ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

ASSESSING & QUANTIFING THE LEVEL OF TRAFFIC CONGESTION AT MAJOR INTERSECTIONS IN ADDIS ABABA

(A CASE FOR EAST-WEST CORRIDOR)

A Thesis submitted to

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By

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Advisor

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MSc Thesis on

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DECLARATION

I certify that this research work titled "Assessing and Quantifying the Level of Traffic Congestion at major Intersection in Addis Ababa (a case for East- West Corridor)" is my own work. The work has not been presented elsewhere for assessment and award of any degree or diploma. Where material has been used from other sources it has been properly acknowledged/ referred.

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Name	Signature	Date

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LIST OF ACRONYMS

aaSIDRA	akcelik & associates traffic Signalized & un signalized Intersections Design and Research Aid
CMS	Congestion Management System
HCM 2000	Highway Capacity Manual 2000
LOS	Level of Service
PCU	Passenger Car Unit
RTA	Ethiopian Road Transport Authority
TOC	Traffic Operation Center
TTI	Texas Transport Institute

ABSTRACT

Traffic Congestion is an ever growing chronic problem in the transportation system soon after the invention and mass production of automobiles. All major cities both in developed and developing countries are facing the problem due to increasing travel demand which follows economic and population growth. Traffic congestion directly affects commuters with an increased travel time, excessive delay in a queue, increased fuel cost, delay for important appointment and job, loss in productive hours; and it indirectly affects the living standard and the environment as well. Hence, traffic congestion cause upon road users and cities to incur a significant amount of money for both economic and social costs. Quantifying the level of the traffic congestion and understanding how much effect and cost are being incurred due to traffic congestion; hence, will be important for making improvement decisions and evaluate implemented mitigation measures.

Following the economic and population growth in Addis Ababa, traffic congestion problem has emerged and the problem is even growing faster. In this study, the level of the traffic congestion in Addis Ababa city was quantified using travel time approach. The city's one of the most congested East-West corridor was considered and travel time, traffic volume, and vehicle occupancy data were collected at four midblock and four intersections. Accordingly, the travel rate, the delay rate, total travel delay (Veh-Min and Per-min), buffer index and planning time index were calculated. And also, the average hourly travel rate is correlated with the average hourly traffic accident data and congestion spots and accident black spots were plotted on the GIS map to see the relationship between the traffic accident and traffic congestion.

Accordingly, the result showed that on average about 18,000 Veh-min or 38 Veh-day and about 169,000 Per-min or 352-person-day are wasted at each major intersection entry and the city incurs annually about 5-8 Million Birr per intersection only for vehicle and fuel cost. The result also showed that the city's traffic accident rate correlated with travel rate better than traffic volume and the congestion spots identified from questionnaire data conside with the black spots identified by the national road safety agency.

1. INTRODUCTION

1.1. Background of study

As history of many cities shows, socio-economic growth usually accompanied with an increasing demand for mobility and transportation. For instance Eurostat (2002) showed that passenger- Km travel demand increases as fast as the gross domestic product (GDP) for European nations. In order to meet such travel demand, countries and cities obligated to spend considerable portion of their GDP on transportation sector. According to the ECMP (2007) European countries expend more than 7% of their GDP on transportation and out of which only traffic congestion costs more than 1% of the GDP. In Ethiopia, different reports estimates the transportation expenditure to be about 10% of the country's GDP; however, the actual cost incurred due to traffic congestion is not yet known.

Addis Ababa, which is the capital city of Ethiopia and the seat of many international organizations with more than 100 embassies, has now become one of the fastest growing relatively modern cities in the sub Saharan Africa. According to the 2007 census the population of Addis Ababa was estimated to be 2.8 Million with an average growth rate of 2.1% (FDRE Population Census Commision, 2008). Following the current economic development in the country, Addis Ababa has become the economic hub of the nation due its geographical as well as political significance. Accordingly, many financial and commercial institutions and about 85 % of the manufacturing industries of the country are located inside and at the periphery of Addis Ababa. Such rapid socio-economic development in the city creates a huge demand for transportation and the passenger-Km travel is increasing. The Urban Transport study report of Addis Ababa estimates that the travel demand of Addis Ababa will be doubled in 2020 and the daily trip will become 7.7 Million trips per day from 3.6 Million in 2004 (CES in association with SABA Engineering, 2005). Accordingly, evidences show that the associated transportation problems in the city; namely, traffic congestion and traffic accident rate are becoming worse and worse.

The problem of traffic congestion in Addis Ababa has emerged and intensified within a short period of time despite efforts of the city administration in expanding the city's road network. Though, the vehicle ownership in Ethiopia is the lowest even compared with the sub Saharan countries, it is assumed that about 80% of the vehicles in the country are found in Addis Ababa and the vehicle number is growing at about 5% yearly (CES in association with SABA Engineering, 2005). Being exacerbated by the above and many more road side factors, traffic congestion and traffic accident are now becoming a chronic problem in the city's transportation system (Birhanu, 2000,).

Currently the Addis Ababa City Transport Authority has realized the problem of traffic congestion and planned to launch an advanced traffic management system and is working on the establishment of Traffic Operation Center (TOC). According to the unpublished draft project profile prepared by the Ministry of Transport and Communication, the planned TOC will serve to improve safety, improve mobility and relief congestion, and provide traveler information service (Ministry of Transport and Communication, 2010).

However, despite the well known problem of traffic congestion and the city's administration effort to improve the problem, limited quantitative researches have been conducted on city's traffic congestion level. Therefore, proper quantification and measuring the extent or level of congestion is an important step for understanding the performance of the existing road network and for evaluation of proposed congestion mitigation measures. Hence, this thesis will focus on this information gap and will asses and quantify the level of the traffic congestion on the selected study corridor of Addis Ababa based on travel time delay approach; and it will assess the effect of traffic congestion on the traffic accident situation of the city.

1.2. Problem statement

In Addis Ababa, despite the intensive road network expansion and the limited number of vehicle ownership compared to the other sub Saharan countries, traffic congestion has now become the major threat in the cities economic growth by restraining the commuters' mobility especially at peak hours. In addition to waiting time for the limited public transportation, both vehicle owners and public transport users are forced to delay within the congested traffic lane. Hence, late arrival to work places and appointments for social or business activities have become common.

Despite the problem being recognized by all road users and transport professionals, there is only insignificant attempt for quantitative research done on the extent of the traffic congestion in Addis Ababa. A single attempt was made by Haregewoin Y. (2010) to assess the amount of travel time delay along *Total-Ayer Tena road section.* However, this study was based on a limited travel time data and most of the analysis was based on a subjective questionnaires' response than engineering parameters. Hence, questions on the major cause, the level and the effect of the traffic congestion on the road user and on the economy are still not well investigated and answered.

Therefore, quantitative researches based on the engineering parameters of traffic congestion should be conducted to answer at least the following questions. These include:

1. What are the main causes and contributing factors for the traffic congestion in Addis Ababa?
2. Which parts of the road network are more prone to traffic congestion and at which area is the situation recurring?
3. What is the level of the traffic congestion quantitatively in terms of explanatory parameters showing its intensity, extent, duration and reliability?
4. How is traffic congestion affecting the traffic accident in the city?
5. If a traffic management scheme is to be applied which sections of the road network or intersection should be prioritized?

Accordingly, this thesis will try to answer some of the problems by assessing and quantifying the traffic congestion along the highly congested East-West corridor of Addis Ababa.

1.3. Literature review

Many researchers and professionals in the field of transportation agree that road traffic congestion is an ever growing problem and global phenomenon of major cities throughout the world. Further to this Lomax (1997) showed that traffic congestion is expanding toward the suburbs as commercial activities are being pulled out of the central business districts (Lomax, Turner, and Shunk, 1997; Maitra, P.K.Sikdar, and S.L.Dhingra, 1999). In fact, it is almost certain that traffic congestion will also get worse during at least the coming decades mainly due to the increasing population number and the growing economy of nations. Traffic congestion is a negative output of a transportation system which has many detrimental effects on the performance of the road network, the traffic flow, the society, the national economy and the environment. Maitra (1999) summarizes some of the negative effects of traffic congestion as; considerable loss of travel time, higher fuel consumption, more vehicle emission and associated environmental and health impact, increased accident risk, stress and frustration on commuters and greater transportation cost.

Since it is a day to day occurrence to almost all road users, the concept of congestion as a serious problem of traffic flow is well known to the public or road users. However, many documents showed that there was no considerable effort to conceptually investigate congestion before 1990's (W.D.Cottrell, 2001; Lomax, Turner, and Shunk, 1997). According to Cottrell (2001), the 1991 Intermodal Surface Transportation Efficiency Act and the subsequent Transportation Equity Acts mark a significant start for researches and investigations on congestion as part of Congestion Management System (CMS) in United States of America. Since then different research efforts to develop methods and parameters for measuring traffic congestion have been proposed by different researchers and manuals. One of such efforts was the research project funded by the National Cooperative Highway Research Program (NCHRP) titled "Quantifying Congestion".

Further to the above; many more researches have been conducted by different researchers and professionals to develop measuring parameters and models (Maitra, P.K.Sikdar, & S.L.Dhingra, 1999; Lomax, Turner, and Shunk, 1997; W.D.Cottrell, 2001). However, many scholars agree that unlike the other traffic flow characteristics, still there is no consistent definition and a single performance measure for traffic congestion (B.Medley and J.Demetsky, 2003). So far, different congestion measures and models have been proposed and used to determine the extent, severity and duration of congestion and also transport professional are still developing different models for congestion prediction and simulation (Moran and Koutsopoulos, 2010).

Proper quantification and measuring the extent or level of congestion is an important step for understanding the performance of the existing road network and for evaluation of proposed congestion mitigation measures. NCHRP-398 states that congestion measures are needed to analyzing and prioritizing system improvement options, to provide quantitative information for policy makers and the public, to determine how much delay and queue size formed, which area or region is more congested (Lomax, Turner, and Shunk, 1997).

1.3.1. Defining traffic congestion

As a general term, congestion is a phenomenon that occurs almost in all walks of life which demand competition for certain service or supply. For instance, at banking desk, fuel stations, theater gates, e.t.c. Similarly, the Hand Book of Transportation explain road traffic congestion as a phenomenon resulted when vehicles compete or demand for the available road space and the demand reaches or exceeds the capacity.

Many scholars agreed that, despite the fact that engineers and other transport professionals had studied traffic congestion for long time, there is no still consensus even within academia on the single and precise definition of traffic congestion (T.Thianniwet and S.Phosaard, 2009). This is mainly due to the fact that traffic congestion is:

1. A ***physical phenomena*** relating to the manner how vehicles impede each other's progression as demand for limited road space approach to capacity (Cambridge Systematics, 2005)
2. A ***relative phenomena*** to users expectation versus road system performance (Lomax, Turner, & Shunk, 1997)
3. It can't be fully described using one dimensional parameter (W.D.Cottrell, 2001)

Hence, there are many definitions given for traffic congestion based on different parameters. If we summarize them they all lie in at least one of the following definition. These are:

- *Traffic Congestion is travel time or delay in excess of that normally incurred under light or free flow travel condition*.
- *Traffic Congestion is a situation where the traffic demand for the road space exceeds the capacity*.
- *Traffic Congestion is an excess of vehicle on the portion of the road way at a particular time resulting in slower speed from normal or free flow speed and mostly characterized by stop or stop*-go traffic.

As it can be seen from the above definitions and the diagram below, definitions of traffic congestion generally fall in to two major categories. These are definitions which base on the cause and which base on the impact of traffic congestion. However, in order to quantify or measure traffic congestions definitions which are based on the impacts are more appropriate due to the fact that the impact of traffic congestion can be felt by many road users and easy to understand.

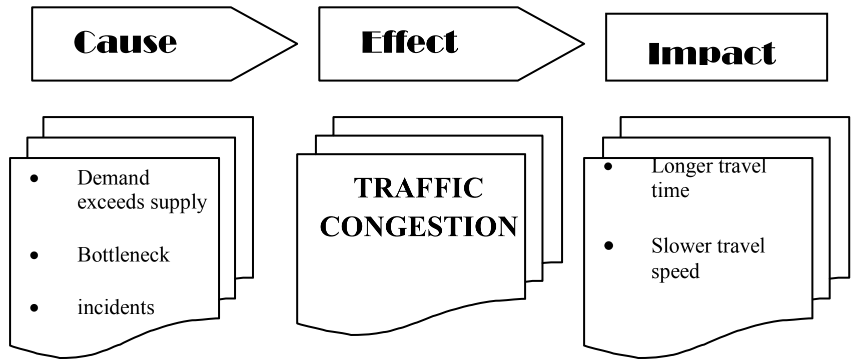


Figure 1: Conceptual frame work of Congestion Cause & Impact

Lomax (1997) argued that traffic congestion is dependent on the perception of the road user's and gives two definitions for "Congestion" and "Unacceptable Congestion". Accordingly; "Congestion" was defined as a travel time or delay in excess of what normally incurred under light or free flow travel condition and "unacceptable congestion" as travel time or delay in excess of an agreed upon norm. However, the later definition involves a subjective aspect and difficult to demark in between. Hence, many researches and reports use the first definition in quantifying traffic congestion.

In traffic engineering, flow is an important parameter that shows the state of the traffic movement. In terms of traffic flow, congestion is usually considered as the state where the speed-flow graph is reverted or sloped positive. Hence, congestion can be defined as a state in the traffic flow pattern which represents the condition at which demand exceeds capacity or the speed is below acceptable value (Yu, Liu, Shi, and Song, 2010).

Depending on its occurrence congestion can be classified as ***recurring and non-recurring*** congestion. Recurring congestion includes congestion due to bottlenecks, traffic signal, and persistent higher demand etc and they are predictable. Whereas non-recurring congestion is includes those congestion caused by mainly accidents and unprecedented events (Skabardonis., P.Varaiya, and F.Petty, 2003).

1.3.2. Causes of traffic congestion

Different researches and reports identified many interrelated factors that cause traffic congestion in developed and developing countries where the road network and road users behavior are different (Cambridge Systematics, 2005; Aworemi et.al., 2009; Kwon, Mauch, & Varaiya, 2006). For instance, Cambridge Systematics(2005) in its "Traffic Congestion and reliablity" report showed the main causes of traffic congestion in United States of America and the research by Aworemi, et.al;(2009) identified the major traffic congestion causes in Lagos Metropolitan. Accordingly, the results showed that in the United States of America the cause and their percentage share are; *bottleneck* (40%), *traffic incidents* (25%), *work zone* (10%), *bad weather* (15%), *poor signal timing* (5%) and *special events* contribute 5% of the traffic congestion.

Adedimila (as quated by Aworemi, et.al: 2009) classifies the major causes of teaffic congestion in lagos metropolitan in to five and the summary of his discussion is shown in the Table 1 below.

Table 1: Major causes of traffic congestion in Lagos Metropolitan

Item No.	Factors	Causes described
1	Social & Economic factors	• Rising population number together with the rural-urban migration • Unplanned land use which result unidirectional traffic flow especially at pick hours • Increased car ownership in line with the improved living standard
2	Road factors	• Smaller number of lane & Narrow road with • Lack of side walk which result occupation of traffic lanes by pedestrians • Distressed pavement which result in a reduced travel speed • Uncontrolled traffic Intersections
3	Vehicle factors	• Size of vehicle • Age of vehicles
4	Human factors	• Perception of drivers • Perception of pedestrians
5	Accident	• The severity, number and location of accident

In his MSc thesis research Haregewoin (2010) identifies causes of traffic congestion in Addis Ababa along Total-Ayer Tena road as; *limited road capacity, road parking, un-integrated urban planning, and lack of mass transit, accident, poor vehicle condition, and road side illegal trade*. Therefore, the common feature in the causes of traffic congestion in developing countries shows that the root causes emanate from the lack of proper planning and improper use of limited road network.

1.3.3. Quantification of congestion

According to Cottrell(2001) and other studies, during the early 1990's the ever growing traffic congestion became the concern of transport agencies of major metropolitans .Then different legislations and acts were drawn in the United States of America which demands transport agencies to establish Congestion Management Systems (CMSs). In response, some state agencies funded researches on measure, threshold, and method of assessing congestion. Further studies and researches then conducted to develop parameters and indexes to quantify traffic congestion. And also developing empirical models that help to predict recurrent and non-recurrent traffic congestion become a concern (B.Medley and J.Demetsky, 2003;W.D.Cottrell, 2001; Skabardonis., P.Varaiya, and F.Petty, 2003; Moran C. A., 2008).

The survey made by Lomax (1997) in 1992 to investigate the existing practice of different agencies for measuring traffic congestion showed that there were a range of empirical measures being used by different agencies and out of these about 90% used the Level of Service (LOS) as congestion measure as defined in Highway Capacity Manual (HCM). However, the same research assesses the suggestion of agencies to on the most appropriate measure for congestion. Accordingly, Travel delay and Travel time/ speed were frequently proposed as the best congestion measure (Lomax, Turner, and Shunk, 1997).

The Highway Capacity Manual 2000 defines six states of traffic flow or operations with clear boundaries of traffic flow parameters. The six states of traffic flow are named with the English alphabet from A to F where A represents a free flow condition while F represents a blocked or a stop and go traffic flow. However, the HCM do not specify a boundary as to which LOS is considered as congested state. Hence, different agencies define their own boundary for congestion and the survey result showed that LOS C, D, E and the worse were used by agencies. Furthermore, as the HCM uses the volume to capacity ratio or saturation index (v/c) as a base for LOS criteria, some agencies were using the v/c ration for measuring congestion and the values ranging from 0.8-1.25 were used as a boundary for defining congested state (Lomax, Turner, and Shunk, 1997;Schrank, Lomax, and Turner, 2010).

However, all the above congestion approaches both LOS and v/c ratio cannot be a comprehensive measure for congestion due to the fact that congestion is a multidimensional phenomenon. Meyer (1994) indicates that there is no consistent congestion measure used by transport engineers and planners to monitor system congestion. Meyer also states "*A good set of congestion measures has the potential to improve not only the quality and consistency of public transportation policy but also pubic understanding of the congestion phenomenon, leading to political support for policy improvements and more rational behavior by individual travelers*". Accordingly, most literatures agree that travel time approach for quantifying congestion gives a better opportunity for public and policy makers to understand the level of congestion.

1.3.4. Components of congestion

All researches done so far agreed that in order to fully express traffic congestion, it is necessary to understand its four components or dimensions; namely, duration, extent, intensity and reliability (Jenks et.al., 2008; W.D.Cottrell, 2001). ***Duration*** express the amount of time that the congestion affects the transportation system or lasts with daily recurrences possible. ***Extent*** concerns the number of persons or vehicles affected by travel delay. ***Intensity*** describes how much the congestion is severe and affects the travel and ***Reliability/Variation*** describes the changes in the above three other parameters and their predictability.

According to Jenks et.al (2008), the four dimensions are actually are very important and can help to define the magnitude of congestion. He explained the relationship of the four components with a three dimensional box as shown in the Figure 2 below and the volume of the box is related with the magnitude of congestion and the variation in the volume of the box with time is an indication of reliability.

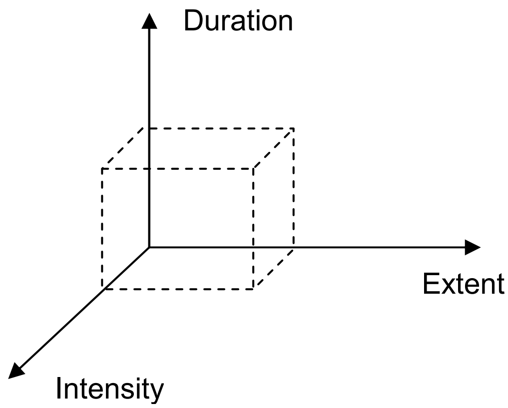


Figure 2: Components of Congestion (adapted from Jenks et.al 2008)

1.3.5. Congestion indicators

As congestion is a relative measure unlike the other traffic flow parameters and it is defined on the road user's feedback on how the transports system is operation at a given period of time; it is essential to define or have indicators of the presence of congestion in the system. According to Cottrell (2001) many other researchers LOS is the best empirical indicator of congestion in transport system. Moreover, according to Lomax (1997) the road user's perception as a measure for "acceptable" or "Unacceptable" congestion can be taken as an indicator or a demarcation for classifying a road section or an intersection as Congested or not.

1.3.5.1. Level of service (LOS) as congestion indicator

The objective of High way Capacity Manual (HCM) is to provide a consistent system and techniques for the evaluation of the quality of service on highways and street facilities. The HCM does not set policies regarding a desirable or appropriate quality of service for various facilities, systems, regions, or circumstances. Its objectives include providing a logical set of methods for assessing transportation facilities, assuring that practitioners have access to the latest research results, and presenting sample problems. HCM presents LOS as an easy-to-understand methodology of analysis and performance measure for single homogenous road segments. LOS is featured for describing conditions in road links and there is no direct methodology for aggregation. LOS has been criticized by analysts and experts in the area, but it is still in use for the easy-to-communicate properties.

As it is stated earlier, HCM doesn't specify the boundary LOS for congestion state but clearly states that the LOS F is defined as the worst state of flow and represents congested flow. Though there are some reports using other level of service (D and E) as congested flow, LOS F is generally accepted as a state of traffic flow and hence LOS is the most appropriate congestion indicator. The LOS criteria on the HCM are given in the form of min speed, flow or density for road way sections and as a max delay in sec for signalized and un-signalized intersection.

The LOS criteria of HCM are summarized in Tables 2 and 3 below

Table 2: Typical Highway Level of Service (LOS) rating (Source: HCM 2000)

LOS	Description	Speed (mile/hr)	Flow (Veh/hr/ln)	Density (Veh/mile)
A	Traffic flows at or above posted speed limit. Motorists have complete mobility between lanes.	Over 60	Under 700	Under 12
B	Slightly congested, with some impingement of maneuverability. Two motorists might be forced to drive side by side, limiting lane changes	57-60	700-1100	12-20
C	Ability to pass or change lanes is not assured. Most experienced drivers are comfortable and posted speed maintained but roads are close to capacity. This is the target LOS for most urban highways	54-57	1100-1550	20-30
D	Speeds are somewhat reduced, motorists are hemmed in by other vehicles. Typical urban peak-period highway conditions.	46-54	1550-1850	30-42
E	Flow becomes irregular, speed vary and rarely reach the posted limit. This is considered a system failure.	30-46	1850-2000	42-67
F	Flow is forced; with frequent drops in speed to nearly zero mph. Travel time is unpredictable.	Under 30	Unstable	67- max

Table 3: Typical Intersection Level of Service (LOS) rating (source: HCM 2000)

Level of Service (LOS)	Delay at signalized intersection	Delay at un signalized intersection
A	≤ 10 sec	≤ 10 sec
B	10-20 sec	10-15 sec
C	20-35 sec	15-25 sec
D	35-55 sec	25-35 sec
E	55-80 sec	35-50 sec
F	≥80 sec	≥50 sec

1.3.6. Performance measures using travel time

Each of the dimensions of traffic congestion stated before can be measured with different operational characteristics (*speed, delay, travel time, density* e.t.c) or volume characteristics (*operating traffic volume, volume to capacity ratio, traffic volume per lane*, e.t.c). Many literatures including the NCHRP report 398 “Quantifying Congestion” provide different measures for congestions based on travel time approach. Most of the measures explain only one or two of the dimension of congestion and hence it is necessary to use more than one congestion measure to explain the level of congestion at a road section. Accordingly, there are quite a number of congestion measures suggested in different literatures for each congestion dimension. However, the following congestion measures are taken & summarized mainly from NCHRP 398: Quantifying Congestion by Lomax (1997) and NCHRP 618 by Jenks et. al (2008) .

Further to the following listed congestion measures in Table 4, new parameters in the form of indexes have been emerging (Anjaneyulu and B.N.Nagaraj, 2009;Maitra, P.K.Sikdar, and S.L.Dhingra, 1999). These indexes give a better understanding of the severity of the congestion in terms of its spread over time and space. Some of the indices indicated in many literatures include; Severity Index, K-factor, Lane –mile duration Index, Road way congestion index, freeway congestion index, travel time index, buffer time index.

Table 4: Summary of Congestion measures (Source: (Tim Lomax, Shawn Turner, and Gordon Shunk, 1997)

Travel Rate	$\frac{\text{Travel Rate}}{\text{Minute/mile}} = \frac{\text{Travel Time (minute)}}{\text{Segment Length (mile)}} = \frac{60}{\text{Average Speed (mph)}}$
Delay Rate	$\frac{\text{Delay Rate}}{\text{(minutes/mile)}} = \frac{\text{Actual Travel Rate}}{\text{(minute/mile)}} - \frac{\text{Acceptable Travel Rate}}{\text{(minute/mile)}}$
Delay Ratio	$\text{Delay Ratio} = \frac{\text{Delay Rate}}{\text{Actual Travel Rate}}$
Delay Per Traveler	$\begin{matrix}\text{Delay per Traveler} \\ \text{(annual hours)}\end{matrix} = \left[\begin{matrix}\text{Actual} \\ \text{Travel Time} \\ \text{(minutes)}\end{matrix} - \begin{matrix}\text{FFS or PSL} \\ \text{Travel Time} \\ \text{(minutes)}\end{matrix}\right] \times \frac{\text{250 weekdays}}{\text{year}} \times \frac{\text{hour}}{\text{60 minutes}}$
Travel Time	$\frac{\text{Travel Time}}{\text{(person - hours)}} = \frac{\text{Actual Travel Rate}}{\text{(minutes per mile)}} \times \frac{\text{Length}}{\text{(miles)}} \times \frac{\text{Vehicle Volume}}{\text{(vehicles)}} \times \frac{\text{Vehicle Occupancy}}{\text{(persons/vehicles)}}$
Travel Time Index	$\text{Travel Time Index} = \frac{\begin{matrix}\text{Actual Travel Rate} \\ \text{(minutes per mile)}\end{matrix}}{\begin{matrix}\text{FFS or PSL Travel Rate} \\ \text{(minutes per mile)}\end{matrix}}$

Buffer Index	$Buffer\ Index\ (\%) = \left[\frac{\underset{(minutes)}{95th\ Percentile\ Travel\ Time} - \underset{(minutes)}{Average\ Travel\ Time}}{\underset{(minutes)}{Average\ Travel\ Time}}\right] \times 100\%$
Planning Time Index	$\underset{(no\ units)}{Planning\ Time\ Index} = \frac{\underset{(minutes)}{95th\ Percentile\ Travel\ Time}}{\underset{(minutes)}{FFS\ or\ PSL\ Travel\ Time}}$
Total Delay	$\underset{(person-minutes)}{Total\ Segement\ Delay} = \left[\underset{(minutes)}{\overset{Actual}{Travel\ Time}} - \underset{(minutes)}{\overset{FFS\ or\ PSL}{Travel\ Time}}\right] \times \underset{(vehicles)}{Vehicle\ Volume} \times \underset{(persons/vehicle)}{Vehicle\ Occupancy}$

1.3.7. Traffic congestion and accident

There are only limited researches available on the relationship between traffic accident and congestion as it relates to the performance of the transportation system .However, Cambridge Systematic, Inc (2008) report and a study by the Victoria Transport Policy Institute showed some evidences that traffic congestion is related with traffic accident.

The evidence is mixed on the degree to which congestion reduces the number of traffic accident on a congested road segment. In some cases, traffic accident shows a reduction in less congested road section. The study concludes that shifting vehicle travel from congested to less congested condition tends to reduce traffic accident but increases the accident severity. Other researches for instance HRD (2008) agreed that traffic congestion causes traffic accident and hence the cost of congestion should include the cost of accident risks.

The traffic accident rate in Ethiopia is reported to be one of the highest accident rates in the world. Though, the vehicle ownership in the country is the lowest among the sub-Saharan countries, the traffic accident is found to be the highest. According to the Ethiopian Road Transport Authority statistics about 1,800 people died, 7000 people injured and over 400 Million Birr was lost only in the year 2003 (RTA web site acceced on 1/9/2003). Birhanu (2000) in his PhD dissertation disclosed that out of the total traffic accident in Ethiopia, 21 % of the fatalities, 42% of injury accidents and 65% of the total accidents occurred in Addis Ababa. Moreover, he related the traffic volume as a parameter in the traffic accident model and concluded that as the travel volume increase the headway between vehicles decrease and minor nose-tail collision rate increases. Even though there are many research have been conducted on the traffic accident & safety issues in Ethiopia, there was no any research so far studied on the relationship between the traffic accident and the traffic congestion in the context of Ethiopia or Addis Ababa.

1.3.8. Cost of traffic congestion

Many transport engineers and economists have been interested in costing traffic congestion for long period and different studies have been done to estimate the cost of traffic congestion. As all planning and congestion mitigation measures decisions require a quantified cost benefit analysis, costing traffic congestion is a critical task in traffic congestion management process. Traffic congestion costs nations for their transportation activities, negatively impact their national economy, impair the quality of life by costing traveler's time and money, degrading the environment and causing accident (HDR, 2008). According to HDR (2008) report the principal economic and social costs of traffic congestion are:

- The costs of reduced economic output and accompanying job losses
- The costs of travel delay or lost time
- Vehicle operating costs (fuel, ideal time)
- Environmental costs and higher frequency of accident risks

Estimating the social and environmental cost is much difficult and different from area to area; but, some literatures try to estimate person hourly cost as a function of considering all trips to work place.

However, the Urban Mobility Report 2010 of TTI, determined the cost of congestion in United States of America as a function of delay time and wasted fuel cost of 2009. Accordingly, the result shows that: (Schrank, Lomax, and Turner, 2010)

- *The congestion cost for extra time and fuel for 439 urban areas were 24 Billion, 58 Billion and 115 Billion for the years 1982, 2000 and 2009 respectively.*
- *3.9 Billion gallon of fuels wasted*
- *4.8 Billion person-hours of extra time wasted*

Similarly, the congestion cost estimated for Toronto and for major Australia's cities estimated to be 3.3 Billion and 9.39 Billion per year respectively (HDR. 2008). The above results show how the traffic congestion costs individual travelers and a nation in general. However, to the knowledge of the researcher of this thesis there is no single attempt so far in Ethiopia to evaluate the cost of traffic congestion in major cities and hence the problem of traffic congestion is felt but it is unknown.

2. OBJECTIVE OF STUDY

2.1 Research goal

As it is stated above, the growing problem of traffic congestion in Addis Ababa has been perceived by all the public, the policy makers and the operators in the city. In addition, the increasing population number, growing national economy and the accompanying travel demand growth are expected to aggravate the traffic congestion and worsen the problem. However, the Addis Ababa city Administration had been implementing an extensive road expansion projects for the last two decades and currently has planned to implement an advanced traffic management system in order to solve the growing chronic traffic congestion problem in the city.

Such huge investments and developments decisions; however, should be backed up with focused researches and research results. Furthermore, even though the problem of the traffic congestion was perceived by all the public and the academicians, the problem was not yet quantified and known. For instance, the travel time delay a traveler will spend at peak period, the total person-hours or vehicle hours delayed and wasted, the cost of fuel wasted due to congestion and the total cost of the congestion the city is incurring e.t.c are not yet known. Therefore, the objective of this study was to try to answer the basic research problems raised and pave a way in quantifying the traffic congestion of Addis Ababa by taking a portion of the city. In doing so the researcher believes that indicative results and an in sighting outputs would be generated which will help decision makers to make an informed decision and initiate further researches.

Furthermore, all previous researches on traffic accident in Addis Ababa is usually tied only with road and vehicle or traffic factors. However, researches in the literature review showed the effect of traffic congestion on accident. Hence, the researcher believed that the relationship of traffic congestion and accident in Addis Ababa should be assessed.

2.2 Research specific objectives

The specific objectives were to:

- identify the peak hours and peak periods of traffic flow within the time of the day
- measure the level of service (LOS) of the intersections along the study corridor using standard procedure
- measure the performance of the intersections during the time period of a day using travel time approach
- determine the level of congestion intensity, extent and reliability based on the parameters identified in literature
- estimate the economic cost of congestion at intersection by considering the vehicle and fuel cost only
- compare and prioritize road sections and intersections based on their traffic congestion level to identify where the traffic congestion is worse.

- asses the relationship of traffic congestion and traffic accident in Addis Ababa

2.3 Scope and limitation

As the topic of congestion assessment touches lots of areas and wide, it is necessary to define the scope of the study so that the untreated topics could be left for other researchers. Accordingly, the scope of this study was limited to the east –west corridor or major road of Addis Ababa and other road sections and intersections were not included in this study. Furthermore, the analysis was segment study rather than area wide or regional study. Hence, it focused mainly on the road segments at the entry of selected intersections and the relative effect of consecutive intersection was not discussed. Since, the main objective of the study is assessment and quantifying the congestion level, the congestion management procedures and measures were not discussed as it is a wide and need its own investigation.

3. METHODOLOGY

The methodology employed for a research work was the critical aspect for ensuring the proper result which aligns with the objective or the research question rose. Hence, this part of the thesis discusses the methodology followed and the reason for the selection of the methods in order to address the research problem stated earlier in chapter 1.2.

3.1. Research approach

The research approach in this thesis involves both quantitative and qualitative approaches. Quantitative data and analysis were used to determine the level of service of intersections and to measure the congestion levels quantitatively. Observation, direct field measurements and secondary data were the main sources of quantitative data. Furthermore, qualitative data from questionnaire were also used to determine whether the congestion in Addis Ababa is considerable or not and to assess other related parameters.

Observations, collecting relevant data and subsequent analysis of the data help to generate inductive conclusions on the level of congestion at the observed or considered Intersections and road sections. Though it is impossible to assess the traffic congestion at all intersections and road sections in the city, representative samples could be taken at different location of the city to derive a generalized conclusion. However, in this research the intersections and road sections considered were only at the East-West corridor of the city; which is connecting the highly populated residential ends and passes through the central business district of the city.

In this thesis the methods followed were designed in such a way that the key questions of the research be answered properly. As it shown in Figure: 3 below, in order to assess whether the intersections or the road sections are congested or not; a key question "*Does traffic congestion exists at this location*?" was raised and answered first using congestion indicator parameters. The congestion indicator parameters used in this research were Level of Service (LOS) and road users' perception. The LOS criterion was according to HCM-2000 and determined using the widely used ***aaSIDRA*** software and the road users' perception was collected using questionnaire.

For the road intersections and road sections identified as "Congested" further analysis for the level of the congestion was done using travel time approach. In doing so, the performance measure parameters were used to measure the intensity, extent and duration of the congestion. As travel time approach is easy to understand and interpret by every people and it is easy to convert to other index parameters, the performance measurement parameters used in this research were based on travel time approach.

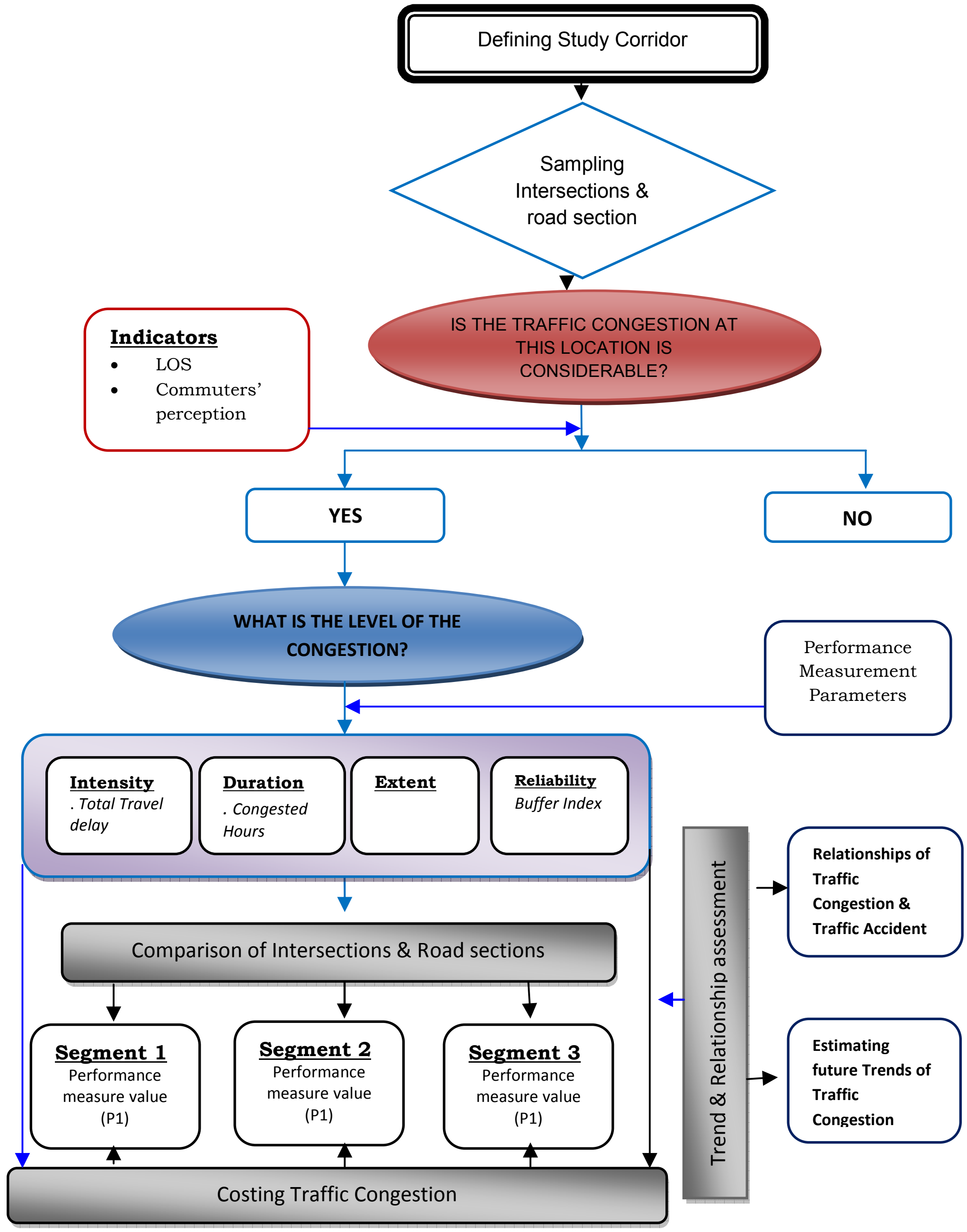


Figure 3: Framework for research approach

3.2. Data collection techniques and equipments

Different types of data were collected for the purpose of this research mainly through primary sources and some data were acquired through secondary sources. For the primary data collection internationally reputable and recommended techniques of traffic data collection were used. The primary traffic flow and travel time data collection technique used were

1. Video recording with manual transcription
2. Manual traffic volume count

In addition to the above traffic flow and travel time data collection techniques other field measurements were done to gather data on the geometrical features of intersection for capacity analysis. These include, number of lanes, lane width, configurations of lanes, grade, width of median, movement policy e.tc. These measures were done for the intersections whose level of service is going to be determined.

The other kind of primary data collection technique used was questionnaire. A structured questioner was developed to gather additional information on the perception of road users' about the Addis Ababa city traffic congestion. The questionnaire also helped to identify congested road sections and intersections in the city and the possible causes of traffic congestion. The questioners were distributed randomly for road users (taxi drivers, private car owners, public transport users) mainly along the east-west corridor.

3.2.1. Video with manual transcription

Video recording and manual transcription or tracing were used to collect travel time data. This method of travel data collection relies on video cameras to collect or capture the traffic flow in the field and human personnel to transcribe or trace vehicles into a database at the office after the actual time of data collection. According to travel time collection handbook; though it is costly, Video capturing techniques is preferred over the manual collection (pen and paper method) because:

- it provides a permanent, easily-review record and show the traffic conditions at any time;
- it permits the reading of required parameters in a controlled environment in which plate characters can be closely examined;
- it provides additional information about traffic flow characteristics such as traffic volume and vehicle headway; and
- It can provide a time stamp for accurate determination of arrival times.
- have better accuracy than manual methods; and
- Able to capture a larger sample of the total number of vehicles.

Therefore, in order to exploit the above advantage and due to its convenience video cameras with tripod were arranged at convenient height where maximum possible view could be captured and visibility was maximized. The locations for video capturing were the roof & floors of high-rising buildings alongside the study sections. Figure 4 below shows the camera setup at one of the locations and Figure 5 shows the four locations of video capturing.

3.2.2. Manual traffic volume and vehicle occupancy count

Manual traffic counts were conducted at different locations (Road mid blocks and Intersections) to determine the directional traffic volume and flow at every 15 min. furthermore, vehicle occupancy study were conducted using manual count method at different road mid-blocks and intersections. However, these counts were not directly done by the researcher. The traffic counts were done by the Addis Ababa City Transport Authority and the raw data was availed to the researcher. The data was manipulated and transformed to the required size for the analysis.

Therefore, from this data collection the following quantitative data were generated. These include,

1. Directional Traffic Volume/flow per 15 min of interval for four Road mid-blocks and six intersections.
2. Vehicle composition
3. Vehicle occupancy

In addition to the primary data acquired in the above methods, some secondary data; mainly on Traffic accident, vehicle population, population and economic growth parameters were taken from other literatures and reports. The sources of these secondary data are properly acknowledged at their respective locations.

3.2.3. Video capturing equipments and setup

Figure 4: Typical Arrangement of Video camera during recording @ Haile G/Silase building

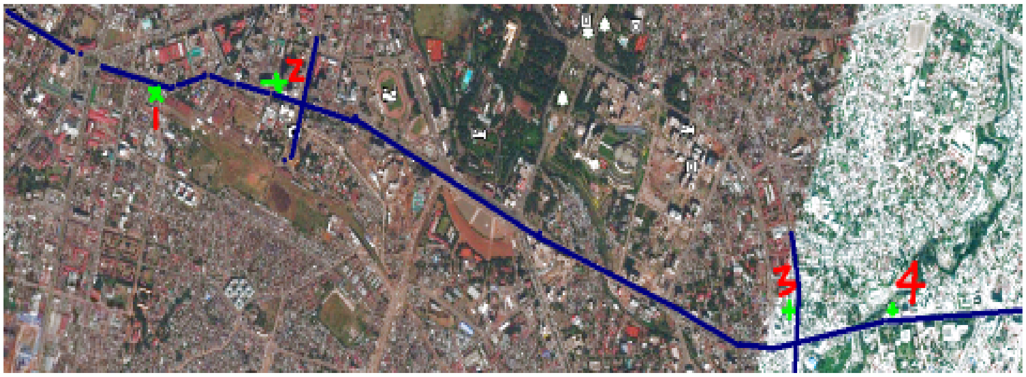


Figure 5: Locations for video capturing

Table 5: Video capturing schedule & locations

Date	Time		Target Section	Station for Vedio Camera
Thursday August 4/2011	Morning	8:30 AM - 12:00 AM	Mexico - Lideta Mid Block	At the 13th floor (about 40m height) of a new building in front of "Buna na' Shai Building" (*Location 1 at the above areal picture)*
	Afternoon	12:00 AM - 6:30 PM		
Friday August 5/2011	Morning	8:30 AM - 12:00 AM	Mexico - Lideta Mid Block	>>
	Afternoon	12:00 AM - 6:30 PM		
Monday August 8/2011	Morning		Legehar - Mexico mid block	At the 6th floor of a new building besides Anti-corruption building (*Location 2 at the above aerial photo)*
	Afternoon	12:00 AM - 6:30 PM		
Tuesday August 9/2011	Morning	9:30 AM - 12:00 AM	Hayahulet- Urael Mid block/Leg of Urael Junction	At the 7th floor of Haile G/Silase Building (*Location 4 at the above aerial photo*)
	Afternoon	12:00 AM - 6:00 PM		
Wednesday August 10/2011	Morning	9:00 AM - 12:00 AM	Urael – Atlas Midblock @ Urael Junction	At 6th floor of a new building (*Location 3 at the above aerial photo*)
	Afternoon	12:00 AM - 5:00 PM		

3.3. Description of study area

The study area selected for this research is Addis Ababa city which is the capital city of Ethiopia. Addis Ababa is not only the capital city of Ethiopia but it is also the seat of African Union head quarter and more than 100 embassies. Due to the fact that Addis Ababa is the political and economic center of the nation, it is the highly populated town in the country.

Most of the economic and social developments in the country manifested at this capital city and hence all the benefits and aftermath of such economic and population growth affect Addis Ababa. One of the undesirable effects of such growth in the city is traffic congestion. In order to study traffic congestion in Ethiopia, there is no a best place like Addis Ababa due to many factors. Hence, this research focuses on the Addis Ababa city and this section of the research describes briefly the study area and the selected corridors. It also discusses descriptive parameters and trends which affect the traffic congestion.

As shown in Figure 6 below Addis Ababa is one of the metropolitans in Africa which is found at the horn of the continent with geographical coordinates ***9°1'48'' North and 38°44'24'' East*** and an average elevation of 2355 above sea level. The city has a total area of about 530.14 Km^2 and a population of 2,738, 248 according to 2007 censes. The city is divided in to 10 administrative sub-cities and 99 kebeles.

3.3.1.1. Study corridor: East –West corridor

The final report of urban transport study for Addis Ababa city defines four major corridors in the road net work of the city. These are; the East-west Axis or corridor, the North-South Axis or corridor, the ring road and the CBD orbit. As summarized in the table below each corridor has its own characteristics. However, only the east west corridor will be considered in this research. This is mainly due to the availability of data and the cost of collecting more data in other corners of the city.

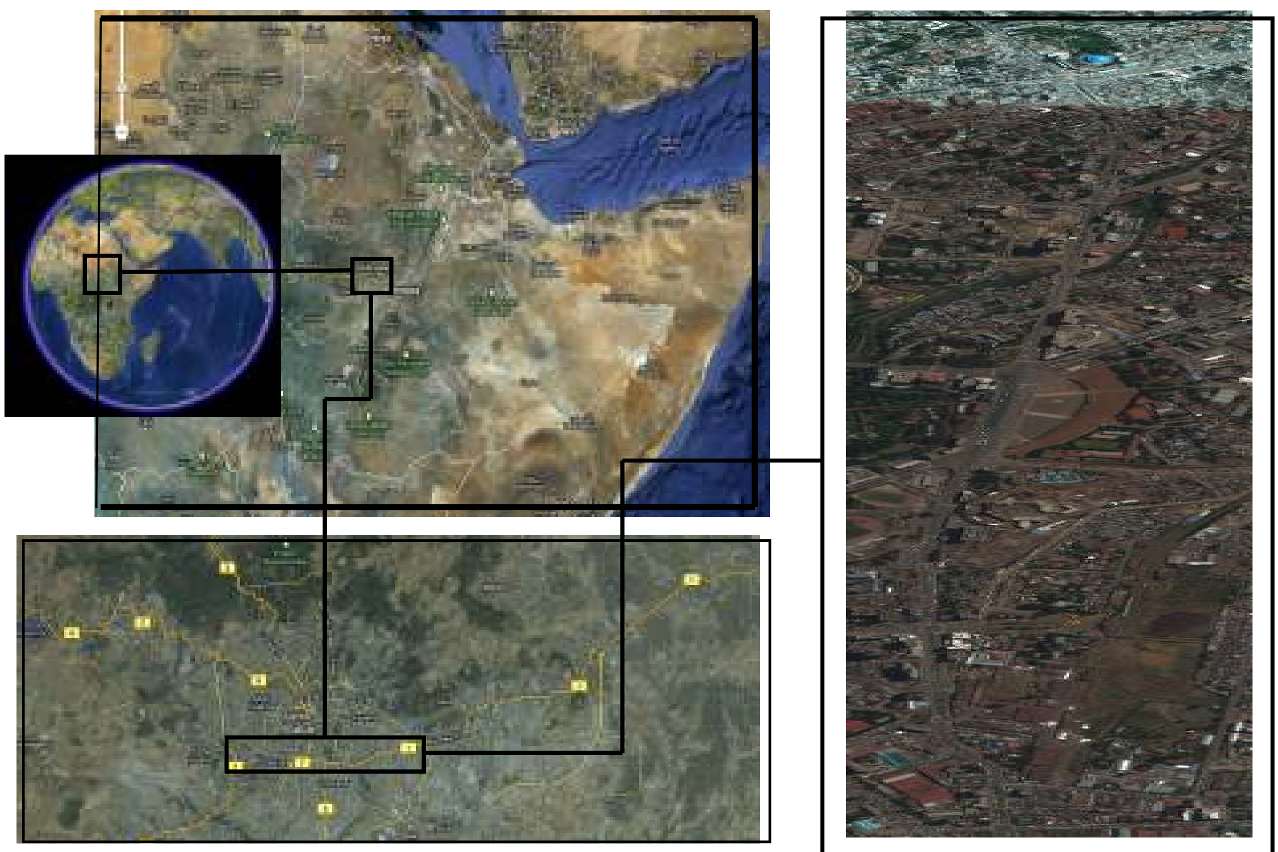


Figure 6: Study Area Location (Source: Google earth, Airodata International Survey et.al 2010; Picture take on 23/08/11)

The east –west corridor of Addis Ababa as shown in Figure 7 below is defined to start its eastern end from the intersection with the ring road at Megenagna and its west end at the Torhailoch intersection with the ring road. This corridor stretches for 9km and encompasses the *Haile G/silase street- Jemo Keniyata street- Ras Mekonen Street- Chad-streets*. This corridor passes through the city's core area of "Meskel Square" and the Mexico area which is a tangent and center for movement toward the Central Body District (Mercato & Piaza). In addition, different trip attraction spots and governmental and nongovernmental institutions are found along this route. This East-West corridor also links the two highly populated residential areas at the west (Ayer Tena) and at the east (Ayat & CMC). Due to the above facts this route is found to be the highly trafficked and congested route during peak hour.

Figure 7: East-West Corridor of Addis Ababa City (source: urban transport study for Addis Ababa city final report, 2006)

3.3.1.2. Study junctions and road sections /midblock/

The East-West corridor of Addis Ababa which is the study corridor for this research as stated above contains more than 14 junctions and mid blocks. Some of the main junctions along this corridor are listed in Table 6 below.

Table 6: Major Intersections along East-West corridor

No.	Junction Name	Type of Junction	Remark
1	“Torhailoch” Junction	3-leged Roundabout	
2	CoCa-Cola Junction	T-Junction	
3	Federal Court Junction	Four Leg Junction	
4	Mexico Junction	6-Leg Roundabout	
5	Commerce Junction	T-Junction	
6	“Legehar” Junction	Four-Leg Junction	
7	Stadium Junction	T-Junction	
8	“Meskel” Square Junction	A six leg weaving Junction	
9	“Bambis” Junction	4-Leg Junction	
10	“Urael” Junction	4-Leg Junction	
11	“Wuhalimat” Junction	T-Junction	

12	"Hai-Hulet" Junction	4-Leg Junction	
13	"Lem-Hotel" Junction	4-Leg Junction	
14	"Megenagna" Junction	4 –leg Roundabout	

Accordingly, there are about more than 13 mid-blocks can be considered between the intersections listed above. However, as traffic flow data which is collected from the Addis Ababa City Transport Authority is only for some of the mid blocks and Junctions, the selection of study Junctions and mid-block somehow guided to some extent by the availability of traffic flow data and Vehicle occupancy data.

Hence, out of the above junctions and Mid-blocks within the study corridor, the following were selected and appropriate data collected for travel time and delay using video camera. The summary of study locations and the type of analysis done is shown in Table7 below.

Table 7: Study Location and type of Analysis

No.	Type of Analysis	Road section studied	Remark
1	Direction Traffic Flow analysis &flow pattern study	Lideta- Mexico Midblock	Midblock or Road segments
		Mexico-Legehar Mid Block	
		Torhailoch – Lideta Mid Block	
		Whalimat – Hai Hulet Mid Block	
2	Level of Service determination using aaSIDRA program	"Legehar "Junction	Junction
		"Urael" Junction	
		"Hai-Hulet" Junction	
3	Travel Time & Congestion Analysis	Mexico –Lideta approach leg of Mexico Roundabout	Junction Legs
		Mexico –Legehar approach leg of Legehar Junction	
		Mexico –Legehar exit leg of Legehar Junction	
		Wuhalimat – Urael entry leg of Urael Junction	
		Kasanchis – Urael entry leg of Urael Junction	
		Atlas Hotel – Urael entry leg of Urael Junction	

3.3.1.3. Population dynamics

According to the 2007 and previous census report the population of Addis Ababa is increasing at an alarming rate. The annual growth rate for 2007 was 2.1% and according to estimates the population number will be about 5 Million by 2020. Migration from rural area contributes more than half the population growth rate. For instance, in the 1994 censes, out of the 3.8% annual population growth about 1.98% of the population growth was due to migration from rural areas (CES in association with SABA Engineering, 2005).

Figure 8 below shows the population growth trend and population numbers during the last three national censes periods.

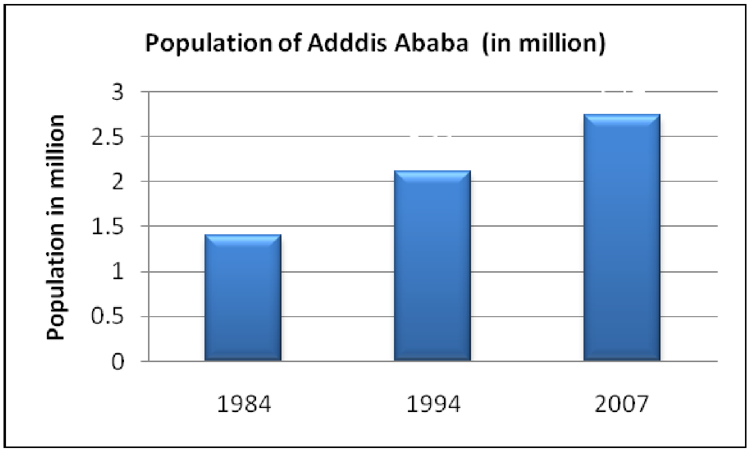


Figure 8: Population of Addis Ababa in millions (Source: FDRE Census result 2007and *Urban Transport Studies 2005*)

3.3.1.4. Economic activity

According to the International Monetary Fund (IMF)-World Economic outlook report October 2010 data, the real GDP growth of the country is summarized in Figure 9 below. The data shows that the country recorded a double digit economic growth after 2003 and keeps the pace despite the current global economic recession.

As most of the economic activities in the country centers the capital city Addis Ababa, such economic growth of the country obviously reflected in the cities economic activities. Therefore, we can conclude that the economic activity in Addis Ababa is increasing with equal or higher rate than the national economic growth rate.

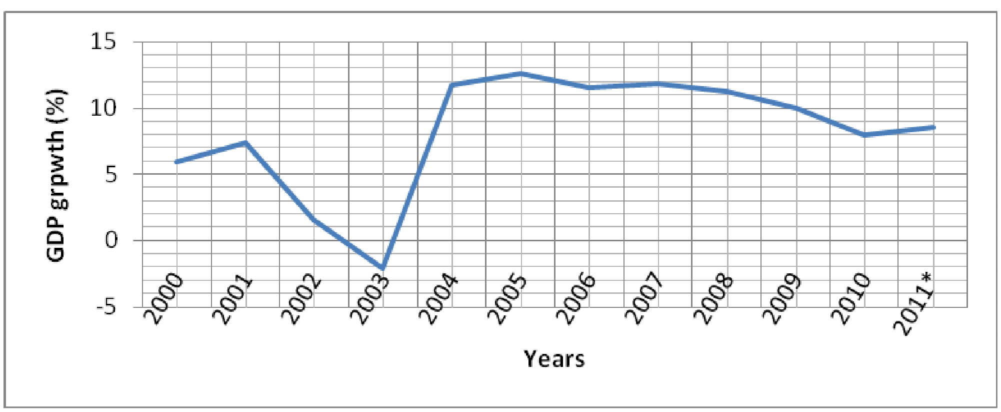


Figure 9: Real GDP Growth of Ethiopia (source: Global Finance Magazine web site, accessed on 28/8/2012)

3.3.1.5. Traffic and transport operations in Addis Ababa

Understanding the characteristics of the traffic and transportation system in the city helps to correlate and interpret the basic parameters and congestion exacerbating factors. Hence, essential data and resources regarding the vehicle ownership, the growth in vehicles number and the trend in traffic demand for Addis Ababa city are discussed below.

3.3.1.6 Vehicle ownership and growth trend

The vehicle ownership per capita of Ethiopia is the lowest in the world, even below from the sub-Saharan countries only better than Afghanistan & Malawi. A vehicle ownership per capital data of about 145 countries for the year 2010 is given on Wikipedia and the data is summarized below to help comparison of the Ethiopia's vehicle ownership with other developed and sub-Saharan countries.

Table 8: Vehicle ownership per capita for some countries in the world

Country	Vehicle per 1000 peoples	Country	Vehicle per 1000 peoples	Country	Vehicle per 1000 peoples
Puerto Rico	858	Libya	234	Cameron	8
USA	779	Algeria	154	Sudan	3
Italy	571	South Africa	123	Somalia	3
Germany	558	Egypt	30	Uganda	2
UK	458	Djibouti	28	**Ethiopia**	**1**
S. Korea	338	Senegal	18	Afghanistan & Malawi	<1

However, despite the fact that the per capital vehicle ownership in the country is so small, data and reports from Transport Authority showed that there were 105,850, 132,938 and 143,366 registered vehicles in 1998, 2002 and 2005 respectively. Out of the total vehicles about 44% are private vehicles and the average vehicle number growth rate is above 5% (RTA website accessed 1/9/2003; CES in association with SABA Engineering, 2005).

One of the interesting information stated on Urban Transport study final report is that about 80% of the total vehicles in the country are believed to be in Addis Ababa only. According to the estimate on the above document the projected vehicle number will be 231,556. Which means about 90,000 vehicles will join the road net work from 2005-2020. However, the absence of adequate public transport and the practices of vehicle assembling activity in the country escalate the vehicle ownership; hence' the estimate could be undermined and the value could reach to the said figure within few years only.

3.3.1.6 Travel demand trend and forecast

According to the result of Urban Transport Study (2005), the 2004 average daily person-trip in Addis Ababa was about 3.63 Million trips per day and out of which 60.5 % is walking and 31.5% of the trip was public transport leaving the private vehicle trip only 8%. However, the projection for year 2020 showed that the travel demand will increase by more than 100% and estimated to be 7.7 Million trips per day.

Table 9: Travel demand for year 2004 and for projected year (2020) (Source: Urban Transport Studies 2005)

Mode	Share of Person Trip per day			
	Base Year 2004		Horizon Year 2020	
	Trip (Million)	%	Trip (Million)	%
Walk	2.03	60.5	3.5	45.45
Public Transport	1.06	31.5	3.5	45.45
Private Vehicles	0.27	8.0	0.7	9.10

Furthermore, as shown in the following Figure 10 the travel demand along the East-West corridor is significantly high showing the fact that this corridor links the two east and west end populated residential areas with the trip attracting institution along the corridor.

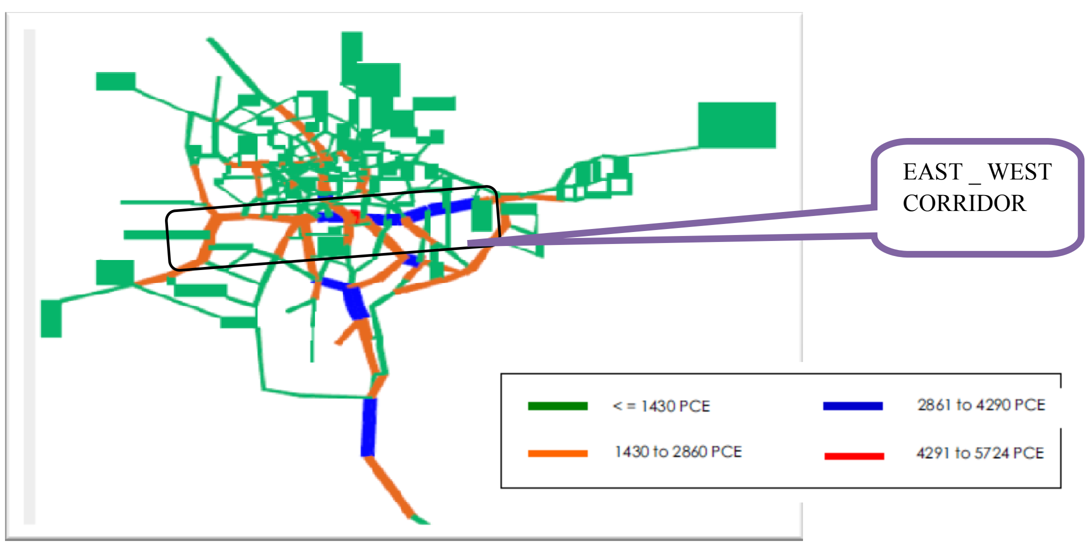


Figure 10: Traffic flow in Passenger car unit – (source: Urban Transport study 2005)

In summary, facts and data showed that the transport demand in Addis Ababa is by far higher than the supply and hence, the number of vehicle joining the cities road will increase with considerable rate. Furthermore, some of the parameters discussed above which are related to the traffic congestion shows an increasing trend. The parameters which affect the traffic congestion level discussed above are summarized in the following Table 10.

Table 10: Summary of Trends in Addis Ababa

Parameter	**Trend**
Population	Increase by average annual rate of 2.1%
GDP	Average yearly GDP of 8.5%
Vehicle Number	Increase 5% yearly
Travel Demand	Will increase by 106% in 2020

3.4. Data collection

To attain the objectives of this research, different types of quantitative and Qualitative data namely; traffic flow or volume data, vehicle occupancy data, travel time data and travel accident data and road users' congestion perception data and causes of traffic congestion were required. Despite the challenges, an attempt was made to collect the data using the techniques stated in the methodology and described below at each section. As there is no a trend in the country for a permanent data acquisition and computerized system in any of the field operating system, acquiring data is highly challenging and costly. Hence, it was difficult to gather primary data at all stations or congestion spots in the city. Rather possible representative road sections and Intersections as shown in Table 11 were considered along the study corridor.

This section of the study discusses how data was sampled, collected and extracted from the data source and also presents the gathered primary and secondary data by systematically organizing and summarizing using standard formats.

3.4.1. Travel time data

Travel time data was the most important data for the congestion analysis. In order to collect the travel time data at the selected locations, the procedures described on travel time data collection handbook (1998) were followed. Accordingly, video with manual transcription was taken and data collected using this technique. This method was chosen because;

- The video data provides a permanent, easy -review record of traffic condition
- Helps to capture as much as data required or helps to capture large sample size data
- Different types of data other than travel time can be extracted if required
- Provide a better accuracy than manual count
- Requires lesser number of peoples but many expensive equipments

Before the actual video capturing started training was given for data collectors and owners of the buildings where we plan to set up the video were requested for permission. Then a trial run was made to identify best locations and possible problems to be happened and get ready for that. A video camera and two Photo-video cameras with adjustable tripod, a laptop and hard disk, power cables and hand books were prepared for the purpose.

Once all preparations are completed capturing video was started at the location and heights as described in the Table 5. Accordingly, a full day traffic flow video data was acquired for further manual transcription at office or on a computer.

3.5.1.1 Sampling

Once the video recorded data was acquired, extracting travel time taken by an individual vehicle to travel a specified length of a road section was determined by tracing every individual vehicle. Since many vehicles negotiate the entry point at a time, vehicles were selected randomly but statistically significant sample size was determined for each 15-30 min of count. The sample size was determined according to the procedure and equation on the handbook.

According to travel time data collection Handbook the sample size for manually transcript travel time data is given by the equation;

Sample size for travel time study (n) = $\left[\frac{t \times C.V}{e}\right]^2$

Where: t= t-statistics from student t-distribution for specified confidence interval
C.V = coefficient of variance
e = relative error

However, the handbook using the above statistical equation provides a sample sizes for different traffic conditions and level of confidence. Accordingly, for congested traffic condition at 90% confidence interval and ± 10% error, the minimum sample size was calculated to be 18 for 15-30 min count. Therefore, for 15 min interval about 10 -15 vehicles travel time were recorded in the case of this research.

3.5.1.2 Travel time data

Table 11 below shows the locations where travel time data were collected with the duration of data recording. Though the travel time data collection handbook recommends a segment length of 400m, it was impossible to clearly see and trace vehicles above the segment length used in the table. Hence, the travel time data were collected for the road segment length shown in the table.

Table 11Travel Time Data collection locations & segment length

No.	Location	Segment length (m)	Time of data collection
1	Mexico –Lideta approach leg of Mexico Roundabout	350	2:30 AM – 5:00 PM
2	Mexico –Legehar approach leg of Legehar Junction	100	2:15 PM – 6:00 PM
3	Mexico –Legehar exit leg of Legehar Junction	100	2:15 PM – 6:00 PM
4	Wuhalimat – Urael entry leg of Urael Junction	150	3:15 AM – 6:00 PM
5	Kasanchis – Urael entry leg of Urael Junction	60	3:30 AM – 5: 00 PM
6	Atlas Hotel – Urael entry leg of Urael Junction	250	3:30 AM – 5: 00 PM

Figure 11: Mexico – Roundabout

Figure 12: Urael Intersection

Figure 13: Legehar Intersection

3.5.1.3 Data reduction and quality control

According to the sample size determined above, travel times were determined for each segment within 15 min interval and recorded in an Excel database. However, the data were bulk and it is necessary to reduce and produce manageable travel time data. The travel time data collection handbook recommends the reduction in two ways:

1. Reduce the number of data records by eliminating invalid data; or
2. Producing a summary data and statistics at different aggregation levels

Accordingly, the data were averaged or mean value was take for the 15 min interval data and central tendency statistical tests were done using the standard deviation and coefficient of variance. In reducing the data outlier values were eliminated. The raw data for the travel time of each section is summarized in tabular form and attached in the Appendix A.

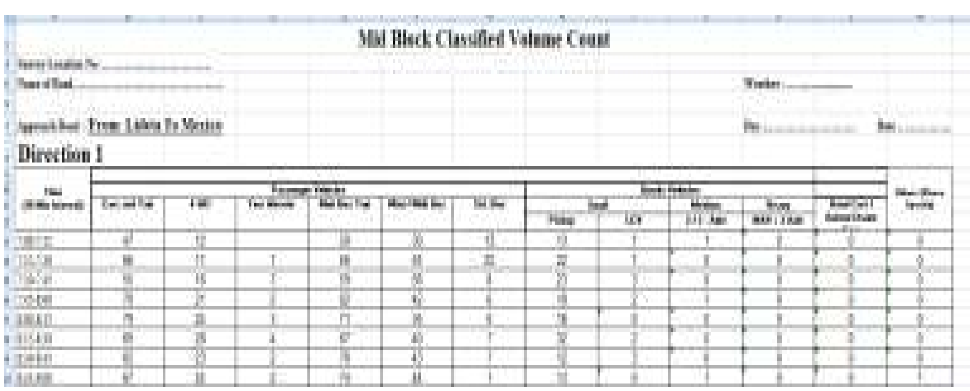
3.5.2 Traffic volume and vehicle occupancy data

3.5.2.1 Traffic volume data

Traffic volume and vehicle occupancy data are very important to determine and understand the flow pattern in the facility, to determine the peak flow rates and peak periods, to assess the relationship between traffic volume and congestion. Furthermore, it is extremely required to analyze the level of service of a facility and quantify the congestion intensity. Hence, acquiring a traffic volume data at selected road sections and intersections in the study corridor were mandatory and luckily enough, the raw data was available at the Addis Ababa City Transport Authority which was collected for their own purpose.

The traffic volume count was made for 12 solid hours starting the morning 7:00 AM to the evening 7:00 PM at 15 minutes interval. The vehicles were counted in category as "Passengers car" and "Goods vehicles". The Passengers cars category includes vehicle types namely; *Cars and Taxi, 4WD, Minibus Taxi, Mid-Bus and standard Bus,* where as the Goods Vehicle category includes vehicle types namely*; Pickups, Light, Medium and Heavy commercial vehicles.*

The following Figure 14 shows the raw data format of traffic count.


Mid Block Classified Volume Count

Direction 1

Figure 14: a screen copy of portion of raw traffic volume data

The traffic count was directional and hence directional traffic flow characteristics can be easily summarized and studied. As travel time data was averaged for all vehicles type and a single travel time was considered in the 15 min time interval as discussed before, it is also necessary that the vehicle volume count should be converted to passenger's equivalent unit to conduct congestion analysis. Therefore, following the Passenger Equivalent factors were used to convert the traffic volume count in to PCU. The traffic volume in PCU is summarized and presented at appendix A.

Table 12: Passenger Car Equivalent factors (source: HCM 2000)

Vehicle Type	**Passenger Vehicles**					**Goods Vehicles**			
						Small		**Medium**	**Heavy**
	Cars and Taxi	**4-WD**	**Mini Bus Taxi**	**Mini / Midi Bus**	**Std. Bus**	**Pickup**	**LCV**	**2 / 3 – Axle**	**MAV > 3 Axle**
PCU factors	1	1	1.5	1.5	3	1	1.5	3	3

The directional traffic volume for each intersection is shown in the appendix as an input data for aaSIDRA analysis.

3.5.2.2 Vehicle occupancy data

Vehicle occupancy; which is the number of peoples per vehicles, is an extremely important parameter in traffic engineering and transportation planning. Usually it is used to convert person trip to vehicle trip in the four step travel demand forecasting process and to determine parking space requirement for public facility and spaces. However, its use is becoming increasingly important in the congestion management process to compute person-delay; person-mile e.t.c. Hence, vehicle occupancy is very important parameter for calculating congestion intensity parameters.

The raw vehicle occupancy data for this study was obtained from Addis Ababa City Transport Authority and it was processed to be used in the congestion analysis. The raw data gave the occupancy for each vehicle type over the period of the study. However, as a single average value is needed for the analysis, the weighted average vehicle occupancy is calculated as per the following equation

Weighted Average Vehicle Occupancy:

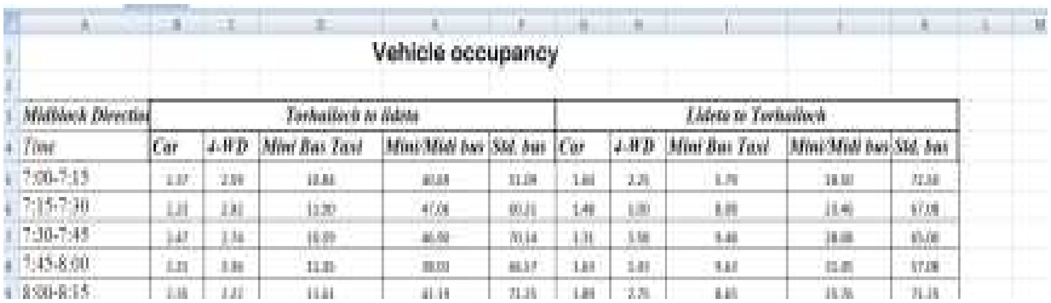
$$AVO_w = \frac{\sum_i^n Vi,t \times VOi,t}{\sum_{i,t}^n Vi,t}$$

Where: **AVO_w** = Weighted Average Vehicle occupancy

$V_{i,t}$ = Traffic volume of i^{th} vehicle category at time interval t

$VO_{i,t}$ = the Vehicle occupancy of the i^{th} Vehicle category at time interval t

The screen picture below shows the portion of the raw data used and the calculated average vehicle occupancy for each segment. The full data is attached in the appendix A.



Vehicle occupancy

Midblock Directio	Torhailoch to lideta					Lideta to Torhailoch				
Time	Car	4-WD	Mini Bus Taxi	Mini/Midi bus	Std. bus	Car	4-WD	Mini Bus Taxi	Mini/Midi bus	Std. bus
7:00-7:15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7:15-7:30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7:30-7:45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7:45-8:00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8:00-8:15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 15: screen copy of raw Vehicle occupancy data

3.5.3 Questionnaires response

A structured questioner was prepared in order to gather additional information for the congestion analysis. As congestion is a function of people's perception toward their time and their trip purpose, it was necessary to gather information and data on how the road users in Addis Ababa perceive the current traffic congestion and know how much delay is acceptable for them.

According to the definition by Lomax (1997) congestion is a travel delay in excess of the acceptable travel time. Hence, according to this definition the road user's element should be included to define the demarcation between congested and uncongested. Hence, the structured questioner was distributed randomly for road users (Taxi drivers, passengers, Traffic polices, company owners, lecturers and other peoples) mainly in the east-west corridor. Furthermore, respondents also requested to list at least 5 congestion spots they know and to prioritize the possible congestion causes identified from literature and asked if there was other possible congestion cause in the city.

The questioners were distributed through e-mail, through interview-questioner (the data collector interview the respondent while filling the questioner) and distributing for respondent. Accordingly, about 70 questioners were distributed and 43 were returned and analyzed. The researcher believes that statistically significant samples should be considered to draw conclusion out of analysis made on such questioner data. However, due to the fact that most of the basic analyses in this research are based on the quantitative data described before and the data on the questioner are a supplement for the result, the respondent size would be sufficient for the purpose of this study.

3.5.4 Traffic accident data

Traffic accident rate in Ethiopia is one of the highest in the world. Girma (2000) showed that out of the total accident in the country about 62% of the total accident occurs in the capital city Addis Ababa. Data and documents show that the traffic accident in the city is alarmingly increasing and different researches were made in this regarded. Most of these researches showed the relationship between traffic flow and traffic accident. However, none of them identify the relationship between traffic accident and traffic congestion. Hence, in this study, in order to see the relationship between traffic accident and traffic congestion, different accident data were collected from secondary data. The most important data collected from secondary sources are:

1. 10 year Accident data by time of a day
2. Accident data by Type of Accident
3. Addis Ababa City Accident Black spot map which was prepared by National Road Safety Coordination Office

4. RESULT

The analysis was made on the gathered quantitative and qualitative data to look in to the trend of the traffic flow with in the day and identify the peak period and peak hour volumes. The level of service for the identified intersections was analyzed using a program aaSIDRA and the intersections were checked if they fall as congested or not congested based on HCM 2000 criteria. Congestion analysis also made on the sections where the travel time data was collected and the results interpreted and discussed. In the congestion analysis, parameters for quantifying congestion were calculated based on travel time approach for each section. Finally, the relationship between traffic accident with Traffic volume and travel rate was seen and a regression equation was generated.

4.1 Traffic flow pattern and vehicle composition analysis at mid-block

4.1.1 Directional traffic volume

A directional traffic volume analysis was conducted on a traffic volume data which is counted at 15 min interval and for 12 solid hours of a day starting from the early morning to the late afternoon. The traffic volume analysis is done for both direction and for four mid blocks along the east –west corridor. The road sections or the mid blocks considered are

1. Torhailoch – Lideta Midblock
2. Lideta – Mexico Midblock
3. Mexico- Legehar Midblock
4. Wuhalimat – Haihulet Midblock

The traffic volume data for the above four mid-blocks was summarized for all class of vehicles and reported as hourly volume in the Table 13 below.

Table 13: Directional Hourly traffic volume for Mid-Blocks

	MEXICO – LIDETA MID BLOCK		MEXICO – LEGEHAR MID BLOCK		TORHAILOCH – LIDETA MIDBLOCK		WUHALIMAT-HAIHULET MIDBLOCK	
Time	Mexico to Lideta	Lideta to Mexico	Mexico to Legehar	Legehar to Mexico	Torhailoch to Lideta	Lideta to Torhailoch	Wuhalimat to Haihulet	Hiahulet to Wuhalimat
7:00-8:00 AM	600	857	948	834	1571	778	848	1463
8:00-9:00 AM	700	945	1019	935	1831	783	1015	1715
9:00-10:00 AM	713	777	931	1233	1262	727	1059	1576
10:00-11:00 AM	822	658	964	1237	1073	859	956	1611
11:00-12:00 AM	830	605	759	1238	973	801	1188	1621
12:00 -1:00 PM	751	622	777	1140	925	876	1173	1399
1:00-2:00 PM	596	603	822	938	902	720	1052	1658
2:00-3:00 PM	793	683	849	1090	1053	755	1068	1541
3:00-4:00 PM	666	923	942	1154	1048	834	1172	1597
4:00 -5:00 PM	776	791	943	1023	1019	970	1155	1405
5:00-6:00 PM	750	692	954	1267	1090	1049	1240	1509
6:00 -7:00 PM	848	620	733	1143	822	1262	1151	1186

The traffic volume analysis of each midblock is discussed below;

4.1.1.1 Torhailoch –Lideta midblock directional traffic volume

This section of the road starts at the Torhailoch roundabout and passes through with the busiest business center Lideta area. This road section carries traffic from the residential areas of the western section of city (Alemgena-Ayertena- Alembank-Betel e.t.c) to the commercial body district of Mexico and Lideta. Figure 16 below shows that the traffic volume for the direction Torhailoch to Lideta is peak during the morning and it decrease to the mid day and shows a slight increase and become nearly steady from 2:00 PM to 5:00 PM. The traffic volume from Lideta to Torhailoch during the morning time is by far less than the traffic volume for the Torhailoch –Lideta direction and relatively stable until the evening peak period. During the evening peak period the traffic volume increases; but, interestingly the traffic volume increase during the evening peak period in this directions is by far less than the morning peak volume in the Torhailoch-Lideta direction.

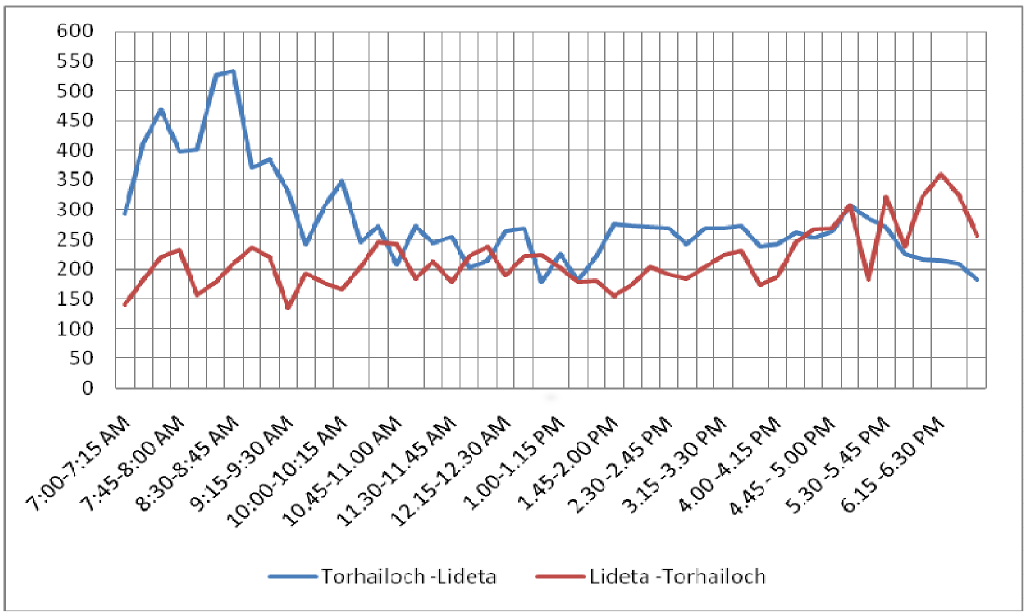


Figure 16: Traffic Volume for Torhailoch-Lideta Mid-Block

When we look in to the traffic volume by vehicle type, we can see that about 70% of the vehicles moving in both directions are private cars, taxi, mini bus taxi and mid buses which indicate that most of the trip purpose could be from home to work place and other activities. Furthermore, out of 13,561 vehicles moving from Torhailoch to Lideta, only 10,409 vehicles (only 77%) returned back from Lideta to Torhailoch direction. Which means about 23 % (3,125) vehicles didn't return back to Torhailoch direction and the vehicles could take other route.

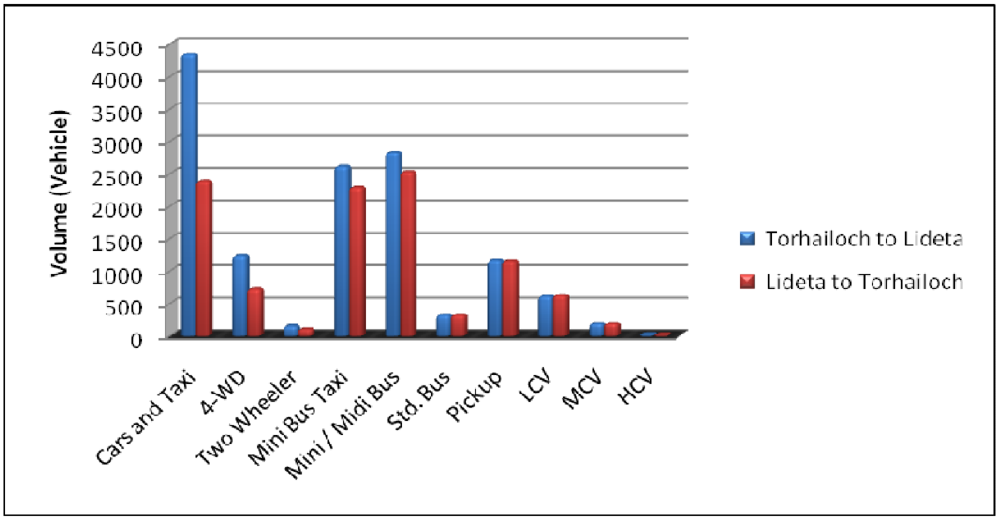


Figure 17: Traffic Volume by vehicle type

4.1.1.2 Lideta to Mexico midblock directional traffic flow

This road section is a link for the traffic from Torhailoch (residential areas) and the Mercato - Abinet area with the Mexico business district. The Lideta - Mexico direction shows the morning peak flow and an evening peak flow where the latter is less than the morning peak flow. The morning peak flow of Lideta- Mexico direction follows the same trend as that of Torhailoch – Ledeta direction in Figure 16 above which explains that the morning flow from Lideta to Mexico is mainly from Torhailoch – Lideta midblock. However, if we see the value of traffic volume in the morning peak the traffic volume in Lideta-Mexico is lower than that of Torhailoch –Lideta traffic volume. This is mainly due to the fact that the traffic from Torhailoch some vehicles diverted to Abinet –Piazza and Abinet –Bus station direction. For Mexico –Lideta direction during the morning the volume is small but starting from early the morning the traffic volume increases and reaches its peak flow at the midday. This flow is mainly the traffic flow toward the Abinet-Mercato –Bus station business district. During the evening peak period both direction shows a peak volume; however, the evening peak volume of Lideta –Torhailoch direction is less than the morning peak volume.

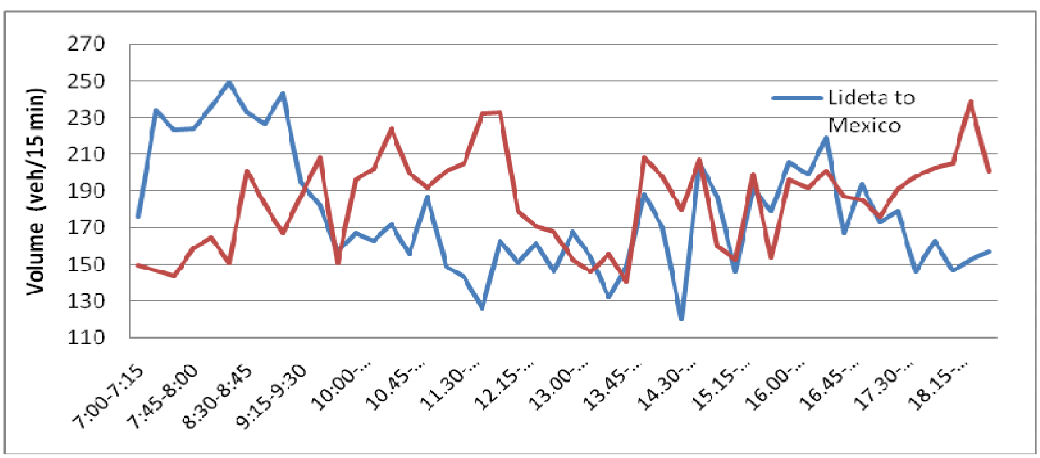


Figure 18: Traffic Volume for Lideta Mexico Mid-Block

Unlike the Torhailoch-Lideta midblock, the traffic volume analysis by volume for Lideta-Mexico midblock shows that the total number of vehicles moving in both direction almost equal even though the flow period is staggered. Furthermore, in this road section again most of the vehicle share is occupied by the three vehicle classes, privet cars, mini bus taxi and mid buses.

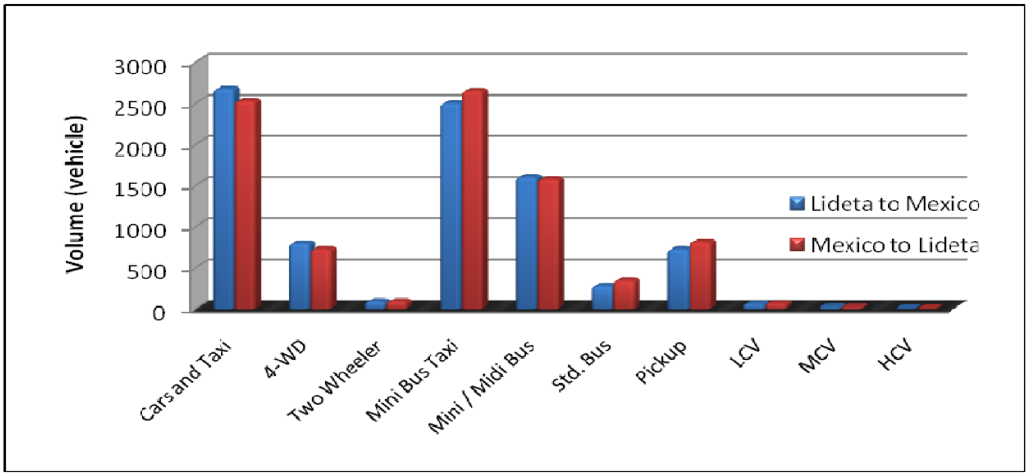


Figure 19: Traffic Volume by Vehicle Type

4.1.1.3 Mexico – Legehar midblock direction traffic volume

In this road section the traffic flow shows a morning peak at 8:00 AM and shows a decreasing trend till mid day and then a gently increase the evening peak period which spans for about two hours and it drops. For the Legehar-Mexico direction, the traffic volume shows a unique trend that the morning peak reached at about 9:00 AM by sharply increasing from its lowest point and the peak volume last for long period until mid day sharp drop. After mid day the traffic volume steadily increases to the evening peak which is the maximum flow.

Figure 20 shows that the traffic volume from Legehar direction dominates at most of the time and the highest flow is from the Legehar-Mexico direction. In general, the trend of peak flow happening at the morning and evening period and the one of the directions dominate either in the morning or evening peak or vice versa.

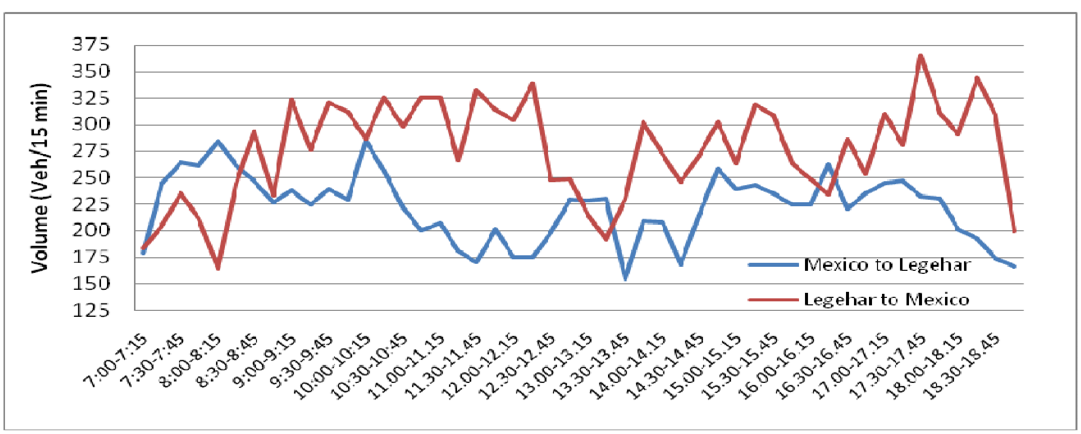


Figure 20: Traffic Volume for Mexico-Legehar Mid-Block

The traffic volume analysis by vehicle type for this road section shows that the volume for Legehar to Mexico dominates and similar to the other road sections passenger cars and minibus taxi takes the huge share in the traffic volume.

4.1.1.4 Wuhalimat – Haihulet midblock directional traffic flow

The traffic flow in this road section is totally unbalanced and the traffic volume in the Haihulet-Wuhalimat direction is higher than that of Wuhalimat to Haihulet. The trend in the traffic volume for Haihulet-Wuhalimat direction is that it has a peak flow starting from the early morning and the flow almost steady or decreases vey gently to the evening. That is in this direction peak flow is during morning period and the flow is almost steady. However, for the traffic volume in the Wuhalimat –Haihulet direction the volume is less than that of the Haihulet –Wuhalimat direction but the traffic volume in this direction is still quite higher volume compared with the other read sections discussed before. The trend in the traffic volume in this section is from steady to gently increasing toward the evening peak period.

The higher and steady flow in the Haihulet-Wuhalimat direction is also manifested in the Legehar-Mexico traffic flow above in section 4.4.1.3. This is because most of the traffic coming in the Legehar direction is from Megenagna-Haihulet-Wuhalimat and Bole side.

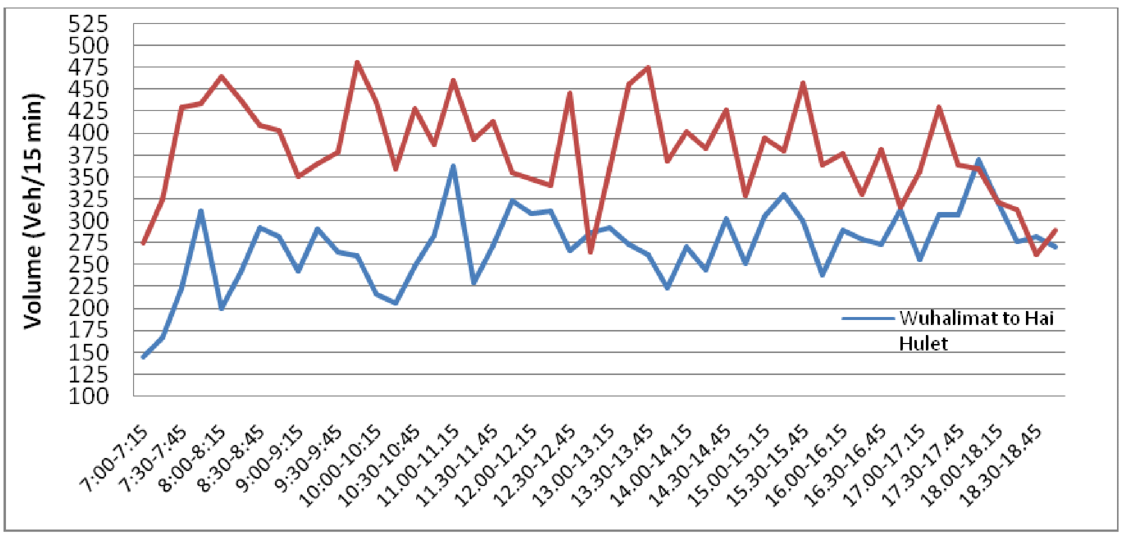


Figure 21: Traffic Volume for Wuhalimat-Haihulet

Like the other road sections, the analysis of traffic volume by vehicle type showed that the dominant vehicle types are Privet cars, 4WD and Minibus Taxi.

4.1.2 Total traffic volume

The total traffic volume during the 12 hours day time count was summed and both directional volume is shown in Figure 22 below. Accordingly, it shows the volume for Haihulet-Wuhalimat direction is the highest and the second highest traffic volume is Torhailoch –Lideta direction. This result indicates that these two roads carry the huge traffic loads from the two ends of residential areas.

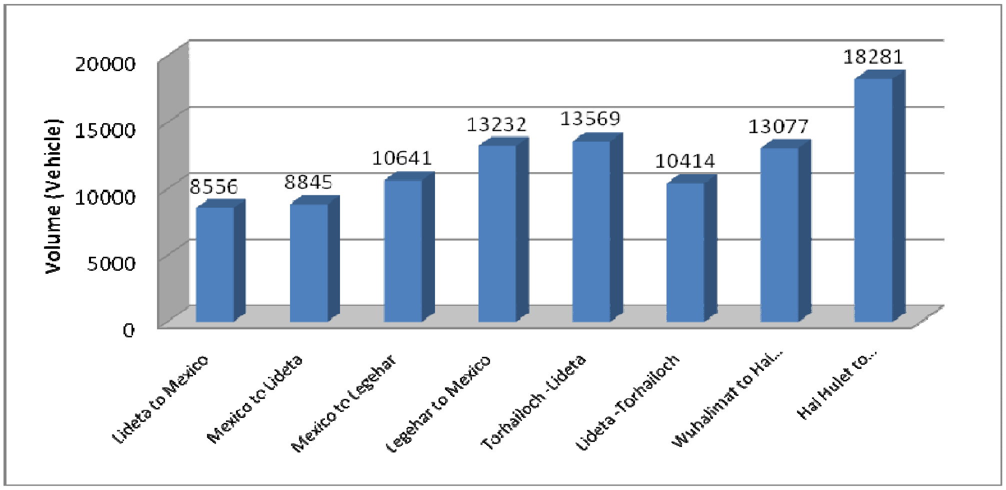


Figure 22: Total directional Vehicle volume for the day light 12-hour count

When we look in to the total traffic volume of both directions for each midblock, the trend of the traffic volume with the time of the day it shows a trend a morning and evening peak periods. The total volume of Haihulet-Wuhalimat is higher than any of the other midblock throughout the day time. The Mexico-Lideta midblock traffic volume shows the lowest value throughout the day periods. However, the traffic volume for Torhailoch-Lideta midblock during the morning peak period is nearly equal to that of Haihulet –Wuhalimat midblock but during the evening peak period the volume is less than it. Traffic volume difference between these mid-blocks creates an interesting question of how the travel rate in these sections behaves and is there a relation between the volume and congestion.

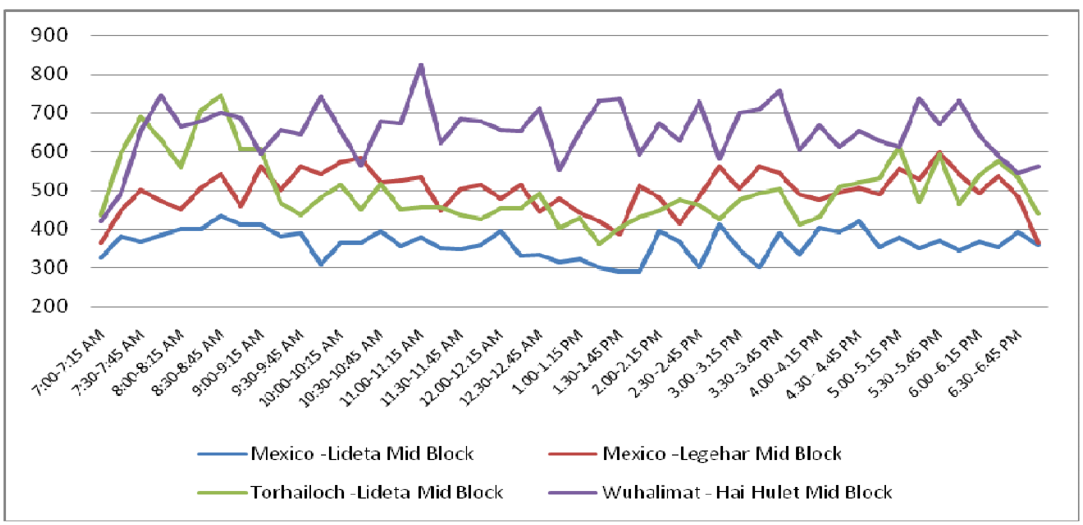


Figure 23: Total both direction traffic volume (veh) of mid-blocks

4.2 Intersections level of service (LOS) analysis

According to the methodology described above, first, it is necessary to justify that the intersections and the road sections to be analyzed are in congested state based on accepted standards and norms. Accordingly, in order to check whether the intersections are congested or not, analysis was made using aaSIDRA program. In order to analyze the LOS using the program, installation was made with the options right-hand driving rule and HCM 2000 metric version which represent the driving rule of Ethiopia. The HCM 2000 metric version was chosen because it is widely accepted Highway capacity manual throughout the world with only minor modifications and calibration. As only the level of service (LOS) will be determined for an indicative result leaving the other out puts of the program, calibration was not taken as an issue for the purpose.

Due to the availability of traffic flow data the level of service (LOS) was made only on three intersections specifically where travel time data was collected. However, for the Mexico roundabout, where travel time measurement was made for congestion analysis is not considered for the level of analysis due to the absence of directional traffic flow data. Even though, level of service analysis was not conducted by the researcher of this study at Mexico roundabout, a secondary data was consulted and the result was taken from Tewodros (2007) where the level of service analysis was conducted as part of his study in 2007.

The three intersections along the study corridor for which the LOS analyzed were:

Intersection 1: *URAEL INTERSECTION*

Intersection 2: *LEGEHAR INTERSECTION*

Intersection 3: *HAIHULET INTERSECTON*

In order to conduct the analysis the geometric and directional hourly traffic volume data were prepared as an input for the program as summarized below in the Table 14. However, recommended and default values were take for other input data; for instance critical gap, saturated flow.

Table 14: Input geometric and traffic demand data.

Int. No	Intersection	Approach Leg	Number of Entry Lanes	Number of Exit Lanes	Lane Width (m)	Width of Median (m)	Total Traffic Volume (Veh/Hr)*		
							LT	TH	RT
1	URAEL INTERSECTION	Meskel Approach	3	3	3.2	4.5	40	734	105
		Wuhalimat Approach	3	3	3.2	4.5	21	809	421
		Atlas Hotel Approach	3	3	3.2	1.5	757	551	32
		Kasanchis Approach	3	3	2.6	1.0	63	571	63
2	LEGEHAR INTERSECTION	Mexico Approach	3	3	3.2	4.8	191	1107	207
		Meskel Square Approach	4	4	3.2	NA	215	1155	266
		Railway Station approach	3	3	2.6	1.5	160	148	214
		Piazza Approach	3	3	2.6	1.2	176	115	176
3	HAIHULET INTERSECTION	Wuhalimat Approach	4	3	3.2	4.8	887		148
		Megenagna Approach	4	3	3.2	4.8	63	1456	95
		Bole Brass Approach	2	2	3.2	NA	187	177	136
		British Embassy Approach	2	2	2.6	NA	221	338	

*N: B: * this volume is total of both light and heavy vehicles, but for the program the actual separate values were used for light and heavy vehicles*

** This flow is a peak period flow*

Even though these intersections are constructed with traffic signal theoretically; practically they are intentionally made non-operational by the city Road Authority due to the fact that the timing or phase is not properly designed. Hence, during the analysis period all the intersections were considered as un-signalized - Give-way intersection type. Accordingly the analysis run and the results of the analysis are summarized below in Table 15 and the outputs of the analysis for each intersection are attached in the Appendix B.

Table 15: summary of output for level of service analysis for intersections

Int. No	Intersection	Approach Leg	Degree of Saturation (V/C)	LOS	Remark
1	URAEL INTERSECTION	Meskel Approach	2.308	F	
		Wuhalimat Approach	3.544	F	
		Atlas Hotel Approach	6.300	F	
		Kasanchis Approach	1.969	F	
2	LEGEHAR INTERSECTION	Mexico Approach	1.792	F	
		Meskel Square Approach	1.792	F	
		Railway Station approach	1.33	F	
		Pizza Approach	1.239	F	
3	HAIHULET INTERSECTION	Wuhalimat Approach	2.464	F	
		Megenagna Approach	3.706	F	
		Bole Brass Approach	1.731	F	
		British Embassy Approach	2.331	F	
4	MEXICO ROUNDABOUT*	Lideta Approach	1.468	F	This result is taken from Tewodros (2007) and hence, the result represents only the 2007 LOS and obviously the LOS of these legs by now most likely decreased.
		Legehar Approach	1.468	F	
		Wabe shebele Approach	0.910	D	
		Agazian Approach	1.116	F	
		Sarbet Approach	0.560	A	
		De Affric Approach	0.552	A	

*N:B: * the LOS of this roundabout is not analyzed by the researcher due to lack of traffic flow data. Hence, the result above is taken from a secondary source Tewodros (2007) which is the LOS of 2007.*

4.3 Congestion analysis

The travel time, traffic volume and vehicle occupancy data were used to analyze the congestion along the study corridor. The congestion analysis was based on the travel time approach and hence the following congestion measures were analyzed. These are; Average travel speed, travel rate, delay rate, delay ratio, total segment delay, buffer index and travel planning time index. Accordingly, the analysis result of each parameter is shown in the subsequent sections.

4.3.1 Travel time

Figure 24, through Figure 26 below shows the average travel time at 15-min interval for the segments selected. According to the result, the morning and evening peak periods recored the higher travel time and the lowest lowest travel time recorded during the mid day or lunch time. However, the full day travel time recorded of Lideta-Mexico leg and the Urael Intersection legs shows that the travel time during the morning peak period is higher than the evening peak period travel time.

For the Lideta-Mexico entry leg segment of Mexico roundabout, the morning peak period travel time is more than five times the lowest travel time and about two time the evening peak period travel time. The travel time data for the Legehar intersection shows that the entry leg which is Mexico-Legehar leg has the higher travel time than the adjucent exit leg of Legehar-Mexico segment.

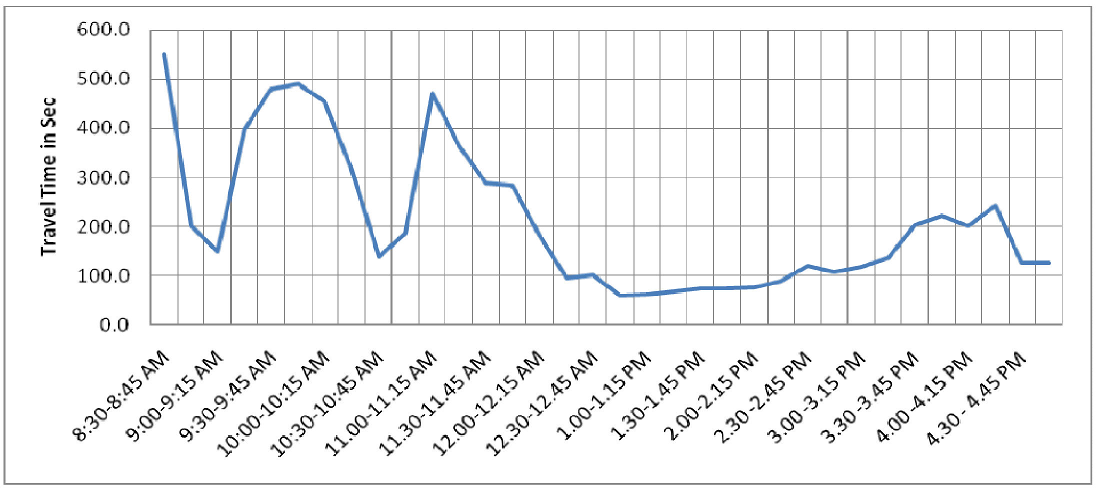


Figure 24: Average Travel Time at Lideta to Mexico entry leg of Mexico Roundabout (350m length)

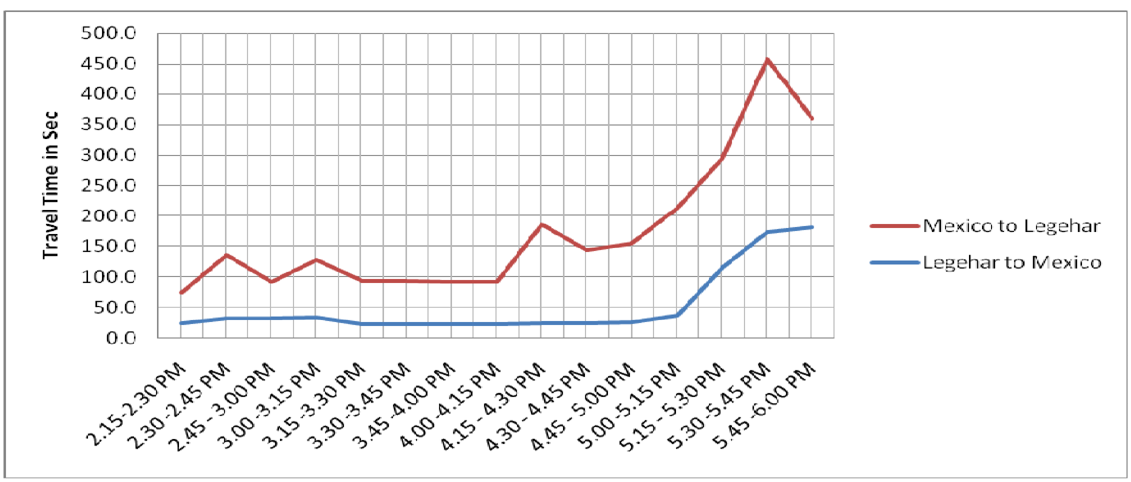


Figure 25: Average Travel Time (Sec) for Legs at Legehar Intersection (100 m length)

The result of the travel time for the three entry leg segments of Urael intersection shows that all the three segments follow the same trend and according to the Figure 26 mornig peak period travel time is about seven times the lowest travel time value at the lunch time and evening peak period travel time is about five time the lowest travel time.

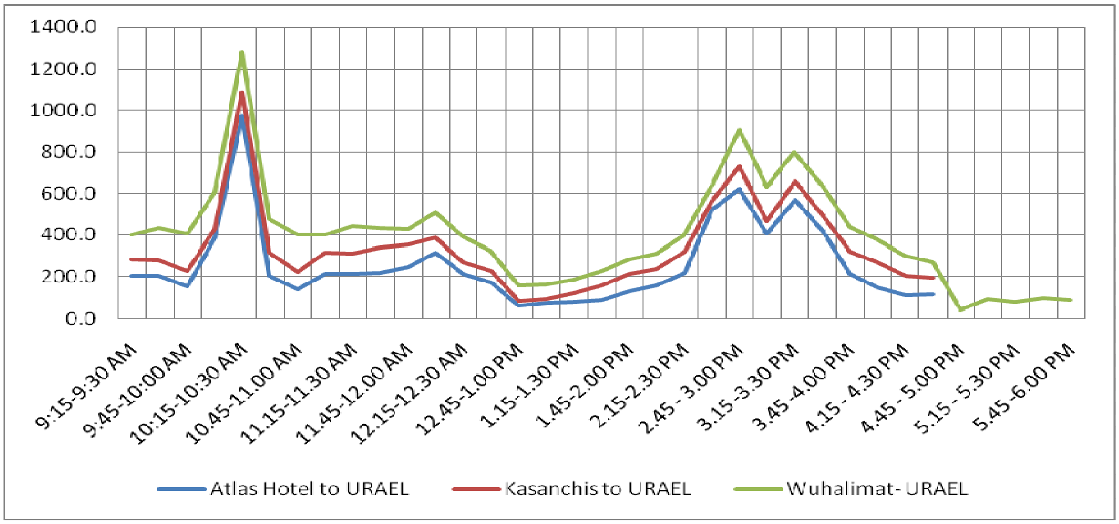


Figure 26: Average Travel time (sec) for Atlas-hotel, Wuhalimat and Kasanchis legs at Urael Intersection (250, 150 and 60m length respectively)

4.3.2 Average speed and travel rate

The average speed calculation at the congested road sections considered in this study is shown in Figure 27. The result shows that during the morning period travel speeds at the sections are almost below 5 Km/hr up to the mid day. However, during mid day the travel speed increased to the maximum value. During the mid day the Lideta –Mexico section shows the highest travel speed and for Legehar –Mexico section until 5:00 PM the travel speed is higher. This is mainly the later section is an exit lane for Legehar intersection. The Kasanchis –Urael leg shows the least travel speed at all the time than the other legs even though it shows a peak at the mid day.

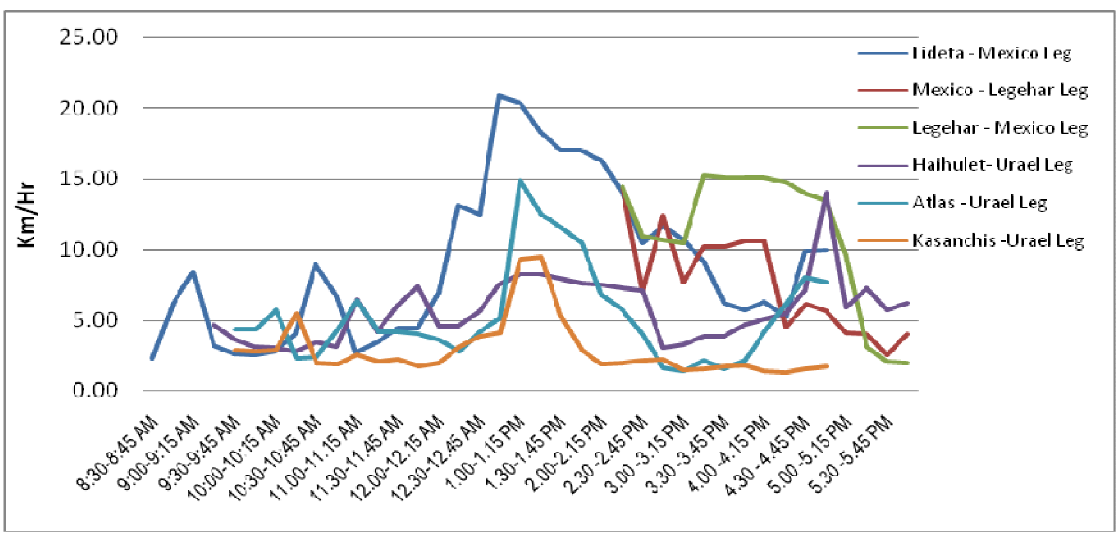


Figure 27: Average Travel Speed (Km/Hr)

The travel rate which is the inverse of travel speed and the very important parameter in congestion analysis is calculated and shown below in Figure 28. The figure shows that the travel rate during the night peak period is higher than the morning peak period except for Haihulet-Urael and Lideta Mexico leg. The travel rate for Kasanchis-Urael leg is the highest of all the other legs throughout the day.

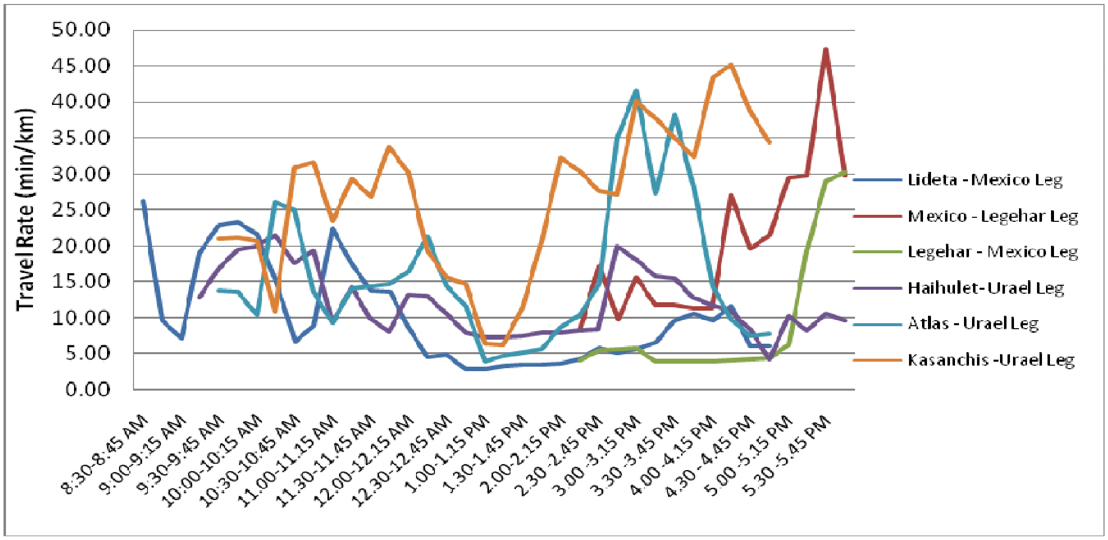


Figure 28: Average Travel Rate (Min/Km)

4.3.3 Delay rate, delay ratio and delay per traveler

The delay calculation was conducted with reference to the daily least travel rate or the travel time recorded during the highest travel speed period which is taken as acceptable or free flow. As both posted speed and free flow speed can't be applicable at these legs the definition of Lomax (1997) was used and the travel rate at the uncongested condition was taken as acceptable travel rate. Accordingly, the results of delay rate, delay ratio and delay per traveler are shown in the figures below from Figure 29 through Figure 32.

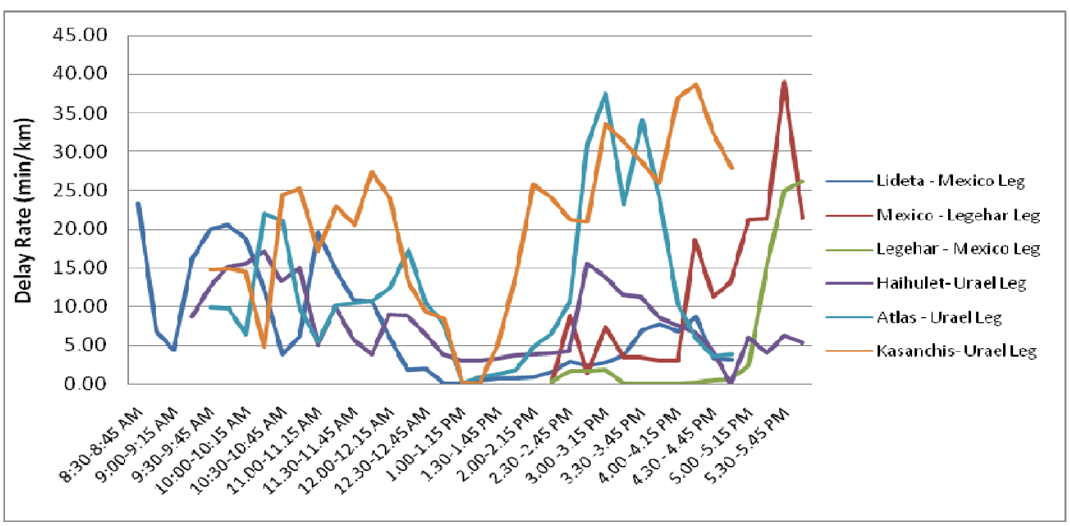


Figure 29: Delay Rate for all intersection (min/Km)

Similar trend is seen in delay rate between travel rate and delay rate for the intersections and hence a much delay is happened during the travel compared with the morning. Interestingly, for Atlas-Urael leg the higher delay rate was recorded from 2:30 PM – 4:00 PM and it decreases however, for Mexico –Legehar leg the highest delay rate was recorded after 5:00 PM. For the morning peak period the highest delay rate was about 25min/Km where as the highest delay rate which is at the evening peak period amounts about 40 min/km.

The figure below Figure 30 shows that the delay ratio which is the ratio of delay rate to actual travel rate for all the legs studied. Accordingly, though the delay rate amount is different for the morning and the evening peaks, the delay ratio are almost the same. The delay ratio for most of the sections for longer period is about 0.8. However, Mexico-Legehar and Legehar-Mexico legs shows the least delay ratio until the evening peak time 5:00 PM and then it becomes almost 0.9

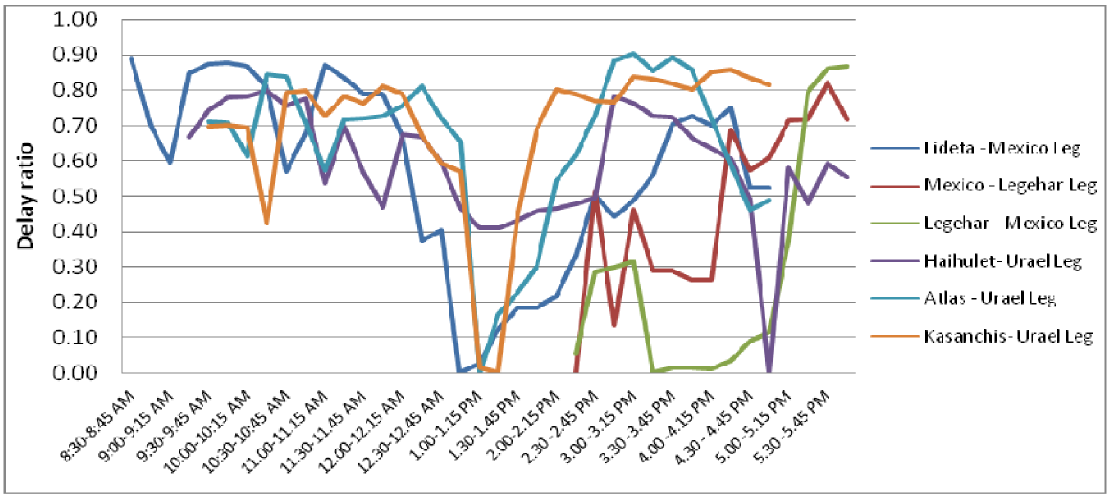


Figure 30: Delay Ratio for all intersection

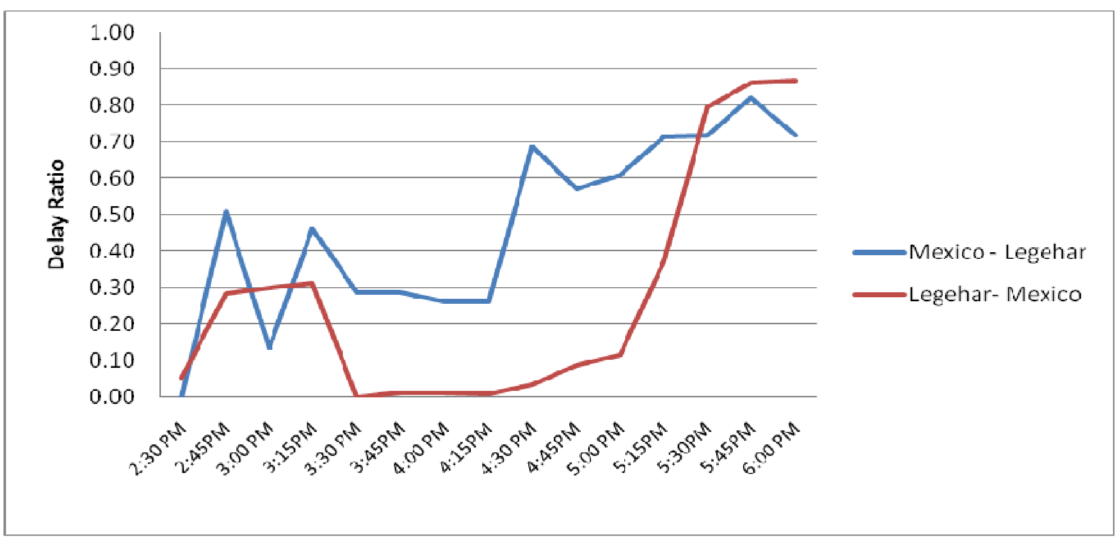


Figure 31: Delay Ratio for Legehar intersection

Delay per traveler or annual-hour delayed per traveler is shown in Figure 32 for the six legs considered and the delay hour calculated for the road section considered and hence it is not possible to compare the different legs as their length were different. However, the result shows that a person traveling the 250m long Atlas –Urael leg of Urael junction at 3:00 PM only once per day will lose about 40 hours of his life in the congestion.

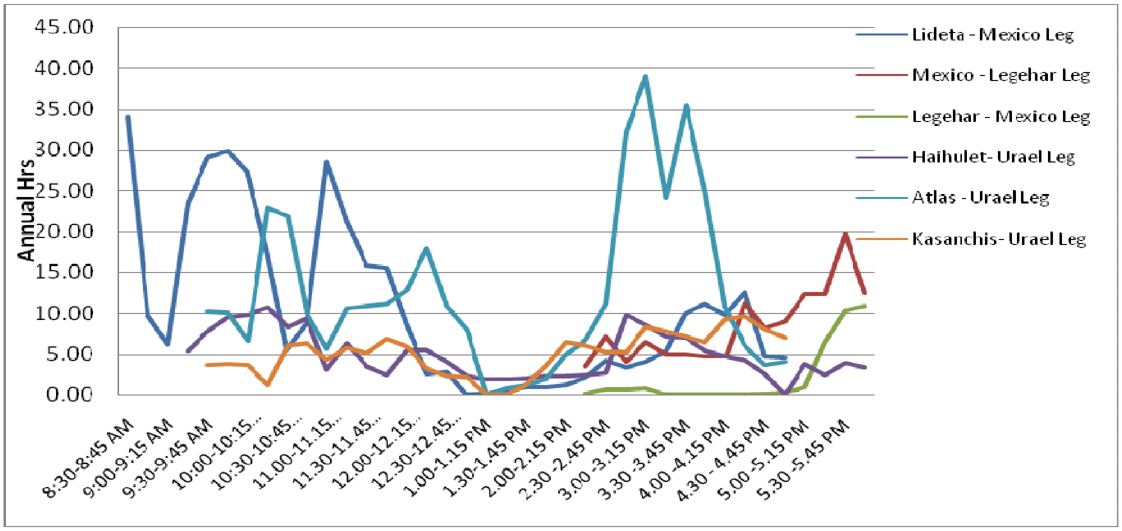


Figure 32: Delay per Traveler (annual-hour)

4.3.4 Total segment delay (vehicle-min and person-min)

Total segment delay measured in Vehicle-min and or Person-hour is the measure of congestion intensity. It shows how the congestion is serious and indicates the extent of the congestion that how much peoples being affected with the congestion. Figure 33 shows the total segment delay in Vehicle-Min for the leg length considered. The total segment delay shown in Figure 33 is calculated for the legs based on their legs which are not equal. Hence, the result should not be compared instead it should be read for a single leg only at once.

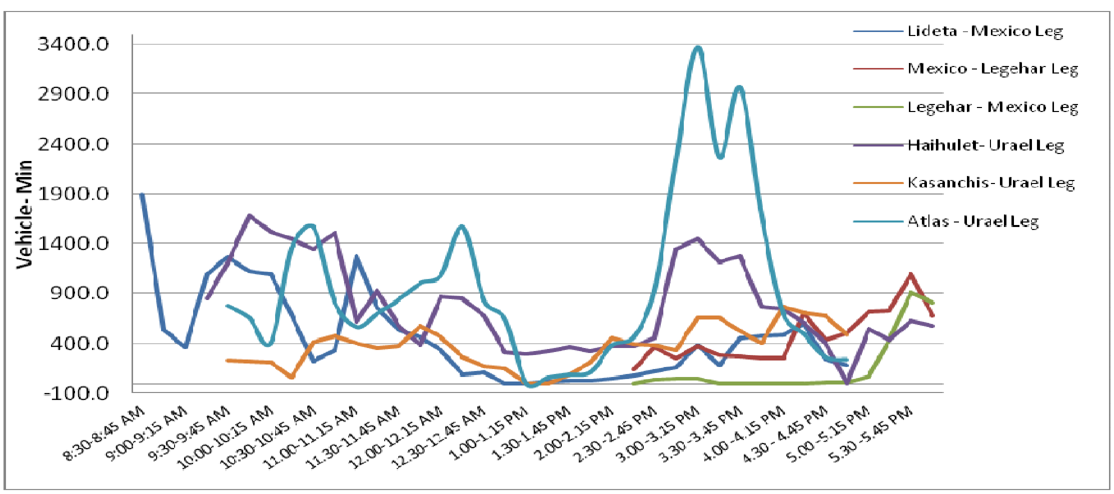


Figure 33: Total Segment Delay

However, in order to compare the six legs the total delay was divided by the length of the segment and the delay was converted to a unit length delay. Accordingly, Figure 34 shows that during the morning peak period the congestion severity at Haihulet-Urael leg is the highest and it is nearly five time that of Mexico-Lideta leg. The highest congestion severity at Kasanchis – Urael leg starts lately at 10:30 AM and goes until the mid day however, immediately after the lunch time the congestion starts and become peak in the evening peak hour of 4:00 PM. In general the comparison shows that the three legs considered at Urael Junction shows the most sever congestion the Mexico & Legehar Intersection.

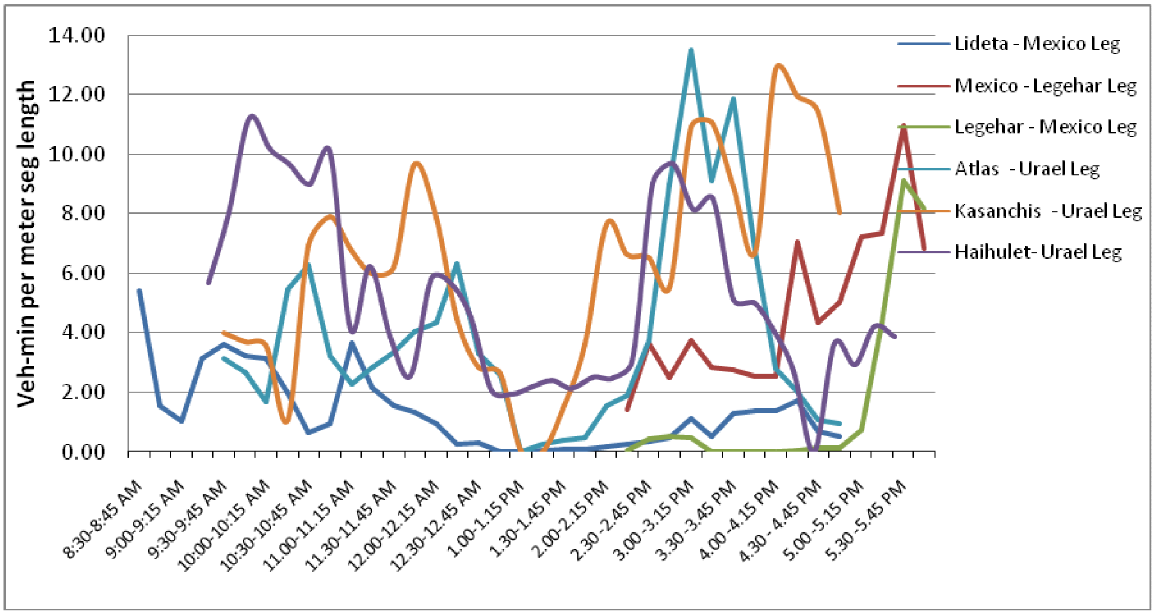


Figure 34: Total Segment delay density (Veh-min)/meter

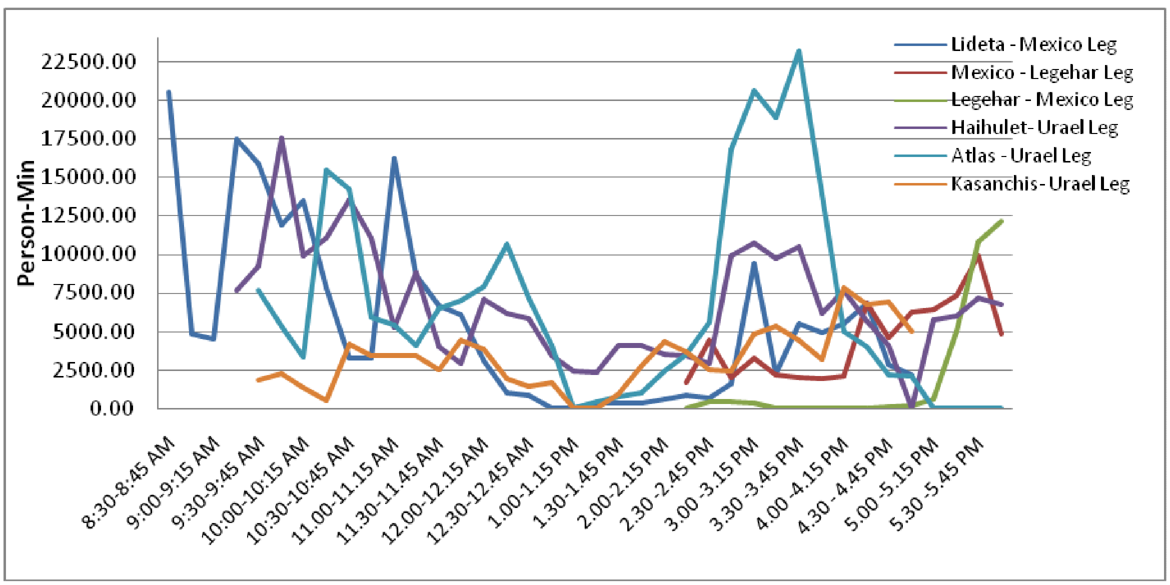


Figure 35: Total Segment delay (Person-Min)

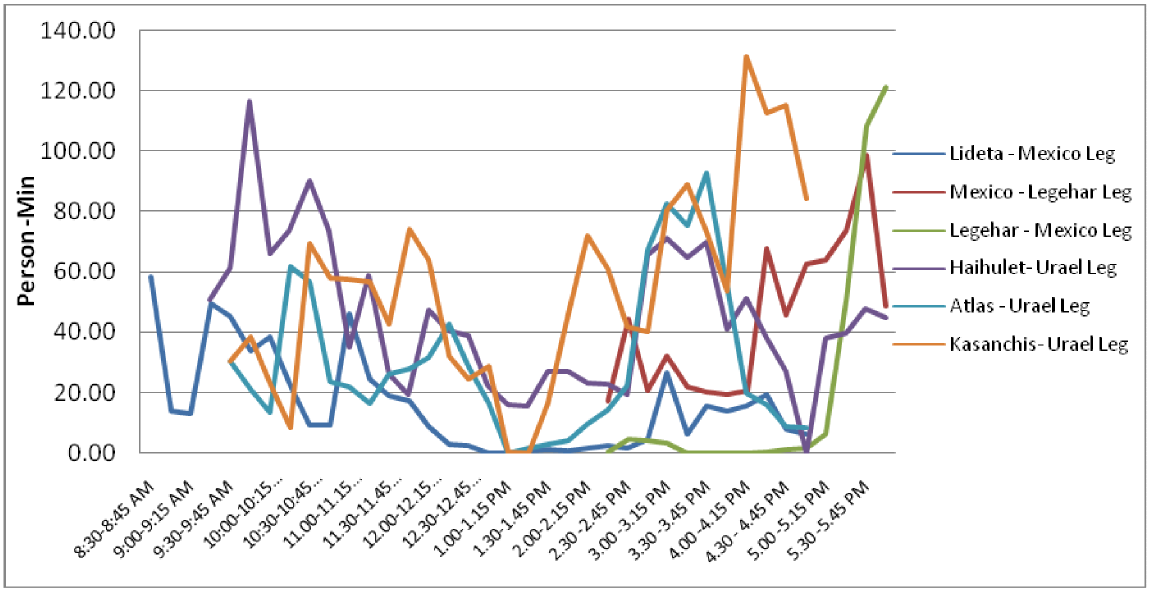


Figure 36: Total Segment Delay density (Person-Min)/meter)

Buffer index (BI) and Planning Time Index are measures of trip reliability and measure the reliability of congestion with in a section or a corridor. Buffer index expresses the amount of extra buffer time needed to be on time for 95% of the trips. Whereas planning time index expresses the total travel time that should be planned when an adequate buffer time is included.

Table 16 and Figures 37 and 38 show the calculated buffer index and planning time index for the five segments analyzed. Accordingly, the Atlas –Urael and Mexico-Lideta mid blocks are less reliable than the other legs. The buffer index for Mexico-Lideta and Atlas-Urael legs are two folds of the other legs.

Table 16: Buffer Index & Travel Time Index

	Lideta – Mexico Leg	**Mexico – Legehar Leg**	**Haihulet-Urael Leg**	**Atlas – Urael Leg**	**Kasanchis – Urael Leg**
95th Percentile Travel Time (min)	482.26	210.16	178.53	550.53	150.49
Average Travel Time (Min)	213.64	120.47	109.03	241.23	95.74
Buffer Index (%)	126%	74%	64%	128%	57%
Planning Time Index	2.26	1.74	1.64	2.28	1.57

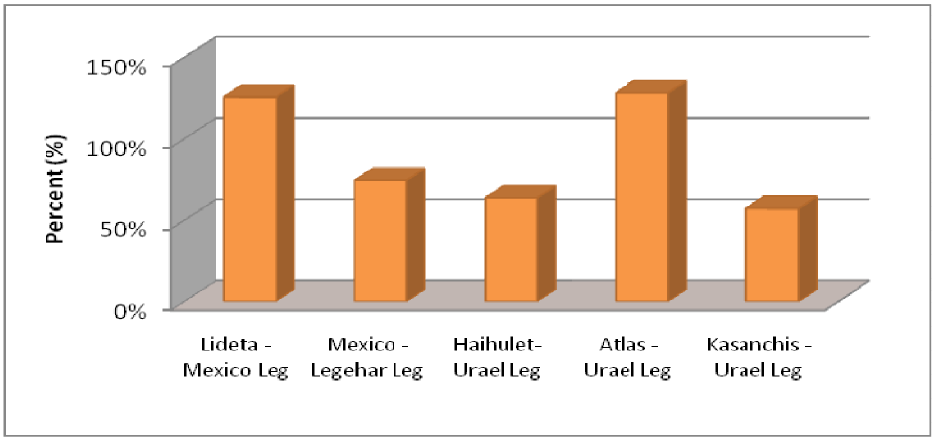


Figure 37: Buffer Index

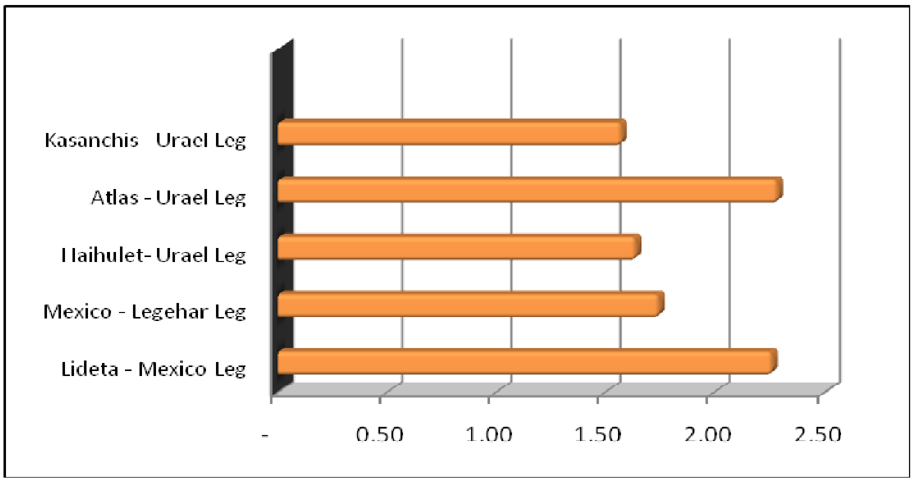


Figure 38: Planning Time Index

Table 17 and Figure 39 below show the economic cost calculation of the congestion for the six road sections considered in this study for only the considered road length. The cost calculation is only based on the vehicle idle time which is converted in to cost using the average rental cost and the fuel cost. In order to calculate the fuel cost a hourly fuel consumption for heavy, medium and small vehicles was taken from Akcelik (2003) and the values were averaged based on the vehicle composition of each. furthermore, for the vehicle idle time cost estimation, the current rental cost of different vehicles were collected from car rental offices and the weighted average rental cost was determined for each segment depending on the vehicle composition and proportion. Accordingly, the result shows the only at Haihulet-Urael leg & Atlas Urael legs congestion costs about 12 million each per year and the congestion at only one leg of 350m long Mexico- Lideta approach costs about 7million per year for only idle vehicle and fuel cost.

Table 17: Fuel & vehicle idle cost

	Lideta - Mexico Leg	**Mexico - Legehar Leg**	**Legehar - Mexico Leg**	**Haihulet-Urael Leg**	**Atlas - Urael Leg**	**Kasanchis Urael Leg**
Total Segment Delay per day (Vehicle-min)	15,745.79	7,082.91	2,409.95	27,326.79	29,187.41	11,200.67
Total Segment Delay per day (Vehicle-Hr)	262.43	118.05	40.17	455.45	486.46	186.68
Weighted Average Fuel Consumption (Lit/hr)	1.30	1.29	1.26	1.23	1.25	1.25
Total Fuel Consumed (lit)	341.39	152.36	50.81	559.93	605.95	233.35
Unit Cost of fuel (birr)	21	21	21	21	21	21
Total Fuel Cost per day	7,169.21	3,199.61	1,066.96	11,758.55	12,724.92	4,900.29
Average daily Rental cost of Vehicles (birr/day)	636.66	618.44	587.29	559.87	574.90	574.00
Total Daily Vehicle cost (birr)	20,884.92	9,125.78	2,948.63	31,874.06	34,958.22	13,394.13
Total Daily Vehicle & Fuel cost cost (birr/day)	28,054.13	12,325.39	4,015.59	43,632.61	47,683.14	18,294.42
Total yearly Vehicle & Fuel cost cost ('000 birr/year)	**7,209.91**	**3,167.62**	**1,032.01**	**11,213.58**	**12,254.57**	**4,701.67**

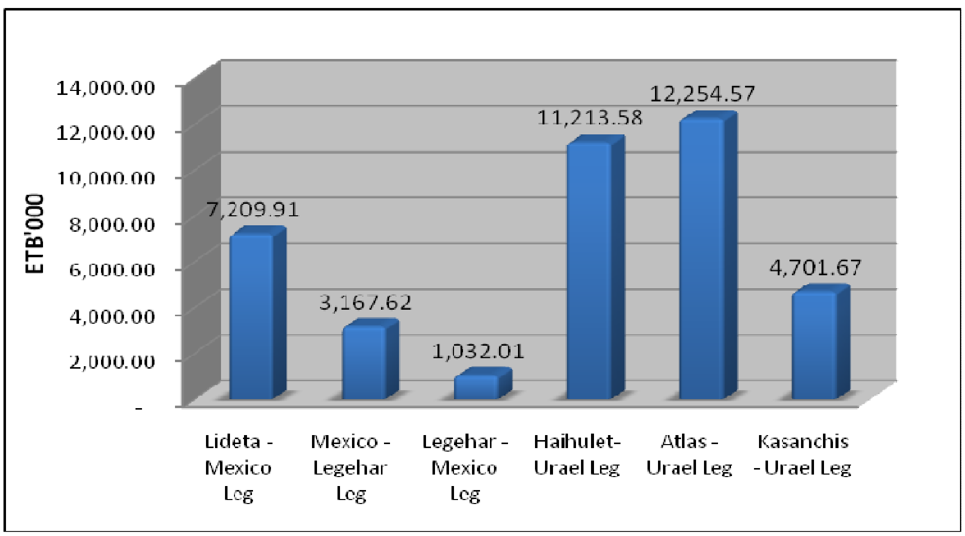


Figure 39: Yearly Fuel & Vehicle cost due to delay

4.4 Questioners respondents profile

The questioner respondents profile is summarized in the Table 18 below and the each questioner data was discussed and presented at appropriate section in the analysis and result part of this thesis. Table 18 shows that about 61% of the distributed questioners were returned and the profile of the respondents showed that most of them were aged between 25-35 and the average distance of home to work place was from 3-10 Km.

Table 18: Questionnaire respondents' profile

		Frequency	Percent
Questioner	Distributed	70	
	Returned	43	61.0%
	Total		
Age Group	Under 25	7	16%
	25- 35	23	53%
	36-45	9	21%
	above 46	4	9%
	Total	**43**	**100%**
Sex	Male	34	79%
	Female	9	21%
	Total	**43**	**100%**
Mode of Movement	Personal drive	17	40%
	Public Transport	23	53%
	Using driver but personal vehicle	3	7%
	Others	0	0%
	Total	**43**	**100%**
Average distance from home to work place	1km- 3km	4	9%
	3km-7km	15	35%
	7km-10 km	16	37%
	10km – 14 km	4	9%
	Above 14 km	4	9%
	Total	**43**	**100%**

4.5 Traffic congestion and traffic accident trend analyses

4.5.1 Traffic accident trend in Addis Ababa

Traffic accident is known to be one of the major transportation problems in Addis Ababa and the subsequent loss of life; injury and property damage are significantly high. Figure 40 and 41 show the trend of the traffic accident within hours of a day. Accordingly, traffic accident is the highest during the morning and evening peak periods. In addition, Figure 41 shows the number of the traffic accident was increasing during the years from 1996-2005. As the data is a sum of all accidents in the city, the severity of the accidents is hidden. However; as congestion is usually involves a lower speed, the possible accident severity during traffic congestion would be a light collisions.

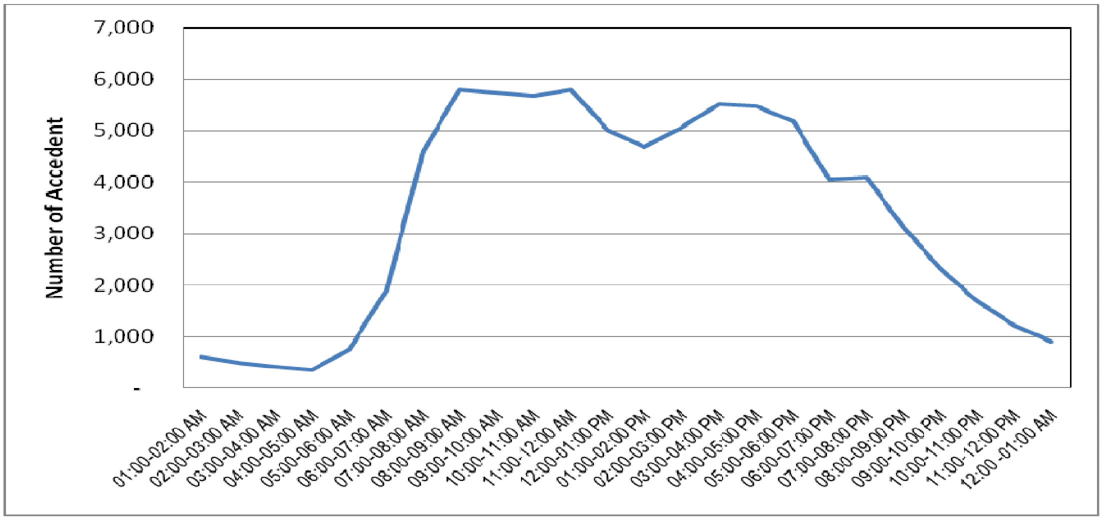


Figure 40: Cumulative Accident trend with the time of a day

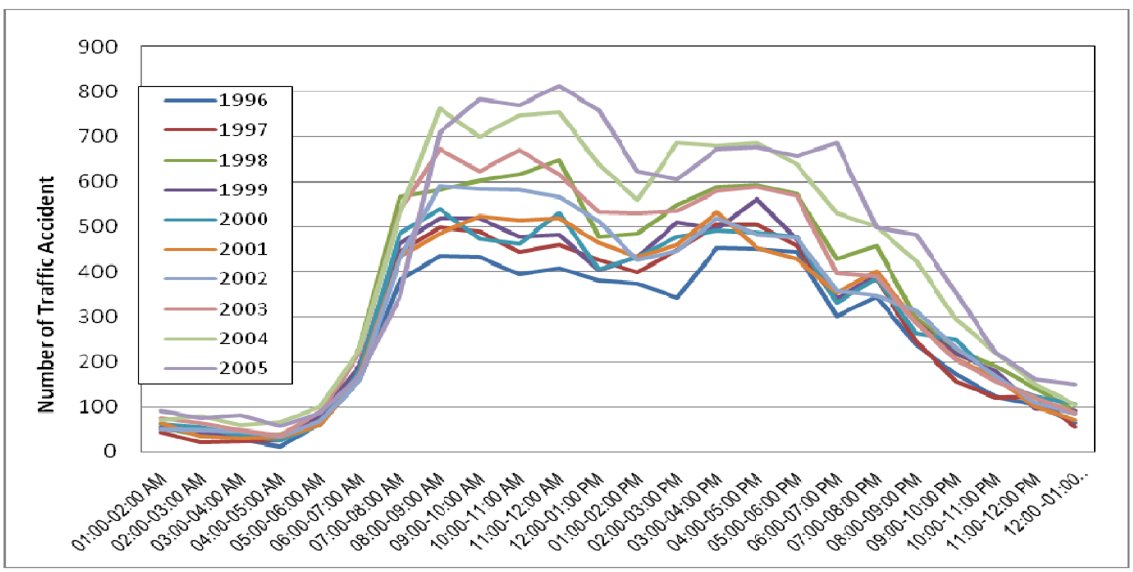


Figure 41: Traffic Accident by times for individual years

4.5.2 Traffic volume vs. traffic accident

As Figure 23 shows the trend flowed by the total (bi directional) traffic volume or flow was almost similar for the three midblock; namely, Mexico-Legehar, Torhailoch-Lideta and Lideta Mexico. However, the trend for Wuhalimat –Haihulet midblock is somehow different from the other three mid-blocks and it keeps almost constant but continuously falling and rising traffic volume trends are shown.

To make the comparison between the traffic trends between the traffic accidents and traffic volume it is logical to take the average traffic volumes of the midblock as most of the midblock show the same trend in traffic volume variation. Hence, the average hourly traffic volume/flow is plotted against with the average hourly traffic accident data in Addis Ababa city as shown below in Figure 42. As the average hourly traffic accident value is by far less than the average traffic volume the physical gap between the plots of the two curves were wide and hence to make the diagram compressive, all traffic accident data were multiplied with a factor of 2.5 and the value was plotted as shown in Figure 42.

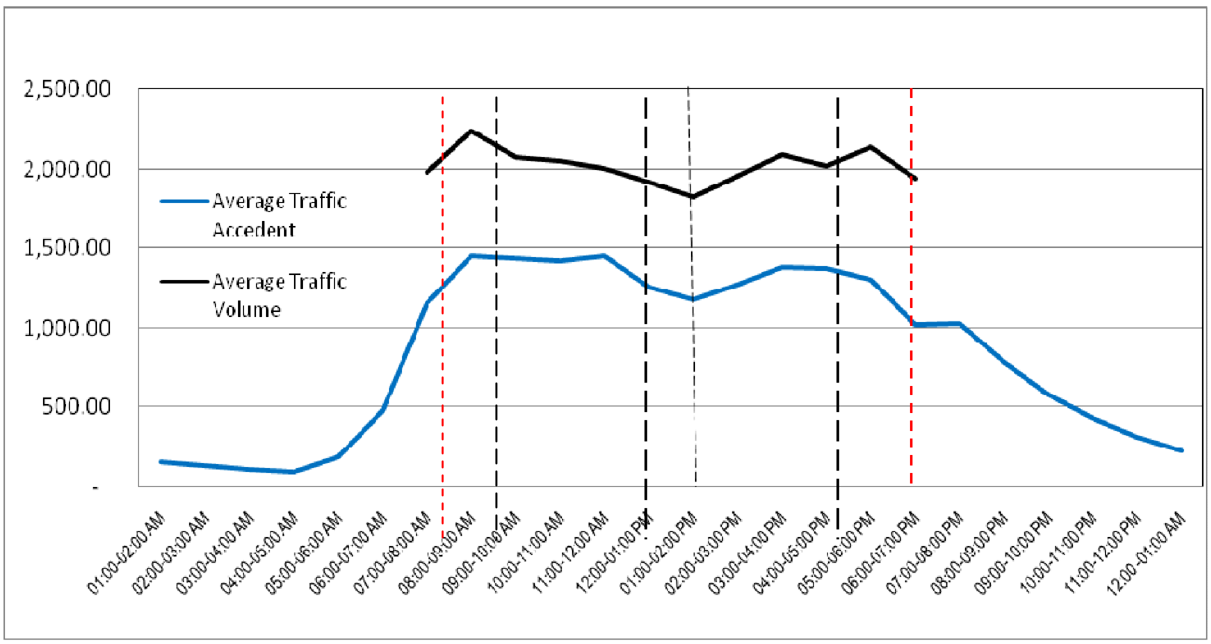


Figure 42: Average Accident & Traffic Volume Trend

The result of Figure 42 shows a surprising trend between the traffic volume and traffic accident that during the morning and evening peak periods both traffic flow and accident increases where as during the mid day time both traffic flow and accident decreases.

4.5.3Travel time vs. traffic accident

Table 19 shows the average travel rate (min/km) for all the six legs assessed and the average of the six travel rate together with the average hourly traffic accident rate (divided by 200) historical data average for ten years. Figure 43 shows the corresponding diagram of travel rate and accident rate along the time of a day. The result shows that both parameters travel rate and traffic accident also follow the same trend as traffic accident and traffic volume.

Table 19: Travel Rate (min/km) and Traffic Accident Data

	Lideta - Mexico Leg	Mexico - Legehar Leg	Legehar - Mexico Leg	Haihulet - Urael Leg	Atlas - Urael Leg	Kasanchis -Urael Leg	Average Travel Time (min/km)	Average Traffic Accident
08:00-09:00 AM	17.89						17.89	28.97
09:00-10:00 AM	18.04			16.37	13.80	21.14	17.34	28.66
10:00-11:00 AM	13.05			19.52	18.78	23.53	18.72	28.39
11:00-12:00 AM	16.76			10.38	13.18	28.35	17.17	28.98
12:00-01:00 PM	5.24			11.19	15.95	20.00	13.09	25.01
01:00-02:00 PM	3.32			7.49	4.95	11.17	6.73	23.46
02:00-03:00 PM	4.72	11.73	5.09	11.13	17.23	29.33	13.20	25.29
03:00-04:00 PM	8.10	12.61	4.41	15.53	33.75	36.19	18.43	27.58
04:00-05:00 PM	8.30	19.83	4.20	8.84	9.86	40.33	15.23	27.43
05:00-06:00 PM		34.06	21.18	9.64			21.63	25.95

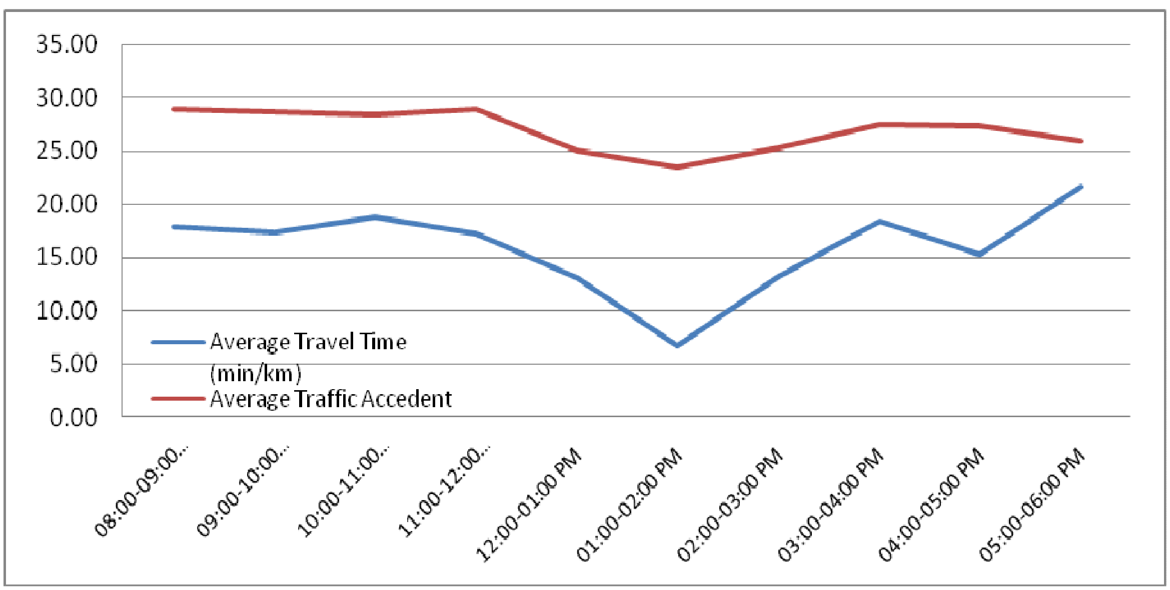


Figure 43: Travel Rate Vs Traffic Accident trend in a day

4.5.4 Traffic accident correlation with traffic volume and travel time

In order to see the correlation between traffic volume and travel time with traffic accident, linear equations and regression coefficients were determined as shown in Figure 44 and Figure 45 respectively. Accordingly, the regression coefficient of travel time with traffic accident is greater than the regression coefficient of traffic volume. Hence, the result indicates that travel time has a relationship with traffic accident.

Though the regression coefficient of traffic volume is not significant due to the outlier values, values above the regression line are so close and follow a trend. Therefore, the result cannot be undermined.

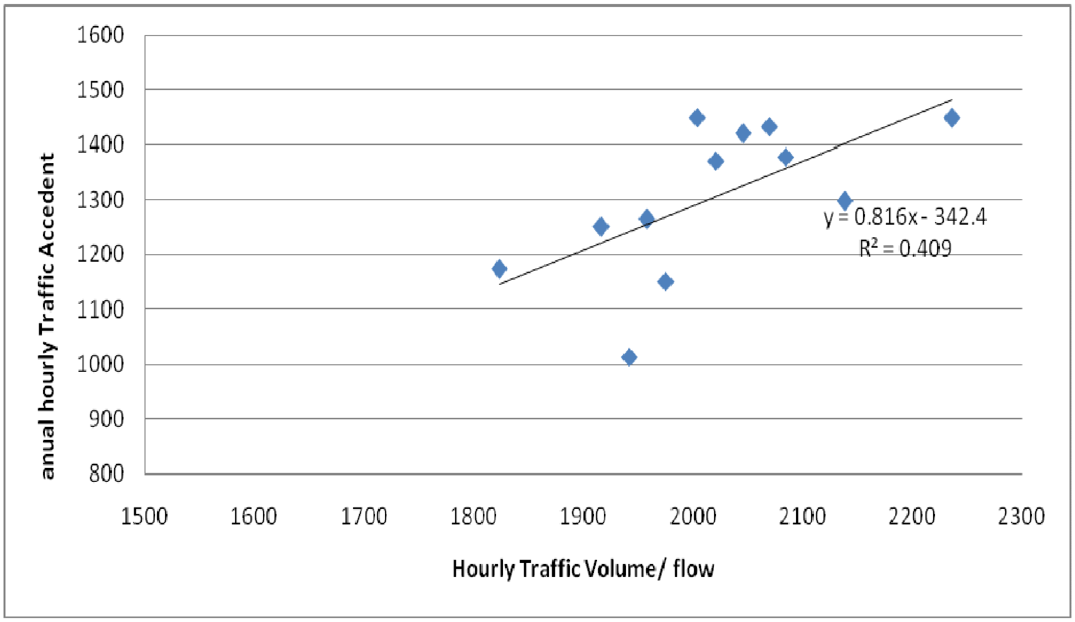


Figure 44: Traffic volume/ flow Vs Traffic Accident

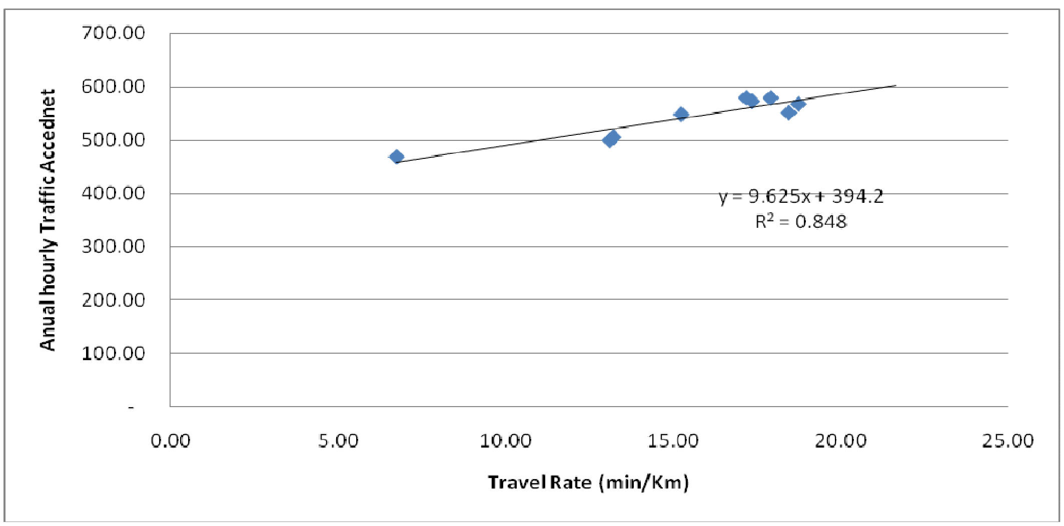


Figure 45: Travel Rate Vs Traffic Accident

4.5.5 Accident spots and congestion spots

The traffic accident spots as identified by the Road Safety Agency are collected and plotted on a GIS map of Addis Ababa (the black dots) these accident spots are only those spots with traffic accident rate of greater than 50 accidents per year. The congestion spots were collected using questioner and the result was plotted on the GIS map as shown in the Figure 46 below. As questioners were given randomly, the congestion spots identified could not be the entire congestion spots in Addis Ababa city. However, the result shows that all the identified congestion spots are also identified as black spots by the road safety agency. Furthermore, the traffic and accident spots follow a trend that the east-west and north-south axis and concentrated at the city centers.

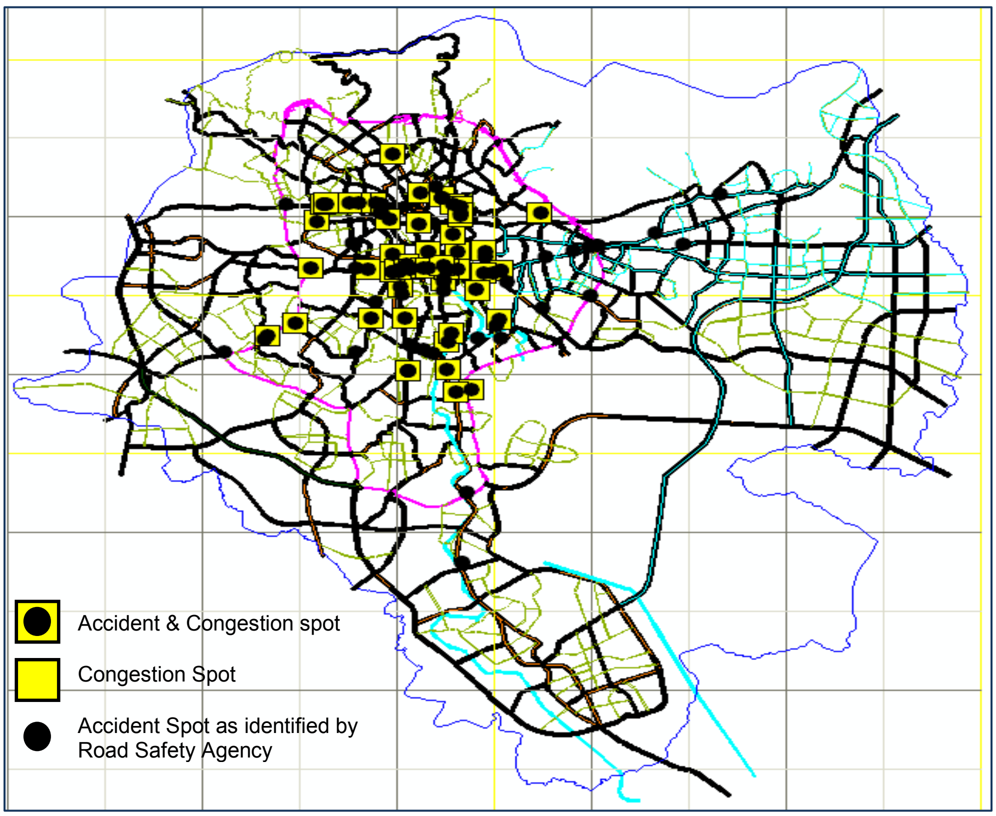


Figure 46: GIS plotting of traffic and conjunction spot

5. DISCUSSION

5.1 Traffic volume/flow trend at mid block and congestion

The directional traffic flow analysis for the four mid-blocks shows some interesting trends that the two mid-blocks namely; Lideta-Mexico mid block and Mexico-Legehar midblock shows the theoretical traffic flow trend which is a morning and evening peak. However, for the other two mid block Torhailoch –Lideta and Wuhalimat-Haihulet midblock the directional traffic flow or volume shows a different trend which indicates special features in these two mid-blocks.

The Torhailoch- Lideta midblock shows a traffic flow trend in which each direction has one peak. Furthermore, the traffic volume in the two direction is not balanced which is the total traffic volume from Torhailoch to Lideta is by far greater than the returning direction. This indicates that there are vehicles which change their route during the evening period. When we look in to the vehicles which change the route all of them are from the vehicle classes of car, taxi, 4WD, minibus taxi and mid bus. The main reason for this flow unbalance or change of route by vehicles in the evening peak period is traffic congestion due to midblock at Torhailoch round about. Unlike the opposite direction this bottleneck is a narrow two lane with highly failed pavement and hence, the vehicle speed highly reduced and the congestion is so intense and vehicles are forced to change their route and also minibus taxis were unwilling to serve in this route during the evening peak. Figure 47 shows the bottleneck at the Torhailoch roundabout.

Figure 47: The Bottleneck at Torhailoch roundabout

The Haihulet –Wuhalimat midblock traffic volume trend also shows nearly constant traffic volume flow throughout the day. The traffic volume from the Haihulet to Wuhalimat direction is higher than the reverse direction throughout the day and become equal at the evening. When compared with the other three midblock this section have the highest traffic volume with about 18,281 vehicles in the 12-hour day time and the next higher traffic volume is the Torhailoch – Lideta midblock. These results indicates that the road sections connecting the residential areas show the highest traffic flow and each direction show different peak periods. which means one of the directions shows either the morning or evening peak period and vice-versa.

5.2 Travel rate and travel delays

The intersections considered in the study corridor are oversaturated according to the level of service analysis especially during the peak period. Since the travel time observation segments were short and at the entry of intersection, it expected to have a lower average speed. However, the result showed that during the morning peak period vehicles move below 4.5Km/hr which is about less than a speed of a walking old man. As Figure 27 shows average speed is higher for a section for which the observed road length is longer. Accordingly, the Mexico-Lideta and Atlas-Urael legs show a relatively higher speed whereas for the shortest leg which is Kasanchis-Urael leg the average speed is small and hence the corresponding delay values become exaggerated.

According to the delay analysis a traveler is expected to spend an extra time or delay of about 20min to travel one Km length of an intersection during the morning peak period and about 35 min during the evening peak period. Even though, the amount of the delay times during the morning time seems different but the delay ratio which is the ratio of delay rate to the actual travel time is nearly equal at both the morning and evening peak hour. An average delay ratio of 0.8-0.9 was observed to all intersection and during both peak periods. That is only 10-20% of the time we invested at an intersection is needed to pass the intersection at uncongested condition and the delay is four fold of the time required to transverse the section.

Up on severity analysis using the parameter total delay (Vehicle-Hr or Person –hr) the result showed that an average total delay of about 1400 Vehicle-min or 15000 person-hr was lost every 15-min during the morning peak period for only the considered length of the road. However, during the evening peak period a relatively lower average total delay of about 800 vehicles –min or 7500 person hours lost for the segments except the Atlas-Urael leg. The congestion severity or intensity for Atlas-Urael segment or leg is highly significant especially during the evening peak and reach to the value of about 2900 veh-hr or 20000 person-hr. However, if we aggregate the total delay within the day for only the road length considered, the total veh-min delay at the six legs will be about ***92,950 Veh-min*** (***1550 Vehicle-hr or 193 Veh-day***) or the total person-min at the six legs will be ***845,230 person-min (14,087 person-hr or 1,760 person-day***). This means due to the congestion at only these six intersections in a single day about 193 vehicles and 1,760 peoples are idle for the full day.

5.3 Traffic congestion effect on Accident

The traffic accident trend within the time of a day has been studied by different researchers Girma (2000), Fanuel (2006) and Bitew (2002). Based on the peak trends of both traffic volume and traffic accident during morning and evening time, all the previous researchers conclude that there is a relationship between traffic flow and traffic accident. However, none of the researches showed the relationship between traffic congestion parameters and traffic accident. It is true that the more vehicles in the road the more likely collision would happen. However, the researcher of this paper doesn't believe that traffic flow or volume is the right parameter to be related with traffic accident. For instance at a freeway we can have the highest traffic flow or volume than other road sections. However, more of traffic accidents can happen at other section of the road.

As it is indicated on Girma (2000) and other report data "Drivers error or behavior" is highly quoted as the main (93%) cause of traffic accident in Addis Ababa accounting more than 93% of the accident. The main mistakes listed under driver's error and causing about 85% of the total accident are; *driving on the wrong side, failure to give way, following too close, improper overtaking, speeding, improper turning*.

As it can be seen together with other road and environmental factors, behavioral factors contribute a lot for the traffic accident in Addis Ababa. Hence, the researcher of this paper believes that having the other road parameters constant, traffic accident would be more related with the behavioral and vehicle to vehicle headway factors than the traffic volume or flow. One of the factors that affect driver behavior is the stress and frustration resulted from delay due to traffic congestion. A questioner result showed that out of 20 drivers interviewed 17 (85%) responded that the traffic congestion make them to stress and frustrate which make them to misbehave and commit wrong driving.

The effect of traffic congestion on drivers or commuters can be easily understood by the amount of delay or by the travel rate. Hence, correlation was made with the traffic accident, traffic volume and travel rate as shown above in Figure 44 and Figure 45 respectively. According to the result, traffic accident is shows a higher R2 or goodness of fit result for travel time than traffic volume or flow which indicates better relation or fitness with travel rate.

Further to the correlation between the travel rate and traffic accident, the assessment of traffic accident spots and congestion spots shows a clear relationship among the traffic accident and traffic congestion in Addis Ababa. The traffic spots plotted in the GIS map of Figure: 46 are identified by Ethiopian Road Safety Agency and the traffic congestion spots are identified from the questioner result. Plotting the two spot on a single GIS map shows that most of the traffic accident and congestion happen at or near intersection and all the identified congestion spots fits with the accident black spots.

Therefore, the link between the traffic accident and the traffic congestion in Addis Ababa is so significant and the researcher believes efforts made to mitigate the traffic congestion will also minimize the traffic accident.

6. CONCLUSION

Based on the findings of the analysis in this study, the following points are concluded.

1. The traffic flow from the residential area of the two ends (namely *the east: Ayat-CMC-Megenaga-Kotebe e.tc and the west: Ayertena-betel-Alembank e.t.c*) are peak during the morning period and only one of the lane is congested during one of the peak period.
2. Traffic congestion during the evening peak hour is more than the morning peak hours and during the mid day the roads are almost uncongested.
3. as seen in Torhailoch intersection, traffic congestion or bottlenecks have a impact on the traffic flow pattern
4. The intersection in the East-West study corridor of Addis Ababa are performing above their capacity and during the peak periods the degree of saturation is almost greater than 2 for most of the intersection and the level of service is F.
5. During both morning and evening peak periods about 80-90% of the travel time needed to negotiate the entry lanes of an intersection is a delay.
6. The average traffic congestion intensity in Addis Ababa expressed in Veh-min or person-min is very high and the result shows on average about ***18,500 Vehicle-min*** or ***38 vehicle-days*** and ***169,000 Per-min*** or ***352-person-day*** are wasted at each intersection legs or congestion spot per day.
7. For only Urael intersection about ***141 veh-day*** and ***1165 person-day*** are wasted per day at its three legs.
8. On average the cost of wasted fuel & idle vehicle time at each entry leg of an intersection is above **7.7 million/year** and only the three legs of Urael intersection costs more than **28 million/year.**
9. The correlation analysis and the spot analysis indicate that the traffic congestion in Addis Ababa is strongly linked with the traffic accident.

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APPENDIXES

APPENDIX A: Travel Time, Traffic Volume and Vehicle Occupancy data

Table 20: AVERAGE TRAVEL TIME AT CONGESTED SEGEMENTS (in sec)

	Lideta to Mexico	Wuhalimat to Urael	Legehar to Mexico	Mexico to Legehar	Atlas to Urael	Kasanchis to Urael
Segment Length	350m	150m	100m	100m	250m	60m
Time						
8:30-8:45 AM	549.6					
8:45-9:00 AM	201.9					
9:00-9:15 AM	149.8					
9:15-9:30 AM	398.1	116.30				
9:30-9:45 AM	478.3	151.00			208.0	75.8
9:45-10:00 AM	489.6	174.80			206.0	76.4
10:00-10:15 AM	453.6	178.60			156.0	74.8
10:15-10:30 AM	315.6	192.80			390.0	39.6
10:30-10:45 AM	140.0	157.90			975.0	110.9
10.45-11.00 AM	187.4	173.30			206.0	113.6
11.00-11.15 AM	470.2	83.40			141.0	84.4
11.15-11.30 AM	365.4	128.30			213.0	105.4
11.30-11.45 AM	287.8	89.20			216.0	96.8
11.45-12.00 AM	284.2	72.60			221.0	121.6
12.00-12.15 AM	182.2	118.20			246.0	108.9
12.15-12.30 AM	96.2	116.90			320.0	69.8
12.30-12.45 AM	101.0	95.50			216.0	56.3
12.45-1.00 PM	60.4	72.20			175.0	53.0
1.00-1.15 PM	61.8	65.40			60.4	23.1
1.15-1.30 PM	68.8	65.40			72.2	22.8
1.30-1.45 PM	74.0	68.00			78.0	40.9
1.45-2.00 PM	74.0	71.00			86.5	69.8
2.00-2.15 PM	77.2	72.00			132.1	81.1
2.15-2.30 PM	90.4	74.00	24.9	50.2	157.2	79.6
2.30 -2.45 PM	120.8	76.20	33.0	102.8	220.8	100.9
2.45 - 3.00 PM	108.0	178.50	33.7	58.1	523.8	40.7
3.00 -3.15 PM	117.6	162.90	34.4	93.5	622.8	108.3
3.15 -3.30 PM	137.6	141.40	23.6	70.5	409.0	56.8
3.30 -3.45 PM	203.6	139.60	23.9	70.5	572.4	85.7
3.45 -4.00 PM	221.2	115.00	23.9	68.1	421.0	73.6
4.00 -4.15 PM	201.2	106.14	23.9	68.1	214.4	107.2
4.15 - 4.30 PM	242.4	98.00	24.4	161.6	147.2	122.0
4.30 - 4.45 PM	127.2	75.70	25.9	117.5	112.4	92.8
4.45 - 5.00 PM	126.8	38.50	26.7	128.6	117.6	77.4
5.00 -5.15 PM		91.90	37.7	176.8		
5.15 - 5.30 PM		74.00	116.0	178.3		
5.30 -5.45 PM		94.90	173.5	283.8		
5.45 -6.00 PM		86.40	181.0	178.6		

Table 21: DIRECTIONAL TRAFFIC VOLUME AT MIDBLOCKS (in PCU)

	MEXICO - LIDETA MID BLOCK		MEXICO - LEGEHAR MID BLOCK		TORHAILOCH - LIDETA MIDBLOCK		WUHALIMAT- HAIHULET MIDBLOCK		URAEL JUNCTION	
Time	**Mexico to Lideta**	**Lideta to Mexico**	**Mexico to Legehar**	**Legehar to Mexico**	**Torhailoch to Lideta**	**Lideta to Torhailoch**	**Wuhalimat to Haihulet**	**Hiahulet to Wuhalimat**	**Kasanchis to Urael**	**Atlas to Urael**
7:00-7:15 AM	233	249	251	245	393	211	205	357	184	128
7:15-7:30 AM	216	334	345	268	542	266	239	413	218	152
7:30-7:45 AM	215	297	352	296	575	325	304	497	330	281
7:45-8:00 AM	216	290	337	248	497	323	406	519	335	277
8:00-8:15 AM	219	300	368	214	495	211	279	549	339	356
8:15-8:30 AM	212	316	330	295	661	254	325	519	351	315
8:30-8:45 AM	263	308	312	348	663	284	369	499	356	381
8:45-9:00 AM	245	289	297	283	469	311	360	508	267	282
9:00-9:15 AM	218	305	297	380	490	299	308	430	306	357
9:15-9:30 AM	243	257	282	323	418	184	367	446	259	278
9:30-9:45 AM	269	241	289	379	310	267	334	445	313	348
9:45-10:00 AM	202	203	270	370	403	238	315	598	284	291
10:00-10:15 AM	241	210	339	338	445	228	271	515	304	281
10:15-10:30 AM	259	212	304	389	309	266	264	428	286	267
10:30-10:45 AM	285	220	266	355	365	324	316	523	344	325
10.45-11.00 AM	246	201	249	397	274	319	343	450	380	357
11.00-11.15 AM	252	237	258	381	363	246	453	557	484	455
11.15-11.30 AM	261	199	214	306	311	301	266	498	319	298
11.30-11.45 AM	260	184	196	395	318	257	325	487	367	349
11.45-12.00 AM	299	165	237	371	261	315	389	415	431	405
12.00-12.15 AM	301	209	196	352	280	328	367	410	401	376
12.15-12.30 AM	241	198	201	389	348	255	358	395	417	390
12.30-12.45 AM	237	199	231	300	355	302	326	542	373	343
12.45-1.00 PM	232	186	274	290	239	290	331	337	382	366

DIRECTIONAL TRAFFIC VOLUME AT MIDBLOCKS (in PCU) Continued

	MEXICO - LIDETA MID BLOCK		MEXICO - LEGEHAR MID BLOCK		TORHAILOCH - LIDETA MIDBLOCK		WUHALIMAT- HAIHULET MIDBLOCK		URAEL JUNCTION	
Time	**Mexico to Lideta**	**Lideta to Mexico**	**Mexico to Legehar**	**Legehar to Mexico**	**Torhailoch to Lideta**	**Lideta to Torhailoch**	**Wuhalimat to Haihulet**	**Haihulet to Wuhalimat**	**Kasanchis to Urael**	**Atlas to Urael**
1.15-1.30 PM	205	199	272	224	241	256	329	533	374	348
1.30-1.45 PM	191	169	196	274	296	251	315	598	353	338
1.45-2.00 PM	191	177	254	346	362	215	272	462	315	290
2.00-2.15 PM	261	244	245	328	359	244	322	483	355	347
2.15-2.30 PM	237	222	212	276	346	275	297	477	332	311
2.30 -2.45 PM	233	147	261	329	368	272	355	508	359	371
2.45 - 3.00 PM	268	260	303	352	315	259	302	389	318	313
3.00 -3.15 PM	192	566	287	310	348	279	363	458	394	385
3.15 -3.30 PM	209	179	291	374	341	307	392	445	426	418
3.30 -3.45 PM	246	243	282	362	345	323	357	561	369	373
3.45 -4.00 PM	195	218	268	316	312	242	288	422	313	302
4.00 -4.15 PM	261	268	279	310	315	263	343	444	397	302
4.15 - 4.30 PM	244	265	326	273	356	323	335	401	350	381
4.30 - 4.45 PM	265	286	282	361	334	361	328	469	391	329
4.45 - 5.00 PM	242	221	347	327	350	347	379	378	341	274
5.00 -5.15 PM	256	259	302	382	407	399	317	422	394	318
5.15 - 5.30 PM	239	224	311	356	376	239	381	544	358	359
5.30 -5.45 PM	250	243	284	476	360	433	388	453	305	345
5.45 -6.00 PM	286	191	280	390	300	332	450	439	468	330
6.00 -6.15 PM	291	218	265	365	305	445	399	389	275	344
6.15 -6.30 PM	286	201	239	441	314	493	336	378	374	279
6.30 -6.45 PM	316	210	216	378	282	420	336	328	314	325
6.45-7.00 PM	269	211	218	244	250	337	335	352	243	193
TOTAL	**11,692**	**11,431**	**13,182**	**15,959**	**17,653**	**14,180**	**16,083**	**22,090**	**16,531**	**15,609**

AVERAGE VEHICLE OCCUPANCY (PERSON/VEH)

	MEXICO - LIDETA MID BLOCK		MEXICO - LEGEHAR MID BLOCK		TORHAILOCH - LIDETA MIDBLOCK		WUHALIMAT- HAIHULET MIDBLOCK		URAEL JUNCTION	
Time	**Mexico to Lideta**	**Lideta to Mexico**	**Mexico to Legehar**	**Legehar to Mexico**	**Torhailoch to Lideta**	**Lideta to Torhailoch**	**Wuhalimat to Haihulet**	**Hiahulet to Wuhalimat**	**Kasanchis to Urael**	**Atlas to Urael**
7:00-7:15 AM	23.4	15.2	16.8	18.0	16.8	18.6	15.9	8.4	8.4	15.9
7:15-7:30 AM	17.0	21.6	14.8	19.6	19.5	19.5	16.5	10.1	10.1	16.5
7:30-7:45 AM	19.3	17.6	13.7	14.3	14.9	20.5	14.8	8.1	8.1	14.8
7:45-8:00 AM	13.1	16.4	10.4	10.8	13.4	16.4	13.0	10.5	10.5	13.0
8:00-8:15 AM	13.3	12.8	10.6	16.6	14.5	14.4	15.9	9.3	9.3	15.9
8:15-8:30 AM	14.8	14.1	9.7	12.6	14.3	16.3	14.3	8.1	8.1	14.3
8:30-8:45 AM	11.5	10.8	9.3	9.5	17.1	10.3	8.5	9.7	9.7	8.5
8:45-9:00 AM	13.5	9.0	7.9	7.4	16.0	12.2	9.4	10.7	10.7	9.4
9:00-9:15 AM	10.1	12.5	8.0	11.0	15.7	11.1	9.7	9.3	9.3	9.7
9:15-9:30 AM	11.8	15.9	9.3	8.8	13.2	11.3	8.4	9.0	9.0	8.4
9:30-9:45 AM	10.2	12.5	6.2	10.6	13.9	12.6	9.7	7.7	7.7	9.7
9:45-10:00 AM	12.5	10.6	8.0	8.8	12.9	12.1	8.0	10.4	10.4	8.0
10:00-10:15 AM	7.2	12.3	8.7	8.5	12.4	11.8	8.2	6.5	6.5	8.2
10:15-10:30 AM	10.1	11.3	7.9	7.1	13.1	8.6	11.3	7.6	7.6	11.3
10:30-10:45 AM	9.7	14.4	7.7	7.5	13.1	10.0	9.0	10.0	10.0	9.0
10.45-11.00 AM	9.1	10.0	8.2	7.2	13.4	10.8	7.3	7.3	7.3	7.3
11.00-11.15 AM	10.8	12.7	11.2	8.9	13.2	12.2	9.6	8.5	8.5	9.6
11.15-11.30 AM	11.7	11.4	7.0	7.2	6.8	13.2	5.9	9.5	9.5	5.9
11.30-11.45 AM	8.8	12.3	6.8	9.8	11.3	17.3	7.8	6.9	6.9	7.8
11.45-12.00 AM	10.5	12.9	8.9	8.4	11.8	13.8	6.9	7.7	7.7	6.9
12.00-12.15 AM	12.1	9.4	4.9	7.0	13.4	13.4	7.3	8.2	8.2	7.3
12.15-12.30 AM	11.8	11.8	6.0	7.0	12.0	13.9	6.8	7.2	7.2	6.8
12.30-12.45 AM	11.7	7.7	8.1	7.8	11.8	9.9	8.6	8.7	8.7	8.6
12.45-1.00 PM	13.7	9.6	7.8	5.0	12.4	13.5	6.4	11.0	11.0	6.4

AVERAGE VEHICLE OCCUPANCY (PERSON/VEH) continued

	MEXICO - LIDETA MID BLOCK		MEXICO - LEGEHAR MID BLOCK		TORHAILOCH - LIDETA MIDBLOCK		WUHALIMAT-HAIHULET MIDBLOCK		URAEL JUNCTION	
Time	**Mexico to Lideta**	**Lideta to Mexico**	**Mexico to Legehar**	**Legehar to Mexico**	**Torhailoch to Lideta**	**Lideta to Torhailoch**	**Wuhalimat to Haihulet**	**Haihulet to Wuhalimat**	**Kasanchis to Urael**	**Atlas to Urael**
1.00-1.15 PM	12.2	10.3	8.5	10.5	10.8	16.9	8.1	8.3	8.3	8.1
1.15-1.30 PM	13.1	16.4	9.5	6.4	12.9	18.2	7.5	7.2	7.2	7.5
1.30-1.45 PM	7.2	12.6	12.7	8.6	12.8	18.9	8.4	11.2	11.2	8.4
1.45-2.00 PM	13.9	10.5	11.1	8.0	10.8	17.3	8.9	12.8	12.8	8.9
2.00-2.15 PM	7.2	11.7	9.2	6.9	9.4	18.8	6.3	9.4	9.4	6.3
2.15-2.30 PM	8.5	10.4	12.3	5.8	11.6	14.2	7.6	9.2	9.2	7.6
2.30 -2.45 PM	12.9	5.5	12.1	10.8	13.4	16.2	6.0	6.4	6.4	6.0
2.45 - 3.00 PM	11.4	10.2	8.2	8.4	11.6	16.0	7.5	7.3	7.3	7.5
3.00 -3.15 PM	9.3	24.2	8.7	7.4	10.5	12.6	6.1	7.4	7.4	6.1
3.15 -3.30 PM	12.1	12.0	7.8	8.6	9.8	13.2	8.3	8.0	8.0	8.3
3.30 -3.45 PM	10.2	12.1	7.3	7.7	9.2	15.5	7.8	8.2	8.2	7.8
3.45 -4.00 PM	11.0	10.2	7.6	10.5	9.2	17.7	8.2	8.0	8.0	8.2
4.00 -4.15 PM	13.1	11.4	8.2	11.7	12.3	20.6	7.1	10.2	10.2	7.1
4.15 - 4.30 PM	11.1	11.3	9.6	7.1	17.3	15.7	8.1	9.4	9.4	8.1
4.30 - 4.45 PM	12.6	11.6	10.6	11.8	13.6	14.2	8.2	10.1	10.1	8.2
4.45 - 5.00 PM	12.3	11.7	12.5	12.6	12.0	13.5	8.8	10.5	10.5	8.8
5.00 -5.15 PM	15.5	14.7	8.9	8.5	13.2	16.0	9.1	10.6	10.6	9.1
5.15 - 5.30 PM	13.4	14.6	10.0	11.6	12.9	15.5	9.7	13.8	13.8	9.7
5.30 -5.45 PM	12.1	16.0	9.0	11.9	14.1	19.6	12.3	11.4	11.4	12.3
5.45 -6.00 PM	17.7	13.0	7.1	14.8	17.6	18.1	9.7	11.6	11.6	9.7
6.00 -6.15 PM	14.5	8.3	10.1	12.2	14.8	20.1	11.5	11.6	11.6	11.5
6.15 -6.30 PM	14.7	13.1	8.8	12.9	13.2	17.8	9.0	9.7	9.7	9.0
6.30 -6.45 PM	13.3	12.1	8.1	10.2	12.7	17.5	8.8	13.0	13.0	8.8
6.45-7.00 PM	14.8	10.5	10.7	8.5	5.4	19.8	10.2	10.1	10.1	10.2

APPENDIX B: Level of Service analysis output using aaSIDRA software

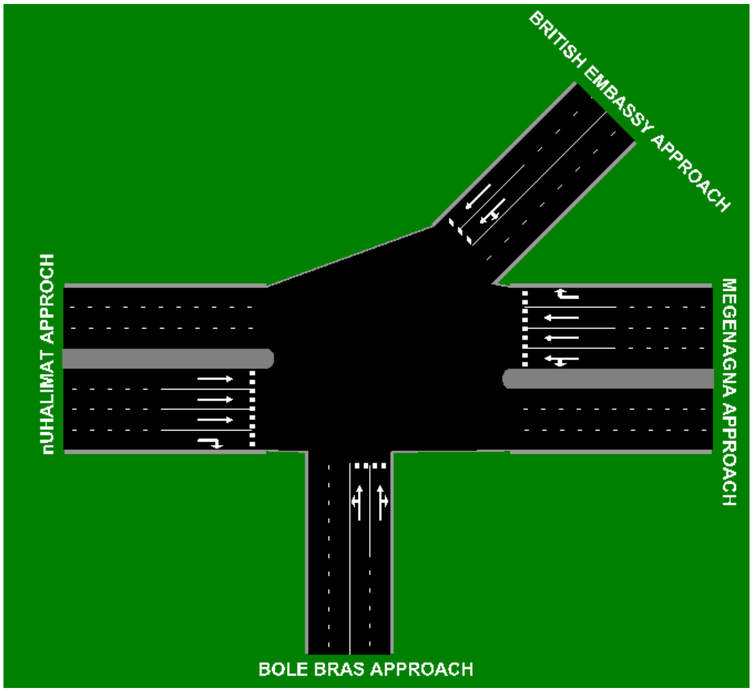

Figure 48: Haihulet Intersection Geometry using aaSIDRA

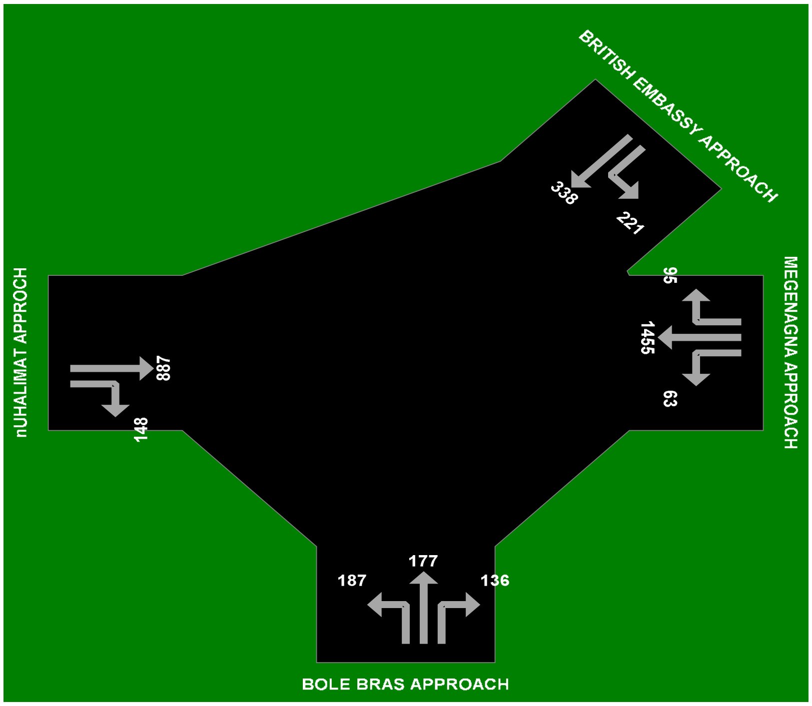

Figure 49: Total Directional Demand flow at Haihulet intersection

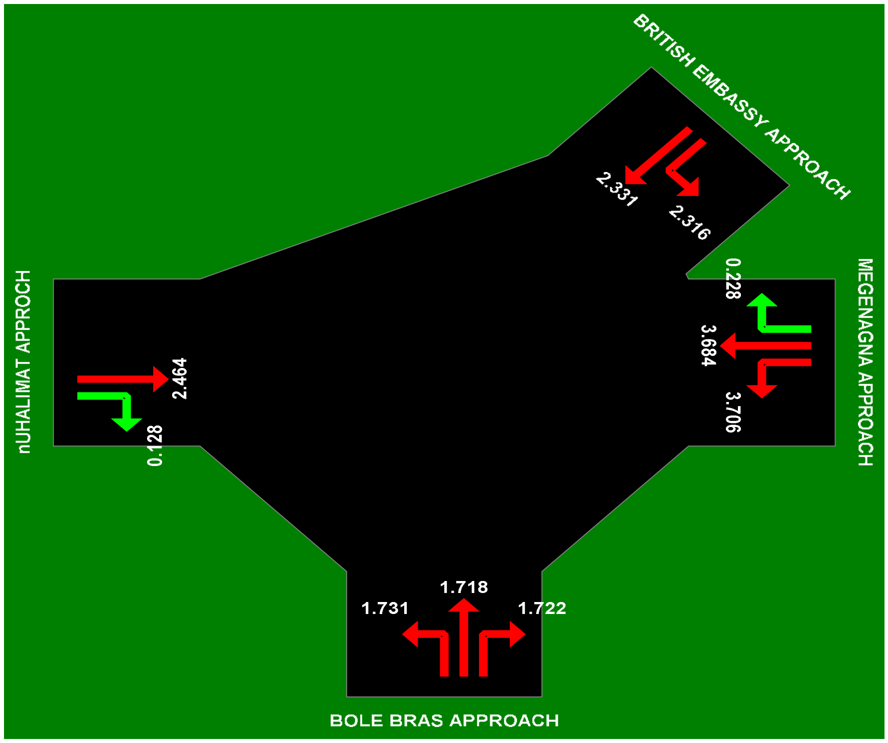

Figure 50: Degree of Saturation at Haihulet Intersection

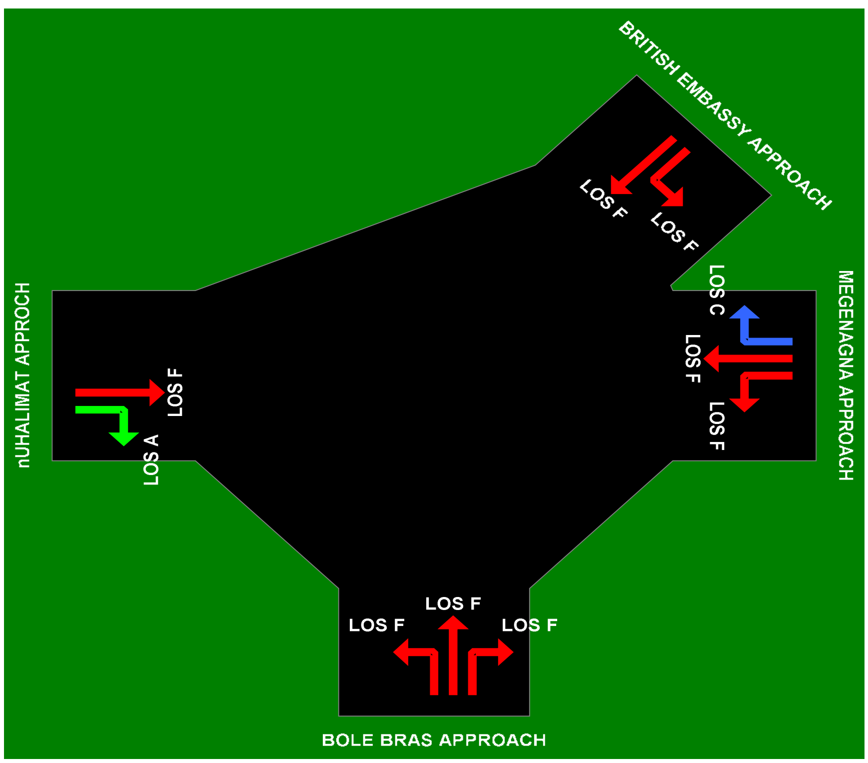

Figure 51: Leg & lane Level of Service of Haihulet Intersection

Title HAIHULET INTERSECTION ANALYSIS
Subtitle
Intersection ID: INT-3
Give-Way Sign Controlled Intersection

Table S.14 - SUMMARY OF INPUT AND OUTPUT DATA

Lane No.	Demand Flow (veh/h) L	T	R	Tot	%HV	Adj. Basic Satf.	Eff Grn (secs) 1st	2nd	Deg Sat x	Aver. Delay (sec)	Longest Queue (m)	Shrt Lane (m)
South: BOLE BRAS APPROACH												
1 LT	187	20		207	1				1.724	416.0	446	
2 TR		157	136	293	2				1.724	391.3	510	
	187	177	136	500	1				1.724	401.5	510	
East: MEGENAGNA APPROACH												
1 LT	63	467		530	2				3.680	1264.3	952	
2 T		494		494	2				3.680	1268.5	892	
3 T		494		494	2				3.680	1268.5	892	
4 R			94	94	1				0.228	11.3	8	
	63	1455	94	1612	2				3.680	1193.8	952	
NorthEast: BRITISH EMBASSY APPROACH												
1 LT	220	59		279	2				2.325	674.9	573	
2 T		279		279	1				2.325	674.9	545	
	220	338	0	558	2				2.325	674.9	573	
West: nUHALIMAT APPROCH												
1 T		296		296	2				2.464	735.9	459	
2 T		296		296	2				2.464	735.9	459	
3 T		296		296	2				2.464	735.9	459	
4 R			148	148	1				0.128	3.6	5	
	0	887	148	1035	2				2.464	631.2	459	

ALL VEHICLES	Total Flow	% HV	Max X	Aver. Delay	Max Queue
	3705	2	3.706	851.6	952

Total flow period = 60 minutes. Peak flow period = 15 minutes.

Queue values in this table are 95% back of queue (metres).

Title HAIHULET INTERSECTION ANALYSIS
Subtitle
Intersection ID: INT-3
Give-Way Sign Controlled Intersection

Table S.15 - CAPACITY AND LEVEL OF SERVICE

Mov No.	Mov Typ	Total Flow (veh /h)	Total Cap. (veh /h)	Deg. of Satn (v/c)	Aver. Delay (sec)	LOS	Longest Queue 95% Back (vehs)	(m)
South: BOLE BRAS APPROACH								
1	L	187	108	1.731	416.0	F	63.2	446
2	T	177	103	1.718	394.0	F	71.9	510
3	R	136	79	1.722	391.3	F	71.9	510
		500		1.731	401.5	F	71.9	510
East: MEGENAGNA APPROACH								
4	L	63	17	3.706*	1264.3	F	133.9	952
5	T	1455	395	3.684	1267.1	F	133.9	952
6	R	94	413	0.228	11.3	C	1.1	8
		1612		3.706	1193.8	F	133.9	952
NorthEast: BRITISH EMBASSY APPROACH								
24	L	220	95	2.316	674.9	F	80.7	573
25	T	338	145	2.331	674.9	F	80.7	573
		558		2.331	674.9	F	80.7	573
West: nUHALIMAT APPROCH								
11	T	887	360	2.464	735.9	F	64.2	459
12	R	148	1158	0.128	3.6	A	0.7	5
		1035		2.464	631.2	F	64.2	459
ALL VEHICLES:		3705		3.706	851.6	NA	133.9	952

Level of Service calculations are based on
average control delay including geometric delay (HCM criteria),
independent of the current delay definition used.
For the criteria, refer to the "Level of Service" topic in the
aaSIDRA Output Guide or the Output section of the on-line help.

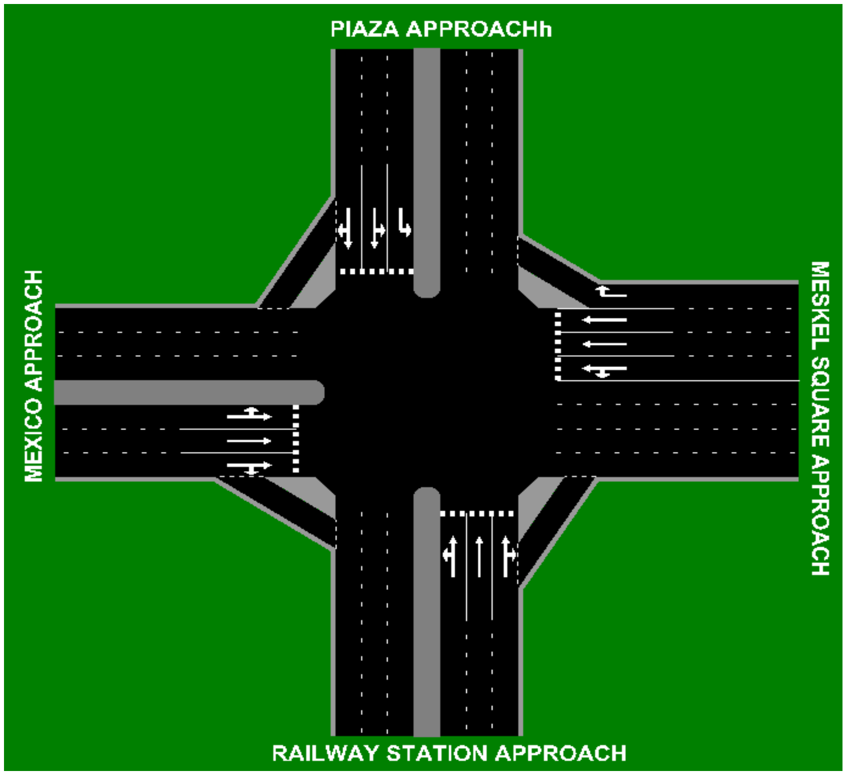

Figure 52: Legehar intersection Geometry using aaSIDRA

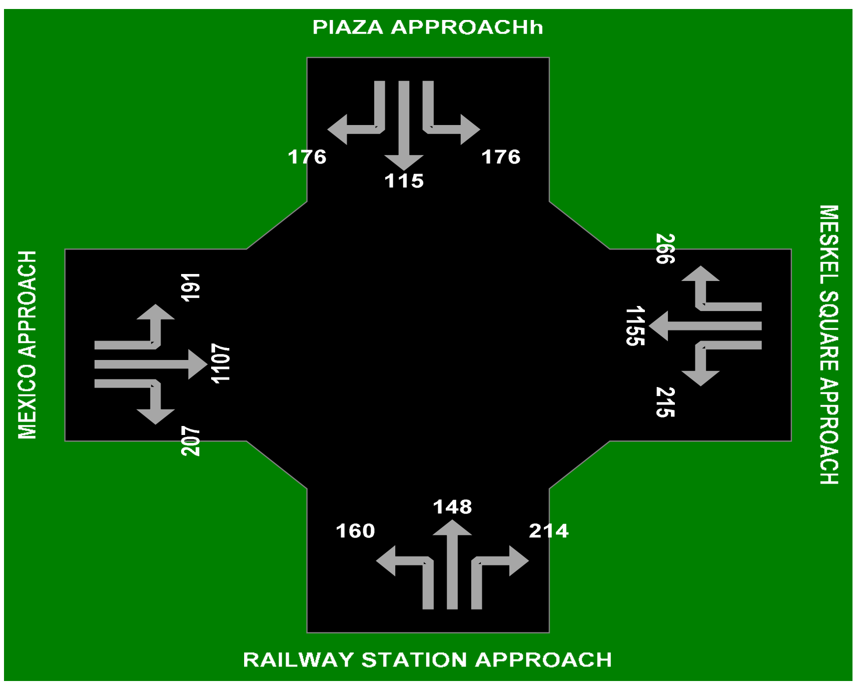

Figure 53: Total Directional hourly Demand flow at Legehar intersection

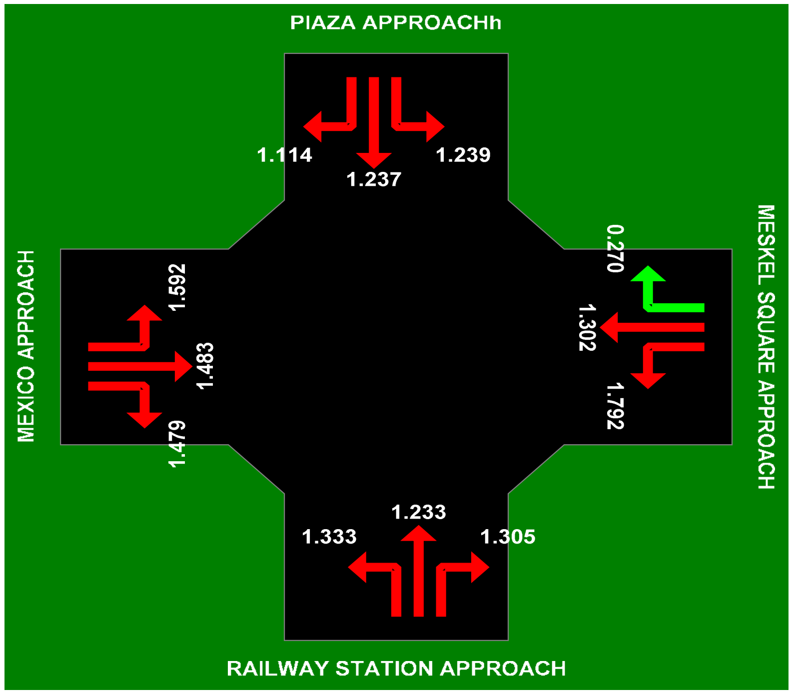

Figure 54: Lane degree of saturation for Legehar intersection

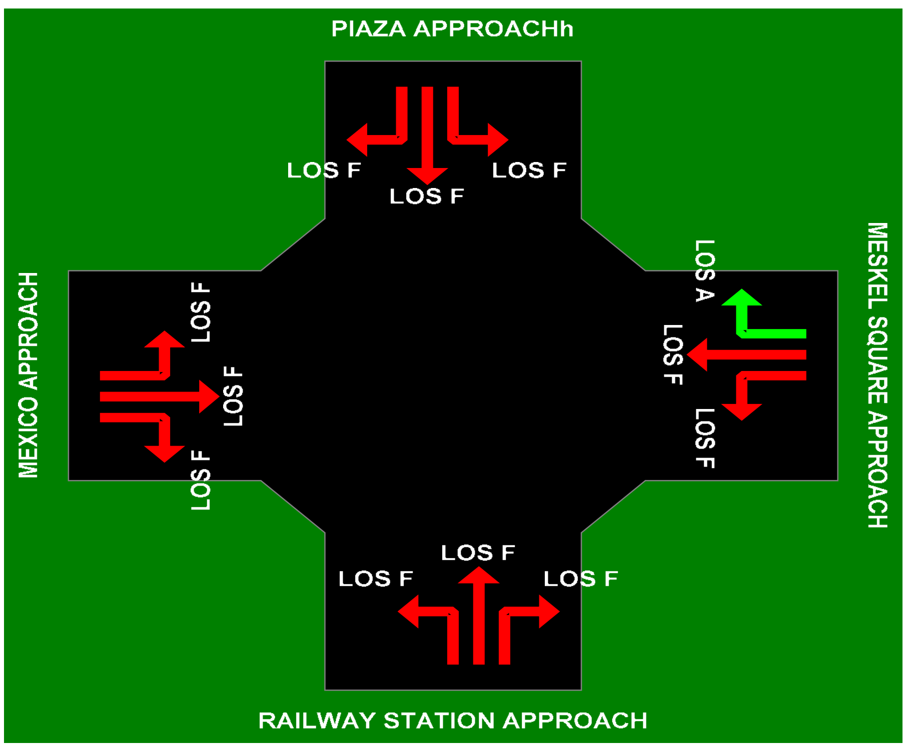

Figure 55: Leg and lane Level of Service for Legehar Intersection

Title LEGEHAR INTERSECTION ANALYSIS
Subtitle
Intersection ID: INT-2
Give-Way Sign Controlled Intersection

Table S.14 - SUMMARY OF INPUT AND OUTPUT DATA

Lane No.	Demand Flow (veh/h) L	T	R	Tot	%HV	Adj. Basic Satf.	Eff Grn (secs) 1st	2nd	Deg Sat x	Aver. Delay (sec)	Longest Queue (m)	Shrt Lane (m)
South: RAILWAY STATION APPROACH												
1 L	160			160	4				1.333	258.7	492	
2 T		148		148	9				1.233	221.8	540	
3 R			214	214	13				1.304	223.0	189	
	160	148	214	522	9				1.333	233.6	540	
East: MESKEL SQUARE APPROACH												
1 L	215			215	11				1.792	444.6	291	
2 T		578		578	1				1.301	172.6	379	
3 T		578		578	1				1.301	172.6	379	
4 R			267	267	3				0.270	5.0	11	
	215	1155	267	1637	3				1.792	181.0	379	
North: PIAZA APPROACHh												
1 L	115			115	1				0.990	146.5	366	U
2 LT	61	87		148	7				1.237	223.3	506	
3 TR		28	176	204	2				1.114	147.8	401	U
	176	115	176	467	3				1.237	171.5	506	
West: MEXICO APPROACH												
1 L	191			191	2				1.592	361.1	216	
2 T		600		600	0				1.483	250.7	503	
3 TR		506	207	713	5				1.483	245.7	627	
	191	1106	207	1504	3				1.592	262.4	627	

ALL VEHICLES	Total Flow	% HV	Max X	Aver. Delay	Max Queue
	4130	4	1.792	216.2	627

Total flow period = 60 minutes. Peak flow period = 15 minutes.

Queue values in this table are 95% back of queue (metres).

Note: Basic Saturation Flows are not adjusted at roundabouts or sign-

Title LEGEHAR INTERSECTION ANALYSIS
Subtitle
Intersection ID: INT-2
Give-Way Sign Controlled Intersection

Table S.15 - CAPACITY AND LEVEL OF SERVICE

Mov No.	Mov Typ	Total Flow (veh /h)	Total Cap. (veh /h)	Deg. of Satn (v/c)	Aver. Delay (sec)	LOS	Longest Queue 95% Back (vehs)	(m)
South: RAILWAY STATION APPROACH								
1	L	160	120	1.333	258.7	F	67.8	492
2	T	148	120	1.233	221.8	F	71.4	540
3	R	214	164	1.305	223.0	F	24.2	189
		522		1.333	233.6	F	71.4	540
East: MESKEL SQUARE APPROACH								
4	L	215	120	1.792*	444.6	F	38.1	291
5	T	1155	887	1.302	172.6	F	53.5	379
6	R	267	990	0.270	5.0	A	1.5	11
		1637		1.792	181.0	F	53.5	379
North: PIAZA APPROACHh								
7	L	176	142	1.239	173.2	F	68.4	506
8	T	115	93	1.237	205.0	F	68.4	506
9	R	176	158	1.114	147.8	F	56.1	401
		467		1.239	171.5	F	68.4	506
West: MEXICO APPROACH								
10	L	191	120	1.592	361.1	F	30.3	216
11	T	1106	746	1.483	248.4	F	85.6	627
12	R	207	140	1.479	245.7	F	85.6	627
		1504		1.592	262.4	F	85.6	627
ALL VEHICLES:		4130		1.792	216.2	NA	85.6	627

Level of Service calculations are based on average control delay including geometric delay (HCM criteria), independent of the current delay definition used.
For the criteria, refer to the "Level of Service" topic in the aaSIDRA Output Guide or the Output section of the on-line help.

Figure 56: URAEL Intersection Geometry using aaSIDRA

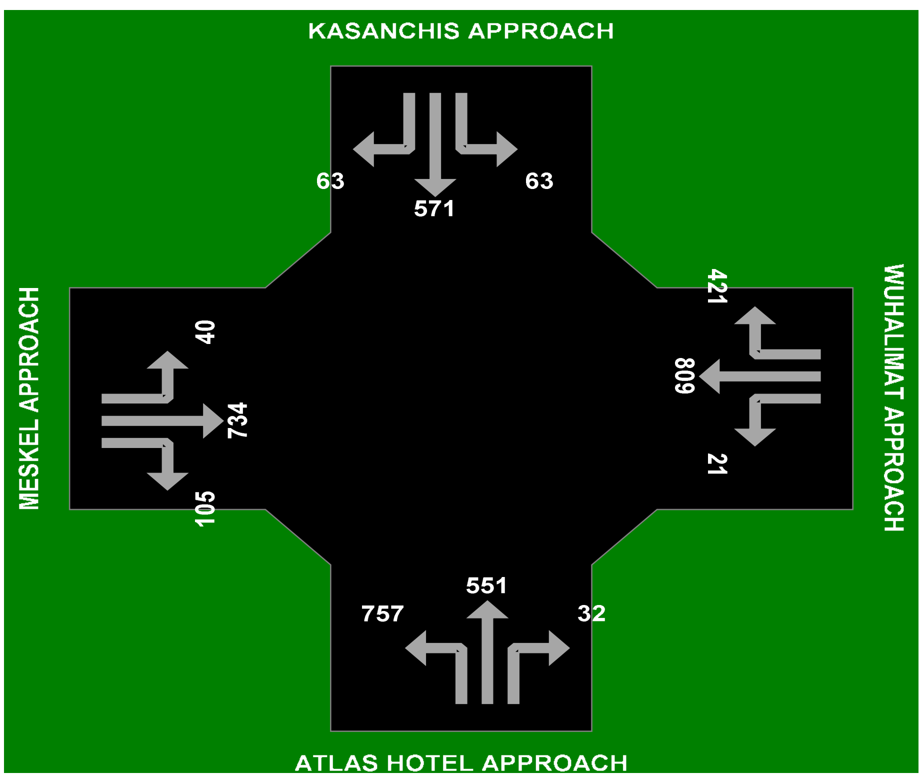

Figure 57: Total hourly directional demand flow for URAEL

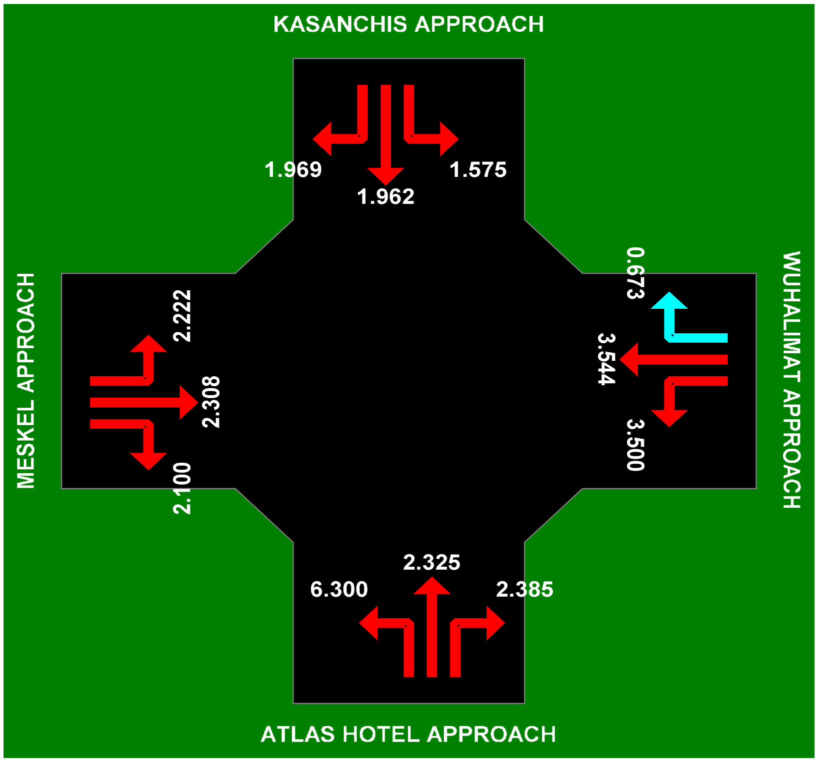

Figure 58: Degree of saturation of URAEL intersection

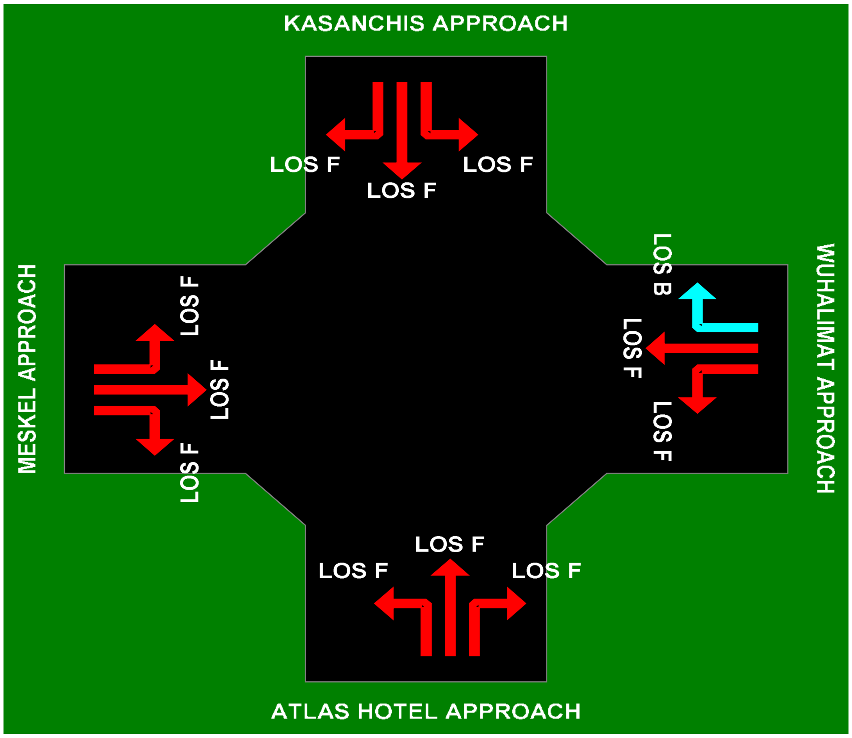

Figure 59: Leg & lane Level of Service at URAEL intersection

Title URAEL CHURCH INTERSECTION
Subtitle
Intersection ID: INT-1
Give-Way Sign Controlled Intersection

Table S.14 - SUMMARY OF INPUT AND OUTPUT DATA

Lane No.	Demand Flow (veh/h) L	T	R	Tot	%HV	Adj. Basic Satf.	Eff Grn (secs) 1st	2nd	Deg Sat x	Aver. Delay (sec)	Longest Queue (m)	Shrt Lane (m)
South: ATLAS HOTEL APPROACH												
1 L	756			756	0				6.300	2450.1	1572	
2 T		279		279	1				2.327	675.9	434	
3 TR		272	31	303	1				2.327	670.1	468	
	756	551	31	1338	0				6.300	1677.1	1572	
East: WUHALIMAT APPROACH												
1 LT	21	383		404	2				3.366	1135.6	715	U
2 T		425		425	2				3.543	1214.6	765	
3 R			421	421	2				0.538	9.8	34	
	21	808	421	1250	2				3.543	783.3	765	
North: KASANCHIS APPROACH												
1 LT	63	125		188	1				1.569	351.9	295	U
2 T		235		235	0				1.961	517.0	405	
3 TR		210	63	273	1				1.961	505.9	464	
	63	571	63	697	0				1.961	468.1	464	
West: MESKEL APPROACH												
1 LT	40	223		263	2				2.195	618.2	391	U
2 T		277		277	2				2.311	668.7	414	
3 TR		233	105	338	2				2.080	547.4	456	U
	40	734	105	879	2				2.311	606.9	456	

ALL VEHICLES	Total Flow	% HV	Max X	Aver. Delay	Max Queue
	4164	1	6.300	980.5	1572

Total flow period = 60 minutes. Peak flow period = 15 minutes.

Queue values in this table are 95% back of queue (metres).

Title URAEL CHURCH INTERSECTION
Subtitle
Intersection ID: INT-1
Give-Way Sign Controlled Intersection

Table S.15 - CAPACITY AND LEVEL OF SERVICE

Mov No.	Mov Typ	Total Flow (veh /h)	Total Cap. (veh /h)	Deg. of Satn (v/c)	Aver. Delay (sec)	LOS	Longest Queue 95% Back (vehs)	Longest Queue 95% Back (m)
South: ATLAS HOTEL APPROACH								
1	L	756	120	6.300*	2450.1	F	224.4	1572
2	T	551	237	2.325	673.1	F	66.4	468
3	R	31	13	2.385	670.1	F	66.4	468
		1338		6.300	1677.1	F	224.4	1572
East: WUHALIMAT APPROACH								
4	L	21	6	3.500	1135.6	F	100.2	715
5	T	808	228	3.544	1177.2	F	107.3	765
6	R	421	626	0.673	9.8	B	4.8	34
		1250		3.544	783.3	F	107.3	765
North: KASANCHIS APPROACH								
7	L	63	40	1.575	351.9	F	41.9	295
8	T	571	291	1.962	476.7	F	66.0	464
9	R	63	32	1.969	505.9	F	66.0	464
		697		1.969	468.1	F	66.0	464
West: MESKEL APPROACH								
10	L	40	18	2.222	618.2	F	54.9	391
11	T	734	318	2.308	614.8	F	64.3	456
12	R	105	50	2.100	547.4	F	64.3	456
		879		2.308	606.9	F	64.3	456
ALL VEHICLES:		4164		6.300	980.5	NA	224.4	1572

Level of Service calculations are based on average control delay including geometric delay (HCM criteria), independent of the current delay definition used.
For the criteria, refer to the "Level of Service" topic in the aaSIDRA Output Guide or the Output section of the on-line help.

APPENDIX C: CONGESTION ANALYSIS SHEET

LIDETA -MEXICO - MIDBLOCK ANALYSIS

Corridor Name LIDETA -MEXICO-MIDBLOCK Date: ____________

Corridor Length 350m Page No. ____________

Duration	Average travel Time (S)	Delay (s)	Average Travel Speed (km/h)	Travel Rate (min/Km)	Delay Rate (min/Km)	Travel Time Index	Traffic Volume (Vec)	Average Vehicle Occupancy (persons/veh)	Travel Time (Person - Min)	Total Segment Delay (Vehicle-Min)	Total Segment Delay (Person-Min)	Delay Per Traveler (Annual Hours)	Delay Ratio
8:30-8:45 AM	549.65	489.25	2.29	26.17	23.30	9.10	233	10.79	23,024.76	1,899.91	20,494.60	33.98	0.89
8:45-9:00 AM	201.85	141.45	6.24	9.61	6.74	3.34	227	9.03	6,897.40	535.15	4,833.48	9.82	0.70
9:00-9:15 AM	149.75	89.35	8.41	7.13	4.25	2.48	243	12.53	7,596.51	361.87	4,532.54	6.20	0.60
9:15-9:30 AM	398.10	337.70	3.17	18.96	16.08	6.59	195	15.87	20,533.78	1,097.53	17,418.38	23.45	0.85
9:30-9:45 AM	478.30	417.90	2.63	22.78	19.90	7.92	182	12.52	18,157.92	1,267.63	15,864.92	29.02	0.87
9:45-10:00 AM	489.60	429.20	2.57	23.31	20.44	8.11	157	10.60	13,577.70	1,123.07	11,902.67	29.81	0.88
10:00-10:15 AM	453.60	393.20	2.78	21.60	18.72	7.51	167	12.34	15,578.72	1,094.41	13,504.31	27.31	0.87
10:15-10:30 AM	315.60	255.20	3.99	15.03	12.15	5.23	163	11.34	9,724.33	693.29	7,863.28	17.72	0.81
10:30-10:45 AM	140.00	79.60	9.00	6.67	3.79	2.32	172	14.42	5,786.77	228.19	3,290.19	5.53	0.57
10:45-11:00 AM	187.40	127.00	6.72	8.92	6.05	3.10	156	10.00	4,871.55	330.20	3,301.42	8.82	0.68
11:00-11:15 AM	470.20	409.80	2.68	22.39	19.51	7.78	187	12.69	18,589.46	1,277.21	16,201.53	28.46	0.87
11:15-11:30 AM	365.40	305.00	3.45	17.40	14.52	6.05	149	11.45	10,386.25	757.42	8,669.42	21.18	0.83
11:30-11:45 AM	287.80	227.40	4.38	13.70	10.83	4.76	143	12.31	8,446.36	541.97	6,673.74	15.79	0.79
11:45-12:00 AM	284.20	223.80	4.43	13.53	10.66	4.71	126	12.88	7,689.89	469.98	6,055.58	15.54	0.79

Duration	Average travel Time (S)	Delay (s)	Average Travel Speed (km/h)	Travel Rate (min/Km)	Delay Rate (min/Km)	Travel Time Index	Traffic Volume (Vec)	Average Vehicle Occupancy (persons/veh)	Travel Time (Person - Min)	Total Segment Delay (Vehicle-Min)	Total Segment Delay (Person-Min)	Delay Per Traveler (Annual Hours)	Delay Ratio
12:00-00:15PM	182.20	121.80	6.92	8.68	5.80	3.02	163	9.36	4,632.45	330.89	3,096.77	8.46	0.67
12:15-12:30 PM	96.20	35.80	13.10	4.58	1.70	1.59	151	11.80	2,856.71	90.10	1,063.10	2.49	0.37
12:30-12:45 PM	101.00	40.60	12.48	4.81	1.93	1.67	162	7.70	2,098.99	109.62	843.75	2.82	0.40
12:45-1:00 PM	60.40	0.00	20.86	2.88	0.00	1.00	146	9.58	1,408.32	-	-	-	-
1:00-1:15 PM	61.80	1.40	20.39	2.94	0.07	1.02	168	10.29	1,781.28	3.92	40.35	0.10	0.02
1:15 -1:30 PM	68.80	8.40	18.31	3.28	0.40	1.14	154	16.37	2,891.08	21.56	352.98	0.58	0.12
1:30 -1:45 PM	74.00	13.60	17.03	3.52	0.65	1.23	132	12.59	2,050.46	29.92	376.84	0.94	0.18
1:45-2:00 PM	74.00	13.60	17.03	3.52	0.65	1.23	149	10.51	1,930.68	33.77	354.83	0.94	0.18
2:00-2:15 PM	77.20	16.80	16.32	3.68	0.80	1.28	188	11.68	2,825.48	52.64	614.87	1.17	0.22
2:15-2:30 PM	90.40	30.00	13.94	4.30	1.43	1.50	170	10.35	2,651.19	85.00	879.82	2.08	0.33
2:30 -2:45 PM	120.80	60.40	10.43	5.75	2.88	2.00	120	5.51	1,330.23	120.80	665.11	4.19	0.50
2:45-3:00 PM	108.00	47.60	11.67	5.14	2.27	1.79	205	10.16	3,749.32	162.63	1,652.48	3.31	0.44
3:00-3:15 PM	117.60	57.20	10.71	5.60	2.72	1.95	407	24.15	19,265.40	388.01	9,370.58	3.97	0.49
3:15-3:30 PM	137.60	77.20	9.16	6.55	3.68	2.28	146	11.95	4,001.41	187.85	2,244.98	5.36	0.56
3:30-3:45 PM	203.60	143.20	6.19	9.70	6.82	3.37	191	12.10	7,841.39	455.85	5,515.16	9.94	0.70
3:45-4:00 PM	221.20	160.80	5.70	10.53	7.66	3.66	179	10.20	6,731.78	479.72	4,893.63	11.17	0.73
4:00-4:15 PM	201.20	140.80	6.26	9.58	6.70	3.33	206	11.37	7,853.86	483.41	5,496.14	9.78	0.70
4:15-4:30PM	242.40	182.00	5.20	11.54	8.67	4.01	199	11.27	9,063.79	603.63	6,805.32	12.64	0.75
4:30-4:45 PM	127.20	66.80	9.91	6.06	3.18	2.11	219	11.63	5,399.99	243.82	2,835.84	4.64	0.53
4:45-5:00 PM	126.80	66.40	9.94	6.04	3.16	2.10	167	11.73	4,141.12	184.81	2,168.54	4.61	0.52

MEXICO - LEGEHAR MIDBLOCK ANALYSIS

Corridor Name MEXICO-LEGEHAR MIDBLOCK — Date: ______

Corridor Length (m) 100 — Page No. ______

Duration	Average travel Time (S)	Delay (s)	Average Travel Speed (km/h)	Travel Rate (min/Km)	Delay Rate (min/Km)	Travel Time Index	Traffic Volume (Vec)	Average Vehicle Occupancy (persons/veh)	Travel Time (Person - Min)	Total Segment Delay (Vehicle-Min)	Total Segment Delay (Person-Min)	Delay Per Traveler (Annual Hours)	Delay Ratio
2:15-2:30 PM	50.20	50.20	7.17	8.37	0.00	1.00	168	12.32	1,732.14	140.56	1,732.14	3.49	0.00
2:30 -2:45 PM	102.80	102.80	3.50	17.13	8.77	2.05	214	12.07	4,426.57	366.65	4,426.57	7.14	0.51
2:45-3:00 PM	58.10	58.10	6.20	9.68	1.32	1.16	259	8.20	2,055.62	250.80	2,055.62	4.03	0.14
3:00-3:15 PM	93.50	93.50	3.85	15.58	7.22	1.86	239	8.68	3,233.34	372.44	3,233.34	6.49	0.46
3:15-3:30 PM	70.50	70.50	5.11	11.75	3.38	1.40	243	7.77	2,219.51	285.53	2,219.51	4.90	0.29
3:30-3:45 PM	70.50	70.50	5.11	11.75	3.38	1.40	235	7.31	2,017.44	276.13	2,017.44	4.90	0.29
3:45-4:00 PM	68.10	68.10	5.29	11.35	2.98	1.36	225	7.61	1,943.94	255.38	1,943.94	4.73	0.26
4:00-4:15 PM	68.10	68.10	5.29	11.35	2.98	1.36	225	8.16	2,083.94	255.38	2,083.94	4.73	0.26
4:15-4:30PM	161.60	161.60	2.23	26.93	18.57	3.22	262	9.63	6,792.28	705.65	6,792.28	11.22	0.69
4:30-4:45 PM	117.50	117.50	3.06	19.58	11.22	2.34	221	10.58	4,577.09	432.79	4,577.09	8.16	0.57
4:45-5:00 PM	128.60	128.60	2.80	21.43	13.07	2.56	235	12.48	6,288.32	503.68	6,288.32	8.93	0.61
5:00-5:15 PM	176.8	176.80	2.04	29.47	21.10	3.52	245	8.88	6,412.45	721.93	6,412.45	12.28	0.72
5:15-5:30 PM	178.3	178.30	2.02	29.72	21.35	3.55	247	10.04	7,368.19	734.00	7,368.19	12.38	0.72
5:30-5:45PM	283.8	283.80	1.27	47.30	38.93	5.65	232	9.00	9,871.75	1,097.36	9,871.75	19.71	0.82
5:45-6:00 PM	178.6	178.60	2.02	29.77	21.40	3.56	230	7.13	4,883.62	684.63	4,883.62	12.40	0.72

LEGEHAR - MEXICO - MIDBLOCK ANALYSIS

Corridor Name LEGEHAR - MEXICO- MIDBLOCK Date: ________

Corridor Length (m) 100 Page No. ________

Duration	Average travel Time (S)	Delay (s)	Average Travel Speed (km/h)	Travel Rate (min/Km)	Delay Rate (min/Km)	Travel Time Index	Traffic Volume (Vec)	Average Vehicle Occupancy (persons/veh)	Travel Time (Person - Min)	Total Segment Delay (Vehicle-Min)	Total Segment Delay (Person-Min)	Delay Per Traveler (Annual Hours)	Delay Ratio
2:15-2:30 PM	24.90	24.90	14.46	4.15	0.22	1.06	246	5.83	594.91	5.33	31.06	0.09	0.05
2:30 -2:45 PM	33.00	33.00	10.91	5.50	1.57	1.40	270	10.84	1,609.01	42.30	458.32	0.65	0.28
2:45-3:00 PM	33.67	33.67	10.69	5.61	1.68	1.43	302	8.37	1,418.98	50.67	424.29	0.70	0.30
3:00-3:15 PM	34.40	34.40	10.47	5.73	1.80	1.46	263	7.36	1,110.46	47.34	348.63	0.75	0.31
3:15-3:30 PM	23.60	23.60	15.25	3.93	0.00	1.00	319	8.63	1,083.07	-	-	0.00	0.00
3:30-3:45 PM	23.90	23.90	15.06	3.98	0.05	1.01	309	7.72	949.93	1.54	11.92	0.02	0.01
3:45-4:00 PM	23.90	23.90	15.06	3.98	0.05	1.01	263	10.53	1,103.57	1.31	13.85	0.02	0.01
4:00-4:15 PM	23.86	23.86	15.09	3.98	0.04	1.01	249	11.69	1,157.49	1.07	12.48	0.02	0.01
4:15-4:30PM	24.43	24.43	14.74	4.07	0.14	1.04	234	7.08	674.07	3.23	22.86	0.06	0.03
4:30-4:45 PM	25.86	25.86	13.92	4.31	0.38	1.10	286	11.84	1,459.84	10.76	127.43	0.16	0.09
4:45-5:00 PM	26.67	26.67	13.50	4.44	0.51	1.13	254	12.61	1,423.61	12.98	163.71	0.21	0.12
5:00-5:15 PM	37.71	37.71	9.55	6.29	2.35	1.60	310	8.45	1,646.89	72.92	616.34	0.98	0.37
5:15-5:30 PM	116.00	116.00	3.10	19.33	15.40	4.92	281	11.64	6,325.40	432.74	5,038.51	6.42	0.80
5:30-5:45PM	173.50	173.50	2.07	28.92	24.98	7.35	365	11.87	12,529.72	911.89	10,825.39	10.41	0.86
5:45-6:00 PM	181.00	181.00	1.99	30.17	26.23	7.67	311	14.83	13,911.66	815.86	12,097.76	10.93	0.87

URAEL JUNCTION : HAIHULET - URAEL LEG ANALYSIS

Corridor Name HAIHULET- URAEL-LEG

Coridor Length (m) 150

Date:

Page No.

Duration	Average travel Time (S)	Delay (s)	Average Travel Speed (km/h)	Travel Rate (min/Km)	Delay Rate (min/Km)	Travel Time Index	Traffic Volume (Vec)	Average Vehicle Occupancy (persons/veh)	Travel Time (Person - Min)	Total Segment Delay (Vehicle-Min)	Total Segment Delay (Person-Min)	Delay Per Traveler (Annual Hours)	Delay Ratio
9:15-9:30 AM	116.30	77.80	4.64	12.92	8.64	3.02	656	9.01	11,450.28	850.61	7,659.77	5.40	0.67
9:30-9:45 AM	151.00	112.50	3.58	16.78	12.50	3.92	644	7.67	12,424.88	1,207.50	9,256.95	7.81	0.75
9:45-10:00 AM	174.80	136.30	3.09	19.42	15.14	4.54	741	10.39	22,440.35	1,683.31	17,497.82	9.47	0.78
10:00-10:15 AM	178.60	140.10	3.02	19.84	15.57	4.64	653	6.50	12,625.56	1,524.76	9,903.93	9.73	0.78
10:15-10:30 AM	192.80	154.30	2.80	21.42	17.14	5.01	565	7.64	13,864.28	1,452.99	11,095.74	10.72	0.80
10:30-10:45 AM	157.90	119.40	3.42	17.54	13.27	4.10	677	10.04	17,883.38	1,347.23	13,522.96	8.29	0.76
10:45-11:00 AM	173.30	134.80	3.12	19.26	14.98	4.50	672	7.33	14,227.61	1,509.76	11,066.83	9.36	0.78
11:00-11:15 AM	83.40	44.90	6.47	9.27	4.99	2.17	823	8.54	9,772.15	615.88	5,261.03	3.12	0.54
11:15-11:30 AM	128.30	89.80	4.21	14.26	9.98	3.33	623	9.49	12,645.51	932.42	8,850.87	6.24	0.70
11:30-11:45 AM	89.20	50.70	6.05	9.91	5.63	2.32	685	6.87	6,992.41	578.83	3,974.38	3.52	0.57
11:45-12:00 AM	72.60	34.10	7.44	8.07	3.79	1.89	678	7.66	6,285.11	385.33	2,952.10	2.37	0.47
12:00-00:15PM	118.20	79.70	4.57	13.13	8.86	3.07	656	8.17	10,562.99	871.39	7,122.42	5.53	0.67
12:15-12:30 PM	116.90	78.40	4.62	12.99	8.71	3.04	652	7.20	9,145.95	851.95	6,133.81	5.44	0.67
12:30-12:45 PM	95.50	57.00	5.65	10.61	6.33	2.48	712	8.66	9,817.23	676.40	5,859.50	3.96	0.60

Duration	Average travel Time (S)	Delay (s)	Average Travel Speed (km/h)	Travel Rate (min/Km)	Delay Rate (min/Km)	Travel Time Index	Traffic Volume (Vec)	Average Vehicle Occupancy (persons/veh)	Travel Time (Person - Min)	Total Segment Delay (Vehicle-Min)	Total Segment Delay (Person-Min)	Delay Per Traveler (Annual Hours)	Delay Ratio
12:45-1:00 PM	72.20	33.70	7.48	8.02	3.74	1.88	552	10.97	7,284.97	310.04	3,400.33	2.34	0.47
1:00-1:15 PM	65.40	26.90	8.26	7.27	2.99	1.70	651	8.28	5,874.99	291.87	2,416.47	1.87	0.41
1:15 -1:30 PM	65.40	26.90	8.26	7.27	2.99	1.70	730	7.22	5,746.67	327.28	2,363.69	1.87	0.41
1:30 -1:45 PM	68.00	29.50	7.94	7.56	3.28	1.77	737	11.20	9,355.39	362.36	4,058.59	2.05	0.43
1:45-2:00 PM	71.00	32.50	7.61	7.89	3.61	1.84	592	12.77	8,943.15	320.67	4,093.69	2.26	0.46
2:00-2:15 PM	72.00	33.50	7.50	8.00	3.72	1.87	673	9.39	7,587.25	375.76	3,530.18	2.33	0.47
2:15-2:30 PM	74.00	35.50	7.30	8.22	3.94	1.92	627	9.22	7,128.30	370.98	3,419.66	2.47	0.48
2:30 -2:45 PM	76.20	37.70	7.09	8.47	4.19	1.98	729	6.43	5,954.49	458.06	2,945.99	2.62	0.49
2:45-3:00 PM	178.50	140.00	3.03	19.83	15.56	4.64	580	7.30	12,600.90	1,353.33	9,883.06	9.72	0.78
3:00-3:15 PM	162.90	124.40	3.31	18.10	13.82	4.23	700	7.37	14,005.61	1,451.33	10,695.51	8.64	0.76
3:15-3:30 PM	141.40	102.90	3.82	15.71	11.43	3.67	710	8.01	13,395.84	1,217.65	9,748.46	7.15	0.73
3:30-3:45 PM	139.60	101.10	3.87	15.51	11.23	3.63	757	8.25	14,526.20	1,275.55	10,520.05	7.02	0.72
3:45-4:00 PM	115.00	76.50	4.70	12.78	8.50	2.99	602	8.00	9,233.08	767.55	6,142.01	5.31	0.67
4:00-4:15 PM	106.14	67.64	5.09	11.79	7.52	2.76	667	10.22	12,054.28	751.96	7,681.97	4.70	0.64
4:15-4:30PM	98.00	59.50	5.51	10.89	6.61	2.55	610	9.42	9,386.26	604.92	5,698.80	4.13	0.61
4:30-4:45 PM	75.70	37.20	7.13	8.41	4.13	1.97	654	10.08	8,316.22	405.48	4,086.70	2.58	0.49
4:45-5:00 PM	38.50	0.00	14.03	4.28	0.00	1.00	629	10.46	4,219.75	-	-	0.00	0.00
5:00-5:15 PM	91.90	53.40	5.88	10.21	5.93	2.39	612	10.55	9,891.83	544.68	5,747.81	3.71	0.58
5:15-5:30 PM	74.00	35.50	7.30	8.22	3.94	1.92	736	13.78	12,513.01	435.47	6,002.86	2.47	0.48
5:30-5:45PM	94.90	56.40	5.69	10.54	6.27	2.46	671	11.38	12,081.30	630.74	7,180.03	3.92	0.59
5:45-6:00 PM	86.40	47.90	6.25	9.60	5.32	2.24	730	11.57	12,167.05	582.78	6,745.39	3.33	0.55

URAEL JUNCTION : KASANCHIS - URAEL LEG ANALYSIS

Corridor Name KASANCHIS- URAEL-LEG Date: ________

Corridor Length 60m Page No. ________

Duration	Average travel Time (S)	Delay (s)	Average Travel Speed (km/h)	Travel Rate (min/Km)	Delay Rate (min/Km)	Travel Time Index	Traffic Volume (Vec)	Average Vehicle Occupancy (persons/veh)	Travel Time (Person - Min)	Total Segment Delay (Vehicle-Min)	Total Segment Delay (Person-Min)	Delay Per Traveler (Annual Hours)	Delay Ratio
9:30-9:45 AM	75.80	53.00	2.85	21.06	14.72	3.32	270	7.7	2,614.94	238.50	1,828.39	3.68	0.70
9:45-10:00 AM	76.40	53.60	2.83	21.22	14.89	3.35	248	10.4	3,282.58	221.55	2,302.96	3.72	0.70
10:00-10:15 AM	74.75	51.95	2.89	20.76	14.43	3.28	247	6.5	1,998.78	213.86	1,389.12	3.61	0.69
10:15-10:30 AM	39.57	16.77	5.46	10.99	4.66	1.74	234	7.6	1,178.53	65.41	499.49	1.16	0.42
10:30-10:45 AM	110.88	88.08	1.95	30.80	24.47	4.86	282	10.0	5,230.72	413.95	4,155.09	6.12	0.79
10:45-11:00 AM	113.60	90.80	1.90	31.56	25.22	4.98	313	7.3	4,343.97	473.67	3,472.12	6.31	0.80
11:00-11:15 AM	84.38	61.58	2.56	23.44	17.10	3.70	394	8.5	4,732.98	404.34	3,454.02	4.28	0.73
11:15-11:30 AM	105.40	82.60	2.05	29.28	22.94	4.62	261	9.5	4,352.36	359.33	3,410.86	5.74	0.78
11:30-11:45 AM	96.80	74.00	2.23	26.89	20.56	4.25	302	6.9	3,347.64	372.71	2,559.15	5.14	0.76
11:45-12:00 AM	121.60	98.80	1.78	33.78	27.44	5.33	352	7.7	5,465.41	579.63	4,440.64	6.86	0.81
12:00-00:15PM	108.86	86.06	1.98	30.24	23.90	4.77	328	8.2	4,864.03	470.45	3,845.26	5.98	0.79
12:15-12:30 PM	69.80	47.00	3.09	19.39	13.06	3.06	342	7.2	2,864.49	267.90	1,928.81	3.26	0.67
12:30-12:45 PM	56.29	33.49	3.84	15.63	9.30	2.47	304	8.7	2,470.46	169.66	1,469.73	2.33	0.59

Duration	Average travel Time (S)	Delay (s)	Average Travel Speed (km/h)	Travel Rate (min/Km)	Delay Rate (min/Km)	Travel Time Index	Traffic Volume (Vec)	Average Vehicle Occupancy (persons/veh)	Travel Time (Person - Min)	Total Segment Delay (Vehicle-Min)	Total Segment Delay (Person-Min)	Delay Per Traveler (Annual Hours)	Delay Ratio
12:45-1:00 PM	53.00	30.20	4.08	14.72	8.39	2.32	313	11.0	3,032.30	157.54	1,727.84	2.10	0.57
1:00-1:15 PM	23.13	0.32	9.34	6.42	0.09	1.01	324	8.3	1,033.89	1.76	14.53	0.02	0.01
1:15 -1:30 PM	22.80	0.00	9.47	6.33	0.00	1.00	303	7.2	831.56	-	-	0.00	0.00
1:30 -1:45 PM	40.88	18.08	5.28	11.35	5.02	1.79	292	11.2	2,228.06	87.97	985.25	1.26	0.44
1:45-2:00 PM	74.00	51.20	2.92	20.56	14.22	3.25	254	12.8	3,999.22	216.75	2,767.03	3.56	0.69
2:00-2:15 PM	115.75	92.95	1.87	32.15	25.82	5.08	296	9.4	5,364.75	458.55	4,308.02	6.45	0.80
2:15-2:30 PM	109.50	86.70	1.97	30.42	24.08	4.80	275	9.2	4,626.30	397.38	3,663.01	6.02	0.79
2:30 -2:45 PM	99.14	76.34	2.18	27.54	21.21	4.35	307	6.4	3,262.58	390.62	2,512.28	5.30	0.77
2:45-3:00 PM	98.00	75.20	2.20	27.22	20.89	4.30	264	7.3	3,148.95	330.88	2,416.33	5.22	0.77
3:00-3:15 PM	143.75	120.95	1.50	39.93	33.60	6.30	325	7.4	5,738.18	655.15	4,828.06	8.40	0.84
3:15-3:30 PM	135.50	112.70	1.59	37.64	31.31	5.94	354	8.0	6,400.37	664.93	5,323.40	7.83	0.83
3:30-3:45 PM	125.57	102.77	1.72	34.88	28.55	5.51	311	8.2	5,368.12	532.70	4,393.43	7.14	0.82
3:45-4:00 PM	116.29	93.49	1.86	32.30	25.97	5.10	258	8.0	4,001.28	401.99	3,216.75	6.49	0.80
4:00-4:15 PM	156.00	133.20	1.38	43.33	37.00	6.84	347	10.2	9,216.77	770.34	7,869.70	9.25	0.85
4:15-4:30PM	162.20	139.40	1.33	45.06	38.72	7.11	308	9.4	7,844.01	715.59	6,741.40	9.68	0.86
4:30-4:45 PM	139.20	116.40	1.55	38.67	32.33	6.11	353	10.1	8,254.03	684.82	6,902.08	8.08	0.84
4:45-5:00 PM	123.38	100.58	1.75	34.27	27.94	5.41	288	10.5	6,191.48	482.76	5,047.28	6.98	0.82

URAEL JUNCTION : ATLAS HOTEL - URAEL LEG ANALYSIS

Corridor Name ATLAS HOTEL- URAEL-LEG Date:

Corridor Length 250m Page No.

Duration	Average travel Time (S)	Delay (s)	Average Travel Speed (km/h)	Travel Rate (min/Km)	Delay Rate (min/Km)	Travel Time Index	Traffic Volume (Vec)	Average Vehicle Occupancy (persons/veh)	Travel Time (Person - Min)	Total Segment Delay (Vehicle-Min)	Total Segment Delay (Person-Min)	Delay Per Traveler (Annual Hours)	Delay Ratio
9:30-9:45 AM	208.0	147.60	4.33	13.87	9.84	3.44	319	9.7	10,759.87	784.74	7,635.37	10.25	0.71
9:45-10:00 AM	206.0	145.60	4.37	13.73	9.71	3.41	273	8.0	7,524.22	662.48	5,318.09	10.11	0.71
10:00-10:15 AM	156.0	95.60	5.77	10.40	6.37	2.58	261	8.2	5,536.85	415.86	3,393.10	6.64	0.61
10:15-10:30 AM	390.0	329.60	2.31	26.00	21.97	6.46	248	11.3	18,245.28	1,362.35	15,419.60	22.89	0.85
10:30-10:45 AM	375.0	314.60	2.40	25.00	20.97	6.21	300	9.0	16,931.49	1,573.00	14,204.39	21.85	0.84
10:45-11:00 AM	206.0	145.60	4.37	13.73	9.71	3.41	334	7.3	8,321.83	810.51	5,881.84	10.11	0.71
11:00-11:15 AM	141.0	80.60	6.38	9.40	5.37	2.33	423	9.6	9,544.73	568.23	5,456.06	5.60	0.57
11:15-11:30 AM	213.0	152.60	4.23	14.20	10.17	3.53	277	5.9	5,766.29	704.50	4,131.16	10.60	0.72
11:30-11:45 AM	216.0	155.60	4.17	14.40	10.37	3.58	324	7.8	9,064.18	840.24	6,529.57	10.81	0.72
11:45-12:00 AM	221.0	160.60	4.07	14.73	10.71	3.66	377	6.9	9,606.66	1,009.10	6,981.13	11.15	0.73
12:00-00:15PM	246.0	185.60	3.66	16.40	12.37	4.07	352	7.3	10,521.15	1,088.85	7,937.91	12.89	0.75
12:15-12:30 PM	320.0	259.60	2.81	21.33	17.31	5.30	364	6.8	13,109.36	1,574.91	10,634.97	18.03	0.81
12:30-12:45 PM	216.0	155.60	4.17	14.40	10.37	3.58	320	8.6	9,958.65	829.87	7,173.92	10.81	0.72

Duration	Average travel Time (S)	Delay (s)	Average Travel Speed (km/h)	Travel Rate (min/Km)	Delay Rate (min/Km)	Travel Time Index	Traffic Volume (Vec)	Average Vehicle Occupancy (persons/veh)	Travel Time (Person - Min)	Total Segment Delay (Vehicle-Min)	Total Segment Delay (Person-Min)	Delay Per Traveler (Annual Hours)	Delay Ratio
12:45-1:00 PM	175.0	114.60	5.14	11.67	7.64	2.90	338	6.4	6,287.57	645.58	4,117.46	7.96	0.65
1:00-1:15 PM	60.4	0.00	14.90	4.03	0.00	1.00	348	8.1	2,836.05	-	-	0.00	0.00
1:15 -1:30 PM	72.2	11.80	12.47	4.81	0.79	1.20	322	7.5	2,888.79	63.33	472.13	0.82	0.16
1:30 -1:45 PM	78.0	17.60	11.54	5.20	1.17	1.29	312	8.4	3,409.81	91.52	769.39	1.22	0.23
1:45-2:00 PM	86.5	26.10	10.40	5.77	1.74	1.43	267	8.9	3,427.19	116.15	1,034.10	1.81	0.30
2:00-2:15 PM	132.1	71.70	6.81	8.81	4.78	2.19	323	6.3	4,487.10	385.99	2,435.47	4.98	0.54
2:15-2:30 PM	157.2	96.80	5.73	10.48	6.45	2.60	291	7.6	5,761.00	469.48	3,547.49	6.72	0.62
2:30 -2:45 PM	220.8	160.40	4.08	14.72	10.69	3.66	348	6.0	7,649.45	930.32	5,556.94	11.14	0.73
2:45-3:00 PM	523.8	463.40	1.72	34.92	30.89	8.67	291	7.5	18,991.86	2,247.49	16,801.89	32.18	0.88
3:00-3:15 PM	622.8	562.40	1.45	41.52	37.49	10.31	360	6.1	22,807.54	3,374.40	20,595.63	39.06	0.90
3:15-3:30 PM	409.0	348.60	2.20	27.27	23.24	6.77	391	8.3	22,083.10	2,271.71	18,821.93	24.21	0.85
3:30-3:45 PM	572.4	512.00	1.57	38.16	34.13	9.48	348	7.8	25,906.99	2,969.60	23,173.26	35.56	0.89
3:45-4:00 PM	421.0	360.60	2.14	28.07	24.04	6.97	281	8.2	16,230.89	1,688.81	13,902.28	25.04	0.86
4:00-4:15 PM	214.4	154.03	4.20	14.30	10.27	3.55	272	7.1	6,925.94	698.26	4,975.05	10.70	0.72
4:15-4:30PM	147.2	86.80	6.11	9.81	5.79	2.44	347	8.1	6,863.29	501.99	4,047.10	6.03	0.59
4:30-4:45 PM	112.4	52.03	8.01	7.50	3.47	1.86	308	8.2	4,732.05	267.08	2,189.85	3.61	0.46
4:45-5:00 PM	117.6	57.17	7.65	7.84	3.81	1.95	253	8.8	4,374.24	241.07	2,127.06	3.97	0.49

APPENDIX D: TRAFFIC ACCIDENT DATA

TRAFFIC ACCIDENT DATA

Time of a day	Year										Total	Average Traffic Accident
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005		
01:00-02:00 AM	51	44	54	51	60	63	50	76	69	92	610	152.50
02:00-03:00 AM	47	21	36	43	54	33	48	64	79	76	501	125.25
03:00-04:00 AM	28	23	36	34	36	29	45	49	58	82	420	105.00
04:00-05:00 AM	12	25	38	31	24	32	34	37	65	57	355	88.75
05:00-06:00 AM	63	75	72	78	57	59	67	90	98	86	745	186.25
06:00-07:00 AM	161	181	232	191	180	167	158	222	228	171	1,891	472.75
07:00-08:00 AM	380	442	566	461	485	432	428	535	528	345	4,602	1,150.50
08:00-09:00 AM	435	497	583	517	540	484	591	673	763	710	5,793	1,448.25
09:00-10:00 AM	433	488	602	517	475	523	585	624	699	785	5,731	1,432.75
10:00-11:00 AM	395	442	617	478	463	515	582	670	746	770	5,678	1,419.50
11:00-12:00 AM	407	459	648	481	531	518	567	616	754	814	5,795	1,448.75
12:00-01:00 PM	380	425	479	402	407	465	512	533	639	759	5,001	1,250.25
01:00-02:00 PM	373	397	485	432	434	433	425	531	558	623	4,691	1,172.75
02:00-03:00 PM	342	447	548	509	479	459	447	535	687	605	5,058	1,264.50
03:00-04:00 PM	453	504	589	494	492	532	518	581	680	673	5,516	1,379.00
04:00-05:00 PM	450	504	593	561	488	453	483	590	685	679	5,486	1,371.50
05:00-06:00 PM	443	457	573	471	478	428	476	568	639	657	5,190	1,297.50
06:00-07:00 PM	301	335	429	339	330	352	357	396	530	688	4,057	1,014.25
07:00-08:00 PM	344	385	457	390	385	401	346	390	499	499	4,096	1,024.00
08:00-09:00 PM	239	245	297	286	263	287	312	287	422	484	3,122	780.50
09:00-10:00 PM	173	157	226	216	250	206	230	204	293	355	2,310	577.50
10:00-11:00 PM	123	121	190	179	156	162	168	158	218	221	1,696	424.00
11:00-12:00 PM	104	123	140	95	121	100	109	120	148	162	1,222	305.50
12:00 -01:00 AM	65	55	91	89	105	70	84	87	104	150	900	225.00
Total	**6,202**	**6,852**	**8,581**	**7,345**	**7,293**	**7,203**	**7,622**	**8,636**	**10,189**	**10,543**	**80,466**	