119	31.75	159	29.77
40	44.59	80	38.27	120	31.1	160	22.02
	1370.27		**1470.95**		**1303.4**		**748.22**
sum	**4892.84**						

Appendix 12 photo shows spot speed data recording

Appendix 13 Table of Travel Time Data and Delay calculation

Vehicle No.	Travel speed (km/hr)	Delay (sec) d_{tu}=(3600/Ut-3600/V_f), sec/Km	Vehicle No.	Travel speed (km/hr)	Delay (sec) d_{tu}=(3600/Ut-3600/V_f), sec/Km	Vehicle No.	Travel speed (km/hr)	Delay (sec) d_{tu}=(3600/Ut-3600/V_f), sec/Km
1	10.59	222.22	64	18.95	72.25	127	14.4	132.28
2	5.85	497.66	65	18	82.28	128	13.58	147.37
3	12.86	162.21	66	7.35	372.07	129	21.82	47.26
4	8.28	317.06	67	18.46	77.29	130	15.65	112.31
5	13.09	157.30	68	21.18	52.25	131	21.18	52.25
6	18.46	77.29	69	18	82.28	132	21.18	52.25
7	17.56	87.29	70	11.43	197.24	133	18.95	72.25
8	16.36	102.32	71	5.29	562.81	134	18.46	77.29
9	15	122.28	72	9.73	252.27	135	11.61	192.35
10	16	107.28	73	18.95	72.25	136	12.86	162.21
11	15	122.28	74	14.12	137.23	137	12.41	172.36
12	17.14	92.31	75	14.12	137.23	138	13.09	157.30
13	19.46	67.27	76	4	782.28	139	12.2	177.36
14	20	62.28	77	21.18	52.25	140	12	182.28
15	24	32.28	78	4.74	641.77	141	13.33	152.34
16	30	2.28	79	19.46	67.27	142	12.63	167.31
17	15	122.28	80	16.36	102.32	143	10.59	222.22
18	14.12	137.23	81	8.89	287.23	144	10.91	212.25
19	16.74	97.33	82	20	62.28	145	11.8	187.36
20	18.46	77.29	83	20.57	57.29	146	11.43	197.24
21	17.56	87.29	84	9.73	252.27	147	12.63	167.31
22	18	82.28	85	12.86	162.21	148	10.43	227.43
23	13.58	147.37	86	13.33	152.34	149	11.43	197.24
24	18.95	72.25	87	9.6	257.28	150	10.91	212.25
25	16.36	102.32	88	25.71	22.30	151	13.58	147.37
26	20.57	57.29	89	20	62.28	152	13.09	157.30
27	21.18	52.25	90	28.8	7.28	153	12	182.28
28	18.46	77.29	91	4.9	616.97	154	14.69	127.34
29	18	82.28	92	16.36	102.32	155	15.65	112.31
30	17.14	92.31	93	17.56	87.29	156	10.29	232.13
31	21.82	47.26	94	18.95	72.25	157	15	122.28
32	17.14	92.31	95	14.69	127.34	158	10.75	217.16
33	19.46	67.27	96	20	62.28	159	10	242.28
34	21.18	52.25	97	20	62.28	160	11.08	207.19
35	16.74	97.33	98	20	62.28	161	9.86	247.39
36	20	62.28	99	24.83	27.26	162	12.86	162.21
37	14.69	127.34	100	18.46	77.29	163	11.61	192.35
38	21.18	52.25	101	18.46	77.29	164	14.4	132.28
39	12.41	172.36	102	21.18	52.25	165	20.57	57.29
40	16.74	97.33	103	20	62.28	166	25.71	22.30
41	13.58	147.37	104	13.85	142.20	167	28.8	7.28

42	8	332.28	105	18	82.28	168	36	-17.72
43	22.5	42.28	106	16.38	102.06	169	9.11	277.45
44	11.8	187.36	107	21.82	47.26	170	24	32.28
45	10.14	237.31	108	20.56	57.37	171	19.46	67.27
46	14.4	132.28	109	18	82.28	172	8.37	312.38
47	18.46	77.29	110	21.17	52.33	173	34.29	-12.74
48	4.83	627.62	111	15.66	112.16	174	9.6	257.28
49	7.42	367.45	112	20.02	62.10	175	22.5	42.28
50	8.57	302.35	113	14.4	132.28	176	27.69	12.29
51	13.58	147.37	114	15.34	116.96	177	8.78	292.30
52	14.69	127.34	115	17.14	92.31	178	8	332.28
53	10	242.28	116	18.95	72.25	179	18.95	72.25
54	12	182.28	117	16.36	102.32	180	25.71	22.30
55	18.95	72.25	118	14.69	127.34	181	8.18	322.37
56	23.23	37.25	119	15	122.28	182	37.89	-22.71
57	24	32.28	120	17.56	87.29	183	23.23	37.25
58	12.63	167.31	121	18.46	77.29	184	8.47	307.31
59	12	182.28	122	16.74	97.33	185	7.83	342.05
60	18.46	77.29	123	16	107.28	186	24.83	27.26
61	21.82	47.26	124	15.32	117.26	187	17.14	92.31
62	12.86	162.21	125	19.46	67.27	188	18.46	77.29
63	20.57	57.29	126	17.14	92.32	189	7.58	357.21

Delay (sec) d_{tu}= (3600/Ut-3600/V_f), sec/Km

Sourse :Akçelik - Speed-Flow Models for Uninterrupted Traffic Facilities,page 7
vu = uninterrupted travel speed at a given flow rate (km/h), and
vf = free-flow speed (km/h)
dtu = traffic delay per unit distance (seconds/km),

Appendix 14 Photo shows travel time distance measurement

Appendix 15 Determining Level of Service

To determine the level of service, the vehicles types should be converted to pcu.

Step 1: Total pc=bajaj (**24**) + cars (**74**) +carts, and bicycles (**13**) +large buses (**18**) +single and dual rear Axle Trucks (**53**) +large and articulated trucks **(96**)

=**278**pc/**200**m/ln

Step 2: Determining of flow rate, $\mathbf{q=k*u_{av}}$

q= flow rate (pc/hr)

k= density (pc/mi/ln)

u_{av}= average travel speed of the vehicles

q=278/ (30/60) pc/hr

=**556 pc/hr**

Step 3: Determining Density of vehicles on the segment.

K=q/u_{av}=556/16.66 =34.41 pc/m/ln.

Step 4: Searching level of service in the table existed in literature review of chapter two.

26<34.41<35… LOS "D".

Which means the segment has been serving near its flow with low speed, but

Before changed to **pcu=192, 18<23<26… LOS "C".** This implies relatively stable flow condition on segment.

Appendix 16 Road Condition Survey

Surveying of road condition of the segment of roadway involves gathering/collecting necessary data and to differentiate the causes of traffic delay as follows.

Photo shows measuring of the road segment elements.

Appendix 17 Photo shows the entrance and exit of Wolenchity town

Appendix 18 Photo shows exit and entrance of Adama town

Appendix 19-questionnaires for key actors

Questionnaire Survey for MSc. Thesis

Prepared for ***drivers***

Thesis title: Assessment on the causes of traffic delay at Adama to Wolenchity road segment

General Information

This research survey is designed to fulfill an academic requirement for M.Sc. degree program in Highway Engineering at Jimma University. I can assure you that the research data will only be used for drivers. Your open and prompt response is highly appreciated.

Please give your response for the questions here under by putting a " ✓ " mark at your appropriate choice or by putting your answers in the space provided. You may use the back side of the paper if the space provided is not sufficient.

For any clarification on this questionnaire, please contact me on 0922316174 (Bedada Germame)

Traffic delay at traversing time

1. Mark the problems that can causes of traffic delay on road segment.

- ☐ Truck congestion
- ☐ Road surface problem
- ☐ Narrow Adama-Wolenchity road
- ☐ There are animals on the road
- ☐ Poor drivers vision for other road
- ☐ Overloaded truck
- ☐ Poor road administration and management
- ☐ Insufficient road lane
- ☐ Carts use road

☐ If there are other problems at road segment

____

____

Traffic delay due to problems related to entrance and exit of Wolenchity town

2. Mark the problems that can causes of traffic delay at entrance and exit of Wolenchity

☐ Illegal on-street parking habit
☐ Many informalities of truck stop
☐ Informal passenger on the road
☐ Insufficient space for stop
☐ Unsuitable parking design for deference types of trucks
☐ Poor sight distance for passing
☐ Poor traffic control
☐ Maximum traffic flow
☐ If there are other problems at Wolenchity town exit

____

____

Causes of traffic delay at entrance and exit of Adama Town.

3. Mark the problems that can causes of traffic delay at entrance and exit of Adama town

☐ More truck turn to expressway
☐ More taxi turning
☐ The carts stop on the road
☐ Steep upgrades
☐ Down grade operation
☐ More bajaj turning
☐ If there are other problems at entrance of Adama town

Which of the following are the **effects of delay** on drivers?

- ☐ Delay cause anger
- ☐ Delay causes tediousness
- ☐ Delay causes fatigue
- ☐ Drivers get restless
- ☐ Delay reduce performance
- ☐ Delay reduce work motivation
- ☐ Delay change driving behavior
- ☐ Delay cause west of time
- ☐ Delay cause fuel-conception
- ☐ Delay cause accident
- ☐ Delay cause complexity of reaction
- ☐ Delay cause extravagance
- ☐ If there are other problems cause of delay on drivers

____

____