IMPACTS OF FREIGHT TRANSPORT AND LAND USE STRUCTURE ON URBAN TRAFFIC AND ENVIRONMENT: THE CASE OF ADDIS ABABA

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Abstract

Addis Ababa city entertains both inner urban goods distribution activity and cross urban freight movements which originate from one part of the country and destined either in Addis Ababa or crosses the city and moves to other part of the country. This frequent movement of freight vehicles on the city streets causes significant problem in exacerbating problems like congestion, pollution and accidents. Mismanagement and lack of knowledge on how these vehicles affect the city also aggravates these problems and makes cities unpleasant.

In this thesis the impacts of freight transport (both inter and intra urban freights) and urban land use structure on the overall traffic functions and urban environment were studied. This thesis mainly focused on the case of Addis Ababa to study the causes of freight and land use related problems, the level of their impact on the urban society and environment and develops appropriate recommendations and possible logistics options to overcome these problems. In doing so, main entry/exit corridors of the city were identified, main freight attraction areas of the city were pointed out and detailed study and analysis were made on the selected intersections in the identified freight areas. Besides these, interviews were made directly and questionnaires prepared and data were collected from stakeholders in the freight transport industry. These data were analyzed and its result interpreted and discussed to meet the objective of the thesis.

Accordingly, Bishoftu road is found to be the most busy entry/exit corridor of the city which accounts for more than 75% share of freight vehicles entering and leaving the city on a daily basis. The Akaki Kality sub city which is along this road corridor, Addis Ketema, Kolfe and Nifas silk Lafto sub cities are some of the major areas where dominant freight mobility were observed because of the concentration of market areas, warehouses, factories and different service providers. The capacity analysis carried out on Akaki Kality and 18-mazoria intersections clearly depicted that the high freight vehicular movement in these areas significantly affected the level of service of these intersections and aggravates pollution problems of the area. The number of traffic accidents caused by freight vehicles in the whole city of Addis Ababa has increased by 37.6% in the past five years. However, in Akaki Kality sub city the increase in number of freight related accidents is around 179%. The proportion (share) of number of accidents compared with other types of vehicles in this sub city is large which is about 57.4% in the year 2011/2012.

Furthermore lack of freight management practices and poor land use structure of the city have also contributed to the problems associated to the city traffic functions and environment. This study identified some of the major management and traffic operation challenges which aggravates these problems and ultimately suggested possible solutions that may alleviate these problems.

Key Words: - City logistics, Freight transport, Land use, Mobility, Environment, Safety

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Abbreviations

UGD – Urban goods Distribution
CDC – City Distribution Center
GDP – Gross Domestic Product
ILC - Integrated Logistics Center
UTS- Urban Transport Study
AACA- Addis Ababa City Administration
dB – deci Bell
EU – European Union
AASHTO – American Association of State Highways and Transport Officials
ERA – Ethiopian Roads Authority
AACRA – Addis Ababa City Roads Authority
UTS – Urban Transport Study
HCM – Highway Capacity Manual
GIS – Geographic Information System
GPS – Global Positioning System
Veh/h – Vehicle per Hour
HV – Heavy Vehicle
ADT – Average Daily Traffic
PFF – Peak Flow Factor
PFT – Peak Flow Time
4WD – Four Wheel Drive
LCV – Light Commercial Vehicle
LOS – Level of Service
NGO - Non Governmental Organization
WFP - World Food Program

1. Introduction

1.1. Background of the study

Freight transportation is the process of conveying different types of goods from one point to another using a variety of transport modes. The transport of freight can involve road solutions, air deliveries and even the use of waterways to move the freight from a point of origin to a point of destination. Freight transport in urban areas is of increasing interest and concern. Urban freight activities include tasks such as the transport of building materials, waste collection, retail deliveries and courier services. All these activities have been taken place using different types of vehicles and at different times of a day. Urban goods distribution (UGD) plays an important role in the sustainable development of cities [Macharis and Melo, 2011]. It helps to support urban life style, to serve and retain industrial and retailing activities and contributes to the competitiveness of industry in the region concerned [Anderson et al, (2005) as sited in Macharis and Melo, 2011]. Despite the relevant role of this activity, goods distribution also conflicts with other urban functions and thus generates negative (economic, environmental and social) impacts on the economic power, accessibility, quality of life and attractiveness of urban areas. The most common examples of such impacts at three dimensions of sustainability are: air pollution (environmental sustainability); fatalities, noise disturbance, local traffic safety (social sustainability); and journey unreliability and delivery delays (economic sustainability). Furthermore, goods traffic reduces the accessibility of passenger transport in urban areas and the efficiency of UGD process itself can be affected by congestion, in this way also affecting mobility in the area.

Despite the critical significance of logistics and freight distribution neither urban studies nor transport research has paid any particular attention to this subject until recently. According to Hesse, (2008) Spatial studies still lack a full understanding of logistics organization and freight distribution, which particularly applies to the role that cities and urban development play in this respect. In turn the relationships between logistics and spatial or urban development are usually neglected by industry stakeholders.

Transportation and land use are inexorably connected matters. Everything that happens to land use has transportation implication and every transportation action affects land use. Mobility is directly influenced by the layout of transportation network and the level of service it offers. Land development generates travel and travel generates the need for new facilities which in turn increases accessibility and attracts further development. The question of whether transportation influences development or weather land use dictates transportation has been a matter of ongoing concern among transportation professionals. Freight as one part of transportation activity takes its part in the interaction of the overall transportation system with the existing land use structure.

Addis Ababa is the capital of Ethiopia and often referred as the “political capital” of Africa due to its historical and diplomatic significance to the continent. The city is located at the center of the country on topography ranging from rolling to hilly areas with several rivers and stream gorges. [Yetnayet, 2012]. The city is extended over 540sq kms divided by 10 administrative sub cities. In recent times the city has significantly experienced a spatial spread mostly towards, south, south east, south west and eastern directions of the city. This spatial spread mainly guided by topography, road network, housing developments (ex, condominium and real-estate) and other types of developments made at the city fringes.

Currently Addis Ababa has been experiencing rapid changes in every aspects of development. However these changes vary spatially across the city. Economically the city is transforming from a predominantly administrative and service center to an industrial and financial center [Yetnayet, 2012]. Due to the rapid economic growth and changes, there is a high mobility of goods and passengers which in turn leads to high transportation demand.

Among these needs in transport, the growth in freight movement has not been given due concern so far. The overall socio-economic development and investment activities taking place around the city causes this abundant growth in freight transport which in turn affects the city’s overall traffic functionality by aggravating congestion, safety and mobility problems. So far profound studies concerning this issue of congestion and freight transport activity of the city has not been made except some which has been carried out in recent years. Although previous works done in this area can be a good starting ground to estimate the overall level of congestion and the contribution of freight transport in the city’s congestion, further studies which encompasses freight transport activity together with city’s land use structure is very necessary as transportation and land use are two highly interrelated factors in optimizing traffic functionality and realizing the overall city’s development.

Therefore the knowledge on the city’s freight transport behavior, its driving factor, the social, economic and environmental impacts of the freight sector, the scope and intensity of those impacts, urban land use and associated challenges and possible remedial measures on both freight transport and land use related challenges that ease the current problems of the city is very necessary for city and transport, freight carriers and the public in large.

1.2. Statement of the problem

The distribution of goods and services in urban areas has become challenging in recent years because of the rapid growth of urban population and economy. Urbanization becomes highly increasing in most areas of the world. A world-wide urbanization trend is emptying the countryside and small towns and is making large cities even larger [Benjelloun and Crainic, 2009]. Urban areas in most cases are narrow and serve large number of population with in a limited land area. This large number of communities needs the delivery of goods and services and collection and disposal of waste that makes urban streets busy and exposes them to different kinds of impacts.

According to Moazami and Noroozi, 2011 urban freight transport is closely associated with the quality of life within urban areas. There are various problems in this regard which are either caused or affecting the transportation of goods in cities. Insufficient infrastructure along with access restrictions prevent the goods vehicles to perform properly in city areas which in return may cause traffic and safety problems. On the other hand the congestion resulted from goods vehicles have negative impacts on people and freight accessibility which in return imposes extra costs for both passengers and freight companies. Freight transport affects the quality of life negatively also by its contribution to the emission of pollutants in local and global level and increase of the noise level in the neighbor areas. Safety is another angle in the life quality which is violated by transport of goods especially on roads inside urban areas. This problem might be the result of inadequate loading/unloading spaces, dangerous driving or the characteristics of the vehicle and the load.

One of the major problems for cities to reach sustainability is the urban freight transport [Behrends et al, 2007]. The goods and services movement is dominantly carried out by land transport using freight vehicles. Apart its considerable importance freight transportation is also a major disturbing factor to urban life. Freight vehicles compete for the street and parking space capacity and contribute significantly to congestion, accidents and environmental nuisances, such as emissions and noise. These nuisances impact the life of people living or working in cities, and the productivity of the firms located in urban zones and of the associated supply chains. They also contribute to the belief that “cities are not safe” that pushes numerous citizens to move out of the city limits. And the problem is not going to disappear any time soon [Benjelloun and Crainic, 2009].

The number and frequency of movement of freight vehicles within city limits is growing and is expected to continue to grow at a steady rate due, in particular, to the current production and distribution practices based on low inventories and the need for Just-In-Time deliveries, and the explosive growth of business-to customer electronic commerce that generates significant volumes of personal deliveries. In addition to these urban activities like construction of new buildings and other infrastructures or maintenance of the existing ones is being carried out intensively to increase the quality life the urban community is demanding. Most of the business and facility rehabilitation activities in urban areas take place around city centers where mobility is very challenging.

In contrast to the growth in their number and frequency of their movements, the level of growth in understanding and concern on the management systems on urban freight transport was very insignificant until recent years that aggravate the problem in most areas. However recently the urban community, the industry, and administrative officials at all levels of government are increasingly challenged by these issues and acknowledge the need to analyze, understand, and control freight transportation within urban areas to reduce its impact on living conditions, e.g., congestion and pollution, and increase mobility, while not penalizing the city activities. In particular, one aims to reduce the number of freight vehicles operating in the city, control their dimensions and characteristics, improve the efficiency of freight movements, and reduce the number of empty vehicle-km [Benjelloun and Crainic, 2009].

The structural land use pattern of the urban areas is the other source of impact in the overall traffic and travel behavior of most urban areas. As land is scarce in cities their distribution and use highly influences the transport activity. In cities with complex land use pattern it is highly likely that their transportation complexity is high with respect to those with well planned and coordinated cities. Since it is difficult to determine the travel behavior in cities with complex land use pattern, the traffic functions are significantly affected by the random movement of vehicles in the city area. Due to social, economic and technological changes in an urban area, physical changes happen in the urban form. These changes affect on urban freight transport due to the alteration of commodities, the location of departure and destination points, traffic flow, frequency of deliveries and the time of freight movements. (Ogden, 1992 as cited in Moazami and Noroozi, 2011)

In developing cities like Addis Ababa the problem associated to freight transport and land use is highly eminent. In Addis Ababa there is no distinct inner urban freight system that only serves the city area separated from the long haul freight vehicles transporting goods either from the port or from different parts of the country to the city or across the city to other destinations. Most warehouses, distribution centers, market areas and freight vehicle service providers like garages are located in city centers that attract all freight vehicles to the center. The business and construction activities in the city are rapidly increasing which in turn increase the number of freight vehicles with an alarming rate. Although there is currently an attempt to develop infrastructures like road networks in the city there is still a huge gap in developing freight facilities like terminals, separate parking areas, loading and unloading facilities in business and market areas. Majority of the existing ware houses are located in city centers and living areas where there is no enough space for parking and maneuvering freight vehicles that resulted in congestion, pollution and safety problems to the community of the city. Besides the warehouses there are lots of factories, distribution centers of different industries (like cement, soft drinks and etc) and heavy vehicle garages are situated in the areas that can be considered as centers.

In addition to the problems associated to infrastructure and land use discussed above, one of the current major problems of Addis Ababa is the traffic management and operation. The rules and regulations related to in urban traffic flow of the city are not closely evaluated and updated in such a way that they are compatible with the current development of the city and increase in vehicular traffic. Even on the existing rules and regulations there is significant implementation problem that aggravates the problem. There are also different operational problems associated to urban traffic in the city. There is a lack of availability and lack of quality in standards on the city traffic signs, signals and road markings. Even the existing ones are highly inefficient in services that worsen the traffic problems of the city.

So, the issues of freight transport management, land use improvements, freight related infrastructure developments and implementation of modern city logistics scheme is the area that has not been given a due concern by the public, freight companies, administrative officials and in general all relevant stakeholders so far. This negligence has caused significant problems like congestion, compressed mobility, frequent accidents, environmental pollution and aesthetically unpleasant city environment.

1.3. Literature Review

1.3.1. City Logistics

1.3.1.1. Overview

Scholars gave different definitions for the term "City Logistics" According to Taniguchi and Thompson "City Logistics is the process of totally optimizing the logistics and transport activities by private companies while considering the social, environmental, economic, financial and energy impacts of urban freight movement". Michael A.P Taylor defines City logistics as the study of the dynamic management and operations of urban freight transport and distribution systems. Scholars from China define City Logistics considering it as a regional logistics for meeting the demand of city economic development and the characteristics of city development. Accordingly Cheng Shi-Dong describes the term as the physical flow of goods in the city that gather and scatter goods between city and external region. The city logistics system serves demanders in the vast services area of city logistics. Thus city logistics system is an open logistics system. From this perspective City Logistics is the effective flow of various terms from suppliers to receivers inside the city or between the city and external areas, to meet the demand of people and economic activities in the city and the city logistics service area, called hinterland [LV Pu, et al, 2010].

According to European research and policy report on urban freight transport and logistics, city logistics entails the processes of transportation, handling and storage of goods, the management of inventory, waste and returns as well as home delivery services. Often many of these processes, or parts of them, are undertaken outside urban areas but they still have impacts on urban operations. Therefore, freight transport and logistics operations in urban areas cannot be viewed and studied in isolation but rather in the context of the entirety of supply chains that typically cross the geographical boundaries of urban areas.

City Logistics is a relatively new field of investigation brought by the challenges of moving growing quantities of freight within metropolitan areas [Dablanc and Rodrigue, 2009]. City Logistics initiatives are required to solve urban freight transport problems including high levels of traffic congestion, negative environmental impacts, high energy consumption and a shortage of labor [Taniguchi, 2001]. City logistics is involved in all the means over which freight distribution can take place in urban areas as well as the strategies that can improve its overall efficiency, such as mitigating congestion and environmental externalities. In its current implementations city logistics includes a subset of the following initiatives, combined and varied for compatibility with transport planning policies for a particular city: [Taylor, 2005]

- load factor controls underground freight transport systems
- traffic management plans
- advanced travel information systems
- cooperative freight transport systems (including local ‘freight brokers’)
- public logistics terminals (transshipment centers), sometimes termed ‘freight villages’

A typical City Logistics implementation will involve a combination of some or all of these initiatives, ensuring compatibility with the transport planning policies appropriate in the local area. City Logistics system would address the reverse movements, from origins within the city to destinations outside, as well as movement among origins and destinations within the city. Currently, however, most City Logistics contributions address in-bound distribution activities only, following the imbalance between entering and exiting flows that characterize most cities [Benjeloun and Crainic, 2009].

Urban freight represents 10 to 15% of vehicle equivalent miles traveled on city streets and 2 to 5% of the employed urban workforce 3 to 5% percent of urban land is devoted to freight transport and logistics [Dablanc and Rodrigue, 2009]. A city not only receives goods, but also ships them: 20 to 25% of truck-km in urban areas is outgoing freight, 40 to 50% is incoming freight, and the rest both originates from and is delivered within the city [Dablanc and Rodrigue, 2009]. The overall development of cities, their functional specializations, the global division of production, the rise of service activities as well as increasing standards of living are all correlated with a higher demand for transport and logistics services in cities, a higher frequency of deliveries, and larger quantities of freight shipments coming from, bound to or transiting through urban areas [Dablanc and Rodrigue, 2009]. The intensity of urban freight distribution depends on local economic, geographic, and cultural characteristics, which leads to different objectives and preoccupations in urban freight distribution.

1.3.1.2. Historical back ground and development of city logistics

Most of the early applications of city logistics were undertaken in Japan and Western Europe as these cities were more constrained by the lack of available land and had an established tradition pertaining to urban planning. Up to the 21st century the consideration of urban freight distribution within the planning discipline remained limited. This implies that urban planning generally does not pay much attention to issues related to urban freight distribution. The beginning of the 70's is a brief period of intense activity dedicated to urban freight transportation issues. This period yielded traffic regulation to avoid the presence of heavy vehicles in cities and limit the impact of freight transport on automobile movements. Very little activity took place from 1975 to the end of the 1980's [Benjeloun and Crainic, 2009].

Historically, the production and consumption of freight has dominantly taken place in cities, but with the industrial revolution and subsequently with globalization this share has increased [Dablanc and Rodrigue]. Since the distances involved in economic activities have increased, the function of distribution has taken a new significance, particularly with the setting of large terminal facilities such as ports, airports, rail yards and distribution centers. With containerization as a tool supporting international trade, intermodal terminals have become a notable element of the urban landscape and handling movements that are originating from, bound to or simply passing through a metropolitan area. The global urban and economic system has also become functionally specialized, permitting a global division of production and its associated freight volumes. Socioeconomic factors, such as rising income and consumerism should also not be neglected. All this incites a greater intensity and frequency of urban freight distribution and correspondingly improved forms, organization and management [Dablanc and Rodrigue].

A substantial school of thought concerning urban freight transport has emerged in recent times, known as ‘City Logistics’ [Taylor, 2005]. Its broad goals are to measure the performance of urban freight systems using multi-criteria analysis and to devise methods for optimizing the overall performance and impact of urban freight. The school has its origins in Japan, The Netherlands and Australia, but it now has adherents from around the world. City Logistics involves a combination of traffic simulation and travel demand methods and models, traffic management and control systems, and the application of ITS technologies to freight transport systems to solve problems of economic efficiency, social concerns, and environmental impacts [Taylor, 2005].

In recent years, in the industrialized countries, studies on urban freight movements have increased because freight transport is a major source of traffic congestion and nuisance including air and noise pollution and have adopted several approaches [ECOMM 2004].

1.3.1.3. Functional classes of city logistics

According to Dablanc and Rodrigue (2009), "All urban freight distribution systems involve a wide array of supply chains, each of various importances depending on the urban setting and the level of development, but coming into two main functional classes". The first as per Dablanc and Rodrigue (2009) is related to **consumer-related distribution**:

- **Independent retailing**. Concerns a wide variety of retailing activities, often of small scale (single store) and which can also take the form of more informal activities such as street stalls (prevalent in developing countries).
- **Chain retailing**. Concerns larger stores (such as "Big box" stores) that tend to be located in suburban locations, enabling them to offer parking space for their customers as well as dedicated delivery bays accommodating larger trucks.
- **Food deliveries**. Concern specialized supply chains supplying outlets (grocery stores and restaurants) with goods that are often perishable. In developing countries, outdoor (or central) markets are particularly important as they represent a dominant supply of fresh food for the urban population.
- **Parcel and home deliveries**. Due to the significant growth of transactional activities (e.g. trade, finance) the movement of parcels has increased on par with the companies specialized in these freight distribution services (e.g. UPS, DHL, TNT, and FedEx). Another emerging dimension concerns home deliveries, particularly with the growth of web-based retail transactions.

The second functional class of city logistics as per Dablanc and Rodrigue (2009) is related to **producer-related distribution**:

- **Construction sites**. The constant renewal and repair of urban infrastructures (e.g. housing, offices, and roads) requires a supply of materials to construction sites.
- **Waste collection and disposal**. Concerns the collection and disposal of the variety of wastes generated by daily urban activities. It is a form of reverse logistics since the waste being discarded were previously goods being delivered. To this can be added recycling activities, all of which using specialized vehicles.
- **Industrial and terminal haulage**. Industrial activities and transportation terminals such as ports, airports and rail yards generate a substantial amount of goods movements within cities. Gate access at intermodal terminals, particularly ports, can lead to congestion (queuing) and local disruptions. Logistics zones and industrial parks also generate substantial amounts of freight movements.

1.3.1.4. Diversity of City Logistics

Cities throughout the world are different and so are their freight transport and logistics activities [Dablanc and Rodrigue, 2009]. Because of the divergence in built environments, each city around the world has different freight transport and logistics activities and level of intensity. This brings the question about the specific size threshold after which urban freight distribution problems, such as delays and congestion, become more prevalent and thus requires a concerted approach [Dablanc and Rodrigue, 2009]. The unique and often non-replicable conditions of each city are influencing the nature and intensity of congestion in its urban freight distribution system. The share of public transit use, land use pattern and density and income levels are common factors relatively unique to each city. [Dablanc and Rodrigue, 2009]

Developed cities

According to Dablanc and Rodrigue, (2009) freight strategies have depended on local economic, geographic, and cultural characteristics. For example, Chicago has been preoccupied with maintaining its role as a rail hub for North America, and is thus concerned about rail freight movements between the numerous rail terminals located within the city, many of which done by trucks. Los Angeles is primarily concerned with air pollution, and thus targets urban trucking associated with the ports of Long Beach and Los Angeles. Shanghai is becoming the largest cargo port in the world and the fact that more than 13% of Shanghai's GDP is value added by logistics underscores the city's vocation as a transport hub [Dablanc and Rodrigue, 2009]. Paris. Aim to limit the environmental footprint of freight distribution so that the quality of life of its residents can be maintained and improved. Mexico. Trying to cope with the contradictory demands related to the dual presence of both modern (motorized) and traditional forms of urban distribution in terms of infrastructure provision and regulations. A European city generates about [Dablanc and Rodrigue, 2009]:

- Delivery or pick-up per job per week.
- 300 to 400 truck trips per 1000 people per day.
- 30 to 50 tons of goods per person per year.

Developing cities

Cities in developing countries are even more diverse, but have some common characteristics that imply specific urban freight issues. According to Dablanc, 2009 in poorer countries, rural migration and population growth have led to very rapid urbanization, while the public supply of infrastructure and transport services has lagged behind. A significant proportion of roads are unpaved and poorly maintained. The road networks are complicated that affected defining the travel behavior in the cities. Air pollution has decreased with the gradual phasing out of leaded gasoline. However, diesel trucks remain a major source of particulate matter and NOx. Traffic congestion is a significant operational problem for the urban freight system, with slow non-motorized vehicles (including hand or animal pulled carts) merging into faster motorized traffic. Parking facilities for both freight and none freight traffic has not been planned.

Other features of cities in developing countries as per according to Dablanc, 2009 include a greater use of manual labor for transport and handling. Also, the recycling of used goods, packages, and cardboard takes specific forms: in developing countries, cities essentially leave a significant share of the recycling of goods to the informal sector. Rag-pickers and scavengers are an important feature of city life. Urban scenes in developing regions also include street vending. In the poorest cities of Africa and Asia, street vendors literally take over streets, selling everything from fresh fruits to electronics goods. Slums are also part of the city landscape in many developing countries, and have specific characteristics and supply needs. In general, the share of urban freight depending on the informal sector is hard to evaluate, as are economic, environmental and social indicators for these underground activities. Finally in some countries (China, Egypt, and Morocco for example) the deregulation of what was previously a tightly controlled truck market has had wide-reaching effects on urban operations [Dablanc, 2009]. Cooperatives and small private firms are largely replacing state-controlled trucking companies expanding freight capacity in cities [Dablanc, 2009].

However, it is important to note that in most cities in intermediate or developing countries, part of the economy is fully integrated into global economic networks. What best characterizes the cities of the developing world is their economic dualism: the informal sector operates alongside very advanced industries and services that have logistics behaviors and concerns similar to those in developed countries[Dablanc, 2009].

1.3.1.5. Stakeholders in city logistics

There are four key stakeholders involved in urban freight transport; (1) shippers; (2) freight carriers; (3) residents; (4) planners and regulators. Each group has its own specific objectives and tends to behave in a different manner and has its own needs to be considered.

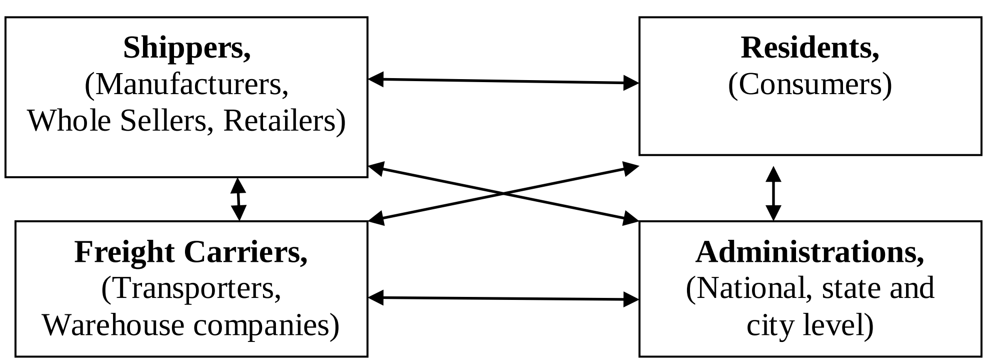

Figure 1-1 Key stakeholders in city logistics
(Source: Eiichi Taniguchi, Russel G Thompson, Tadashi Yamada and Ron Van Duin, 2007)

Shippers are customers of freight carriers who either send goods to other companies or persons or receive goods from them. Shippers generally tend to maximize their level of service, which includes the cost, the time for picking up or delivering and the reliability of transport as well as trailing information. Freight carriers typically attempt to minimize the cost associated with collecting and delivering goods to customers to maximize their profits. There is much pressure to provide higher levels of service to customers at lower total cost. This is especially important when carriers are requested to arrive at customers with in designated time period. However freight carriers often face difficulty in operating their vehicles on urban roads due to traffic congestion. This has led to the in efficient use of trucks, where smaller loads are being transported and trucks often have to wait near the location of customers when they arrive earlier than the designated time. Residents are the people who live, work and shop in the city. They do not welcome large trucks coming in to the local streets; nevertheless these trucks are carrying commodities that are necessary for them. They would like to minimize traffic congestion, noise, air pollution and traffic accidents near their residential and retail areas. City administrations attempt to enhance the economic development of the city and increase employment opportunities. They also aim to alleviate traffic congestion, improve the environment and increase road safety within the city. They should be neutral and play a major role in resolving any conflict among the other stakeholders who are involved in urban freight transport. Therefore it is the administrators who should coordinate and facilitate city logistics initiatives.

1.3.1.6. City logistics models

Quantification of the consequences of city logistics initiative is necessary for their evaluation and planning [Taniguchi *et al* (2001)]. Predicting the impacts of city logistics initiatives for evaluation purposes requires modeling to be undertaken. Models should describe the behaviors of the key stakeholders involved in urban freight transport. They should also incorporate the activities of freight carriers including transporting loading/unloading goods at depots or customers. Models are also required to quantify the changes in costs of logistics activities, traffic congestion, and emission of hazardous gases and noise levels etc. after implementing city logistics initiatives.

Taniguchi *et al* (2001) developed a modeling framework for City Logistics applications. The framework defines three component models and their data and information needs, and is based on the generic traffic systems modeling framework described by Taylor, Bonsall and Young (2000). The three component models are:

- A *supply model* predicts the level of service of freight system using the network characteristics and an estimate of network usage (e.g. link travel times)
- A *demand model* predicts the demand for urban goods movement using the population and industry characteristics of the region (e.g. land use distribution) and the estimate of network level of service, and

- A set of *impact models* predicts the financial, energy, social, environmental and economic impacts of city logistics schemes based on the predicted demand and level of service.

The supply model and the demand model operate as a combined model subsystem, iterating until equilibrium between network usage and level of service is obtained. Impacts are estimated once the equilibrium state is established. These three types of models interact with each other to form an integrated modeling framework as shown in the figure below.

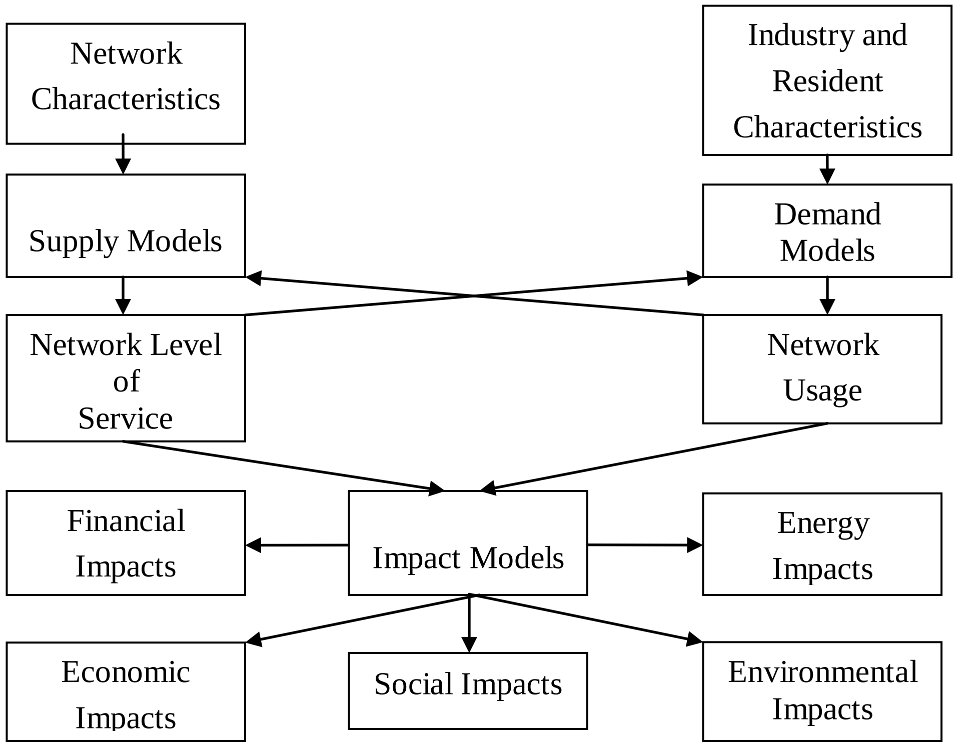

Figure 1-2 City Logistics Modeling Framework

(Source: Eiichi Taniguchi, Russel G Thompson, Tadashi Yamada and Ron Van Duin, 2007)

According to Taniguchi *et al* (2001), models are limited in their ability to quantitatively predict all the impacts of city logistics measures because urban goods movement is a very complex system with many stakeholders and the interaction between stakeholders is not well represented in existing models. City logistics involves the economic activities of private companies and vehicle flow on road networks so that it is difficult to deal with both aspects of logistics activities in a single model. In addition model calibration and validation is not easy in real situations, because of the lack of appropriate data describing current goods movement patterns.

1.3.2. City and Freight distribution

1.3.2.1. General

Freight transportation maintains a set of core relations with urban areas since a city is concomitantly an entity where production, distribution and consumption take place. A salient issue relates to urban freight distribution in the context of global supply chains where global processes are imposing local forms of adaptation to insure that freight is delivered in a timely and reliable fashion. Urbanization and the international division of production are compounding the challenges of city logistics. A city is supplied by an impressive variety of supply chains servicing a wide array of economic activities such grocery stores, retail, restaurants, office supplies, raw materials and parts, construction materials and wastes. The level of economic development is linked with the level of urban freight activity as income and consumption levels are interdependent. Because of the divergence in built environments, each city around the world has different freight transport and logistics activities and level of intensity. This brings the question about the specific size threshold after which urban freight distribution problems, such as delays and congestion, become more prevalent and thus requires a concerted approach. Using the United States as evidence, congestion starts to be a serious issue once a threshold of about one million inhabitants is reached.

According to Benjeloun and Crainic,(2009) the *consolidation* of loads of different shippers and carriers within the same vehicles associated to some form of *coordination* of operations within the city are among the most important means to achieve rationalization. The utilization of so-called green vehicles and the integration of public-transport infrastructures (e.g., light rail or barges on rivers or water canals) enhance these systems and may further reduce truck movements and related emissions. But consolidation and coordination are the fundamental concepts of City Logistics. Consolidation activities take place at so-called City Distribution Centers (CDC; the term Urban Freight Consolidation Center is also used) [Benjeloun and Crainic, 2009]. Long-haul transportation vehicles of various modes dock at a CDC to unload their cargo. Loads are then sorted and consolidated into smaller vehicles that deliver them to their final destinations.

In the urban context there are three distinct types of freight movements which need to be understood. One segment is the freight traffic which is entirely generated and destined within the urban area. The second segment is the intercity freight traffic which is either generated or destined to the city from the external regions. The third segment is the freight traffic which passes through the city to the points beyond. The significance and volume of traffic of each segment depends up on the economic importance and primacy of the city. Planning and evaluation of freight transport system and facilities require a good understanding of the volume and characteristics of freight transport in this three segments.

1.3.2.2. Freight facilities and their location

The more general term for freight facility which encompasses all freight related activities is *logistics terminal*. Goods movement is assumed to be divided in to two parts; line-haul, where long-distance transport is made by large trucks on express ways, and local pick-up/deliveries, with transshipment being delivered there. Goods distribution involves several functions relating to nodes and links on a network. The functions of links are transportation and pickup delivery; node functions including storage, deposit, handling, processing, assembling, packaging, wrapping and loading unloading. Logistics terminals are required to fulfill these node functions and to make both functions interact with each other. Therefore the location and/or relocation of logistics terminals should be incorporated into re-established urban logistics system.

The selection of freight facilities location is a trade-off between land price and distance to the final distribution points (Hesse & Rodrigue, 2004, (as cited in Moazami and Noroozi, 2011)). In terms of accessibility, the optimal location for freight facilities is the center which has an optimal accessibility to the market. However, the rent of a land is a function of the availability of land and so, central areas have the highest rate and the rent decreases dramatically while moving away from the center since available lands increase. The land-use of an area is dependent on the capacity of different economic actors to pay the rent for that area (Rodrigue, Comtois, & Slack, 2009). Information transfer, consumers' preferences changes and close competition exert high pressure on supply chain which in turn, influence the current location of freight facilities. "Suburban sites" in comparison to "core urban areas" provide larger and cheaper lands, and unrestricted transport access, in addition to advantages of connecting local and long distance flows. As a result, the freight facilities recently are constructed in metropolitan areas, "at the urban fringe or beyond" (Hesse & Rodrigue, 2004, pp. 178,179(as cited in Moazami and Noroozi, 2011)).

Hesse and Rodrigue discussed only the baseline to compare suburban areas and core urban areas as seen above, not giving the possibility to compare different suburban areas to each other. So Ogden's opinion which covers more criteria in this regard is discussed as follows. As Ogden (1992) states there are four main factors which influence the location of freight facilities:

- Closeness to the main roads, freeways and services
- Closeness to customers (reduced vehicle-kilometer)
- Site availability
- Labor availability

Among these factors proximity to main roads has the greatest influence. In addition, several other factors are influential for the consideration of a location for freight facilities which among them sufficient site area, adequate road capacity, no restriction on truck operations in the area, possibility of access by largest vehicles and no undesirable noise or zoning restriction can be mentioned [Ogden, 1992].

1.3.2.3. Urban freight impacts

Road transportation is the most polluting per unit of distance travelled, but there are limited alternatives than the road to provide for urban deliveries [Dablanc and Rodrigue, 2009]. As urban roads are used by different modes of transport including pedestrians and road side venders (in the case of developing cities) it is highly likely to be congested and exposed to different social and economical externalities unless closely managed and frequently evaluated of its performances. Freight distribution is more polluting than other transportation activities in cities. The main reasons according to Dablanc and Rodrigue, (2009) are:

- Freight delivery vehicles are older on average. It is common that trucks end their life cycle in drayage operations between port terminals and urban distribution centers.
- Operating speeds are slower due to congestion and traffic restrictions, implying that the engine is running consistently lower than optimal speed (75 km per hour on average).
- Constant acceleration and deceleration, due to traffic lights and congestion.
- Vehicle idling is frequent either for deliveries or at stops.

According to Dablanc and Rodrigue, (2009) in large European cities, freight transport is responsible for one-third of transport-related NOx and half of transport-related particulate matter. In the metropolitan area of Mexico, 71% of the 3,500 tons of PM2.5 generated in 2002 by mobile sources were from freight vehicles. Greenhouse gas emissions and noise pollution are also among the most severe environmental effects of urban freight transport. In Dijon, France, freight transport consumes 26% of the total road traffic-related TOE (tons of oil equivalent, the amount of energy released by burning one ton of crude oil) [Dablanc and Rodrigue, 2009]. It has been calculated that during the morning rush hour in Bordeaux, France, freight transport traffic added five decibels (dB(A)) to the noise from the circulation of private cars.

Urban freight vehicles can be quite old. In Dublin in 2004, a fourth of all vehicles were manufactured in or before 1994. Only 15% of vehicles were new (one year or less) [Dablanc and Rodrigue, 2009]. In the Milan region, 40% of circulating trucks are more than ten years old [Dablanc and Rodrigue, 2009]. The renewal of the freight fleet is generally slower than for non-urban road freight traffic, because urban freight involves numerous competing small operators that cut costs as much as possible [Dablanc and Rodrigue, 2009].

Another important issue is road safety. Trucks participate in a small share of the accidents in cities, but the accidents involving them are serious. Freight vehicles are mostly larger in size compared with other transport vehicles causing blockage of roads and visibility problems that ultimately resulted in safety problems. On London's roads in 2005, about 14 per cent of all collisions involving goods vehicles result in serious or fatal injuries, which is higher than the figure for other road users [Dablanc and Rodrigue, 2009]. The conciliation of truck traffic with bicycle use has been a recent policy target in Paris and London following fatal collisions that received a lot of media attention [Dablanc and Rodrigue, 2009].

1.3.2.4. Urban Freight distribution policies and strategies

According to Taylor, (2005) The possible policy instruments that could affect impacts like emissions, congestion and other traffic impacts related to urban freight transport may be grouped into three broad classes:

- *Policies that operate on measures related to vehicle technology*. These involve requirements that can be set at the level of the individual vehicle, and could include measures such as targets or limits on emission rates per unit distance travelled or per unit time when stationary, specific technology, or fuel use requirements. Note that vehicle technology includes vehicle design, propulsion system, fuel or energy source, and vehicle-based aspects of ITS technology
- *Policies that operate on the transport system*. These could involve changes to the transport system and infrastructure, such as expansion of capacity, utilization of capacity, intermodal enhancements, congestion management, road pricing and road user charges, access restrictions, traffic control and traffic management, ITS technology and similar factors, and
- *Policies that operate on land use distribution and intensity*. These include zoning-related measures, new industrial development and redevelopment, measures that influence the number, types and locations of households and businesses, and other measures that could affect the flow of commercial vehicles in a region.

As a distributional strategy, city logistics can take many forms depending on the concerned supply chains (e.g. retailing, parcels, food deliveries, etc.) as well as the urban setting in which it takes place. Urban freight distribution strategies are however difficult to implement as they systematically imply higher costs and additional delays. Based on Dablanc and Rodrigue, (2009) the mitigation strategies that are the most considered concern three interrelated realms of engagement:

Rationalization of deliveries: Relates to adjustments about how freight is delivered (or picked up) in urban areas so that externalities, namely congestion, are minimized. Such a strategy tries to better use existing assets. One of the simplest strategies is to regulate access to specific parts of the city, such as forbidding daytime deliveries in central areas. Distributors can also opt for night deliveries or at least extended delivery windows to avoid peak hour traffic. There is an array of information technologies that are increasingly been used to manage urban freight distribution systems. Among the most used technologies related to global positioning systems that improve vehicle tracking and urban navigation as well as load management applications that can assist in building routes and delivery schedules. Under such circumstances it becomes more effective to match trip sequences, such as deliveries and pickups to strive towards forms of collaborative distribution. Still, urban freight distribution remains highly imbalanced as deliveries are more numerous than pickups and the most significant relation concerns very different supply chains; retail deliveries / garbage disposal.

Freight facilities*:* Relates to the development of freight distribution infrastructures that are better adapted to the urban context. This can involve the setting of designated parking areas for deliveries, as well as the usage of urban freight distribution centers and local freight stations. If the opportunity arises, such as the availability of a brown field site in proximity to the city center, urban logistics zones can be developed, which can provide a counterweight to logistics zones that have emerged in the periphery of most large urban agglomerations.

Modal adaptation*:* Relates to the usage of adapted vehicles for urban freight distribution. Smaller vehicles tend to be better suited for urban deliveries because of their lesser footprint, their ability to maneuver and their higher than average load factor. Yet, a similar amount of freight would require move vehicles to be delivered. Regulations can therefore be enforced concerning the permitted size of delivery vehicles and even their age if environmental concerns such as emissions and noise are salient.

Although each of these strategies has its own advantages, there are also drawbacks that are commonly related to higher distribution costs and additional delays. City logistics is facing the paradox of being incited to look at sites located at the urban periphery where land availability is less an issue while most consumers tend to live in more central areas. The urban freight distribution center could be a neutral facility interfacing with a set of distribution centers, each being connected to their respective supply chains. Thus, a wide array of supply chains connected to the city can achieve a better distributional efficiency within the central city [Dablanc and Rodrigue, 2009].

Dablanc and Rodrigue, (2009) discusses the usage of public transit system has also been considered for urban freight distribution. However, there are no cost and logistically effective strategy to date. Urban transit is not well adapted to freight distribution and often involves additional load break and costs.

Since each city represents a unique setting with its own prevalence of transport infrastructure and modal choice there appear to be no single encompassing strategy to improve urban freight distribution, but a set of strategies reflecting challenges that are rather unique for each city [Dablanc and Rodrigue, 2009]. As underlined, a salient difference relates to city logistics between developing and developed countries.

1.3.2.5. Urban freight distribution challenges

According to an overview of European research and policy on urban freight transport and logistics (2006), the urban environment is characterized by high settlement and population densities and high consumption of goods and services. In such environments traffic infrastructure and the possibilities for its extension are both limited and unsustainable. This dichotomy between demand and limitations of the urban environment has resulted in significant problems associated with urban freight transport. The most commonly mentioned are congestion, pollution, safety, noise and carbon creation. In fact, the transportation of goods accounts for 40% of air pollution and noise emissions [COST321, 1998]. The combined effects of these problems are both economic and societal, in that they not only reduce the efficiency and effectiveness of urban freight transport and logistics operations but also impact on the well-being of a nation by decreasing the quality of life of citizens and through detrimental effects on health.

Although urban transport is an important indicator of an urban area's growth and employment, it results in increased traffic which in turn leads to congestion, air and noise pollution [Moazami and Noroozi, 2011]. Urban freight transport is closely associated with the quality of life within urban areas. There are various problems in this regard which are either caused or affecting the transportation of goods in cities. Insufficient infrastructure along with access restrictions prevent the goods vehicles to perform properly in city areas which in return may cause traffic and safety problems. On the other hand the congestion resulted from goods vehicles have negative impacts on people and freight accessibility which in return imposes extra costs for both passengers and freight companies. Freight transport affects the quality of life negatively also by its contribution to the emission of pollutants in local and global level and increase of the noise level in the neighbor areas. Safety is another angel in the life quality which is violated by transport of goods especially on roads inside urban areas. This problem might be the result of inadequate loading/unloading spaces, dangerous driving or the characteristics of the vehicle and the load [Moazami and Noroozi, 2011].

According to Dablanc and Rodrigue, (2009) addressing city logistics requires an understanding of urban geography as well as supply chain management, which tends to be an uncommon set of skills. Urban freight distribution thus has a unique array of challenges as a multidisciplinary field. Urban freight distribution reflects many dimensions of contemporary logistics such as route and delivery sequence selection. It also exacerbates its constraints such as on-time deliveries. Among the most salient challenges of city logistics: [Dablanc and Rodrigue, 2009]

***Commuting and peak hours**:* Passengers and truck movements are not interacting efficiently as freight and passenger circulations are a zero-sum game; road capacity taken be freight transportation is at the expense of capacity available to passenger transportation. They share the same road infrastructure and peak hours due to commuting exacerbate the difficulties of freight distribution.

***Congestion**:* City logistics, like logistics in general, depend of consistent and reliable deliveries. The urban environment that tends to have high congestion levels is challenging. To avoid congestion, deliveries take place during the night (or off peak hours) if possible.

***Parking**:* There is limited parking capacity to accommodate deliveries in high density areas. Delivery vehicles cope with this challenge by double parking, thus seriously impeding local circulation.

Cargo load contradictions: Urban freight distribution is characterized by smaller volumes and high frequency deliveries. This is not prone to economies of scale and involves higher delivery costs.

***Land use**:* Land use patterns determine many features of the urban movement of goods, where the pattern of industrial, commercial and logistics facilities has a direct impact on the flow of commercial goods. Logistics sprawl has been a dominant land use change of the last decades with is the relocation of logistics facilities towards peripheral areas.

Reverse (green) logistics: While cities are major consumers of final goods, there are also reverse logistics activities related to the collection of wastes and recycling.

E-commerce: Related to new forms of demands and new forms of urban distribution with a growth in the home deliveries of parcels. While the concerned volumes were relatively small, the diffusion of information technologies has impacted the urban distribution structure of retail goods.

1.3.2.6. Freight transport management

According to Victoria Transport Policy Institute, (2011) Freight Transport Management includes various strategies of increasing the efficiency of freight and commercial transport. Logistics is a technical term for efficient freight management, including shipping practices (e.g., vehicle type, shipment size, frequency, etc.), facility sitting, and related activities. Below are examples of Freight Transport Management activities [Victoria Transport Policy Institute, (2011)].

- Improve scheduling and routing to reduce freight vehicle mileage and increase load factors (e.g., avoiding empty backhauls). This can be accomplished through increased computerization and coordination among distributors.
- Organize regional delivery systems so fewer vehicle trips are needed to distribute goods (e.g., using common carriers that consolidate loads, rather than company fleets).
- Reduce total freight transport by reducing product volumes and unnecessary packaging, relying on more local products, and sitting manufacturing and assembly processes closer to their destination markets.

- Use smaller vehicles and human powered transport, particularly for distribution in urban areas.
- Implement fleet management programs that reduce vehicle mileage, use optimal sized vehicles for each trip, and insure that fleet vehicles are maintained and operated in ways that reduce external costs (congestion, pollution, crash risk, etc.).
- Encourage businesses to consider shipping costs and externalities in product design, production and marketing, for example by minimizing excessive packaging and unnecessary delivery frequency, and relying on more local suppliers.
- Change freight delivery times to reduce congestion.
- Increase land use accessibility by clustering common destinations together, which reduces the amount of travel required for goods distribution.
- Pricing and tax policies to encourage efficient freight transport.
- Increase freight vehicle fuel efficiency and reduce emissions through design improvements and new technologies. These include increased aerodynamics, weight reductions, reduced engine friction, improved engine and transmission designs, more efficient tires, and more efficient accessories.
- Improve vehicle operator training to encourage more efficient driving.

Heavy trucks represent about 10% of total vehicle mileage, and smaller commercial vehicles represent another 5-10% of total vehicle traffic [Victoria Transport Policy Institute, May 2011]. Heavy trucks represent a major share of total traffic on some highways, particularly around major ports, rail terminals and industrial areas. Because of their size, freight trucks impose relatively high congestion, road wear, accident risk, air pollution and noise costs, so travel reductions can provide significant benefits in areas where they are concentrated.

Truck transport tends to impose the greatest congestion costs, although exact impacts depend on specific conditions, such as the route and travel time (CSPPSFT, 1996). Many goods must be transported by local truck to their final destination, and long-haul trucking tends to impose relatively modest congestion impacts.

1.3.2.7. Sustainability in urban freight transport

As part of the general sustainable development, sustainable transport systems have to full fill the basic principle “Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [Behrends et al, 2007].

A *sustainable urban transport system* has the following specific objectives [Behrends et al, 2007]:

- Ensuring the accessibility offered by the transport system to all categories of inhabitants,
- commuters, visitors and businesses, in line with the objectives below;

- Reducing the negative impact of the transport system on the health, safety and security of the citizens, in particular the most vulnerable ones;
- Reducing air pollution and noise emissions, greenhouse gas emissions and energy consumption (including contributing to meeting legislative requirements on air quality and environmental noise e.g. EU directive 2002/49/EC);
- Improving the efficiency and cost-effectiveness of the transportation of persons and goods, taking into account the external costs;
- Contributing to the enhancement of the attractiveness and quality of the urban environment.

According to [Behrends et al, 2007], as part of the general objectives in sustainable transport system freight transport should full fill the following objectives of sustainability:

- To ensure the accessibility offered by the transport system to all categories of freight transport;
- To reduce the air pollution, green house gas emissions, waste and noise to levels without negative impacts on health of the citizens or nature;
- To improve the resource- and energy efficiency and cost-effectiveness of the transportation of goods, taking into account the external costs and
- To contribute to the enhancement of the attractiveness and quality of the urban environment, by avoiding accidents, minimizing the use of land and without compromising the mobility of citizens.

An indicator set for different actors could be used to monitor and measure the effects of actions taken towards this objective. There are many easily understandable and applicable indicator sets for actors involved in urban transport, but they fail to reduce the complexities and grapple with the contradictions of sustainable transport [Behrends et al, 2007].

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1.3.3. Urban land use

1.3.3.1. Land use and transport

The connection between transportation and land use is a fundamental concept in transportation. Transportation and land use are inexorably connected. At a minimum, the coordination of land use and transportation requires that those concerned with the well-being of a community (or region, state or nation) assess and evaluate how land use decisions affect the transportation system and can increase viable options for people to access opportunities, goods, services, and other resources to improve the quality of their lives. In turn, the transportation sector should be aware of the effects the existing and future transportation systems may have on land use development demand, choices, and patterns. Coordinating (or integrating) land use and transportation planning and development are commonly considered today as one fact of "smart growth", sustainable development, new urbanism, or other similar concept.

Urban land use comprises two elements; the nature of land use which relates to which activities are taking place where, and the level of spatial accumulation, which indicates their intensity and concentration [Rodrigue, 2009]. Central areas have a high level of spatial accumulation and corresponding land uses, such as retail, while peripheral areas have lower levels of accumulation. The behavioral patterns of individuals, institutions and firms have an imprint on land use in terms of their location choice. The representation of this imprint requires a typology of land use, which can be formal or functional: (Rodrigue, Comtois, & Slack, 2009)

Formal land use representations are concerned with qualitative attributes of space such as its form, pattern and aspect and are descriptive in nature.

Functional land use representations are concerned with the economic nature of activities such as production, consumption, residence, and transport, and are mainly a socioeconomic description of space.

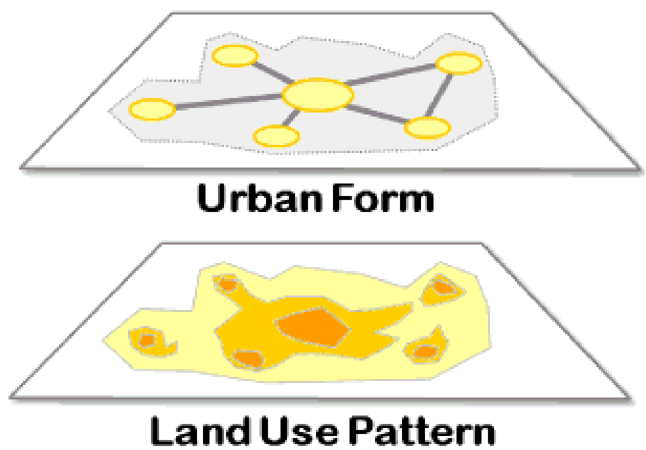


Figure 1-3 the relationship between land use pattern and the activity nodes
Source: (Rodrigue, Comtois, & Slack, 2009)

As it is illustrated in Figure 1.3 above the land use pattern can be used to identify the distribution of activity nodes and their intensity within an area. In this thesis while referring to the land use it mean to say that the formal land use representation.

According to [Rodrigue, 2009] at the global level, cities consume about 3% of the total land mass. Although figures can vary considerably depending on the city, residential land use is the most common, occupying between 65 and 75% of the surface of a city. Commercial and industrial land uses occupy 5-15% and 15-25% of the surface respectively. Land use, both in formal and functional representations, implies a set of relationships with other land uses. For instance, commercial land use involves relationships with its supplier and customers. While relationships with suppliers will dominantly be related with movements of freight, relationships with customers would include movements of people. Thus, a level of accessibility to both systems of circulation must be present. Since each type of land use has its own specific mobility requirements, transportation is a factor of activity location, and is therefore associated intimately with land use.

Urban transportation aims at supporting transport demands generated by the diversity of urban activities in a diversity of urban contexts. A key for understanding urban entities thus lies in the analysis of patterns and processes of the transport / land use system. This system is highly complex and involves several relationships between the transport system, spatial interactions and land use [Rodrigue, 2009]:

- **Transport system**. Considers the set of transport infrastructures and modes that support urban movements of passengers and freight. It generally expresses the level of accessibility.
- **Spatial interactions**. Consider the nature, extent, origins and destinations of the urban movements of passengers and freight. They take into consideration the attributes of the transport system as well as the land use factors that are generating and attracting movements.
- **Land use**. Considers the level of spatial accumulation of activities and their associated levels of mobility requirements. Land use is commonly linked with demographic and economic attributes.

Transportation and land use interactions mostly consider the retroactive relationships between activities, which are land use related, and accessibility, which is transportation related. These relationships have often been described as a classic "chicken-and-egg" problem since it is difficult to identify the triggering cause of change; do transportation changes precede land use changes or vice-versa? There is a scale effect at play as large infrastructure projects tend to precede and trigger land use changes while small scale transportation projects tend to complement the existing land use pattern. Further, the expansion of urban land uses takes place over various circumstances such as infilling (near the city center) or sprawl (far from the city center) and where in each case, transportation plays different role.

1.3.3.2. Urban land use models

The relationships between transportation and land use are rich in theoretical representations that have contributed much to the regional sciences. Since transportation is a distance-decay altering technology, spatial organization is assumed to be strongly influenced by the concepts of location and distance [Rodrigue, 2009]. Several descriptive and analytical models of urban land use have been developed over time, with increased levels of complexity. All involve some consideration of transport in the explanations of urban land use structures. The following is a non-exhaustive categorization [Rodrigue, 2009]:

Central places and concentric land uses: Von Thunen's regional land use model is the oldest representation based on a central place, the market town, and its concentric impacts on surrounding land uses. It was initially developed in the early 19th century (1826) for the analysis of agricultural land use patterns in Germany. It used the concept of economic rent to explain a spatial organization where different agricultural activities are competing for the usage of land. The underlying principles of this model have been the foundation of many others where economic considerations, namely **land rent** and **distance-decay**, are incorporated. The core assumption of the model is that agricultural land use is patterned in the form of concentric circles around a market that consumes all the surplus production, which must be transported. Many concordances of this model with reality have been found, notably in North America.

Concentric urban land uses: The Burgess concentric model was among the first attempts to investigate spatial patterns at the urban level (1925). Although the purpose of the model was to analyze social classes, it recognized that transportation and mobility were important factors behind the spatial organization of urban areas. The formal land use representation of this model is derived from commuting distance from the central business district, creating concentric circles. Each circle represents a specific socioeconomic urban landscape. This model is conceptually a direct adaptation of the Von Thunen's model to urban land use since it deals with a concentric representation. Even close to one century after the concentric urban model was designed, spatial changes in Chicago are still reflective of such a process.

***Polycentric and zonal land uses**:* Sector and multiple nuclei land use models were developed to take into account numerous factors overlooked by concentric models, namely the influence of transport axis [Hoyt, 1939] and multiple nuclei [Harris and Ullman, 1945] on land use and growth. Both representations consider the emerging impacts of motorization on the urban spatial structure. Such representations also considered that transportation infrastructures, particularly terminals such as rail stations or ports, occupy specific locations and can be considered as land uses.

Hybrid land uses: Hybrid models are an attempt to include the concentric, sector and nuclei behavior of different processes in explaining urban land use. They are an attempt to integrate the strengths of each approach since none of these appear to provide a completely satisfactory explanation. Thus, hybrid models, such as that developed by Isard [1955], consider the concentric effect of central locations (CBDs and sub-centers) and the radial effect of transport axis, all overlain to form a land use pattern. Also, hybrid representations are suitable to explain the evolution of the urban spatial structure as they combine different spatial impacts of transportation on urban land use, let them be concentric or radial, and this at different points in time.

Land use market: Land rent theory was also developed to explain land use as a market where different urban activities are competing for land usage at a location. It is strongly based in the market principle of spatial competition where actors are bidding to secure and maintain their presence at a specific location. The more desirable a location is, the higher its rent value. Transportation, through accessibility and distance-decay, is a strong explanatory factor on the land rent and its impacts on land use. However, conventional representations of land rent leaning on the concentric paradigm are being challenged by structural modifications of contemporary cities.

Most transportation - land use models are essentially static as they explain land use patterns, but they do not explicitly consider the processes that are creating or changing them. Their applicability is related to issues such as the age, size and the location setting of a city. For instance, concentric cities are generally older and of smaller size, while polycentric cities are larger and relate to urban development processes that took place more recently. While most of the conceptual approaches related to transportation and land use relationships have been developed using empirical evidence related to North America and Western Europe, this perspective does not necessarily apply to other parts of the world [Rodrigue, 2009].

1.3.3.3. Freight transport and urban land use

According to New York metropolitan transportation council, land use planning near freight facilities can minimize potential conflicts between freight transport and nearby land uses while supporting any relevant region-wide freight transport plan. This practice has the following economic and employment benefits for a community or region at large:

- Reduces land use conflicts, avoiding potentially costly and time-consuming litigation,
- Provides opportunities for increased efficiency and business synergy in a targeted area,
- Relieves congestion and reduces overall vehicle miles traveled, and
- Provides a coordinated re-use opportunity for former or current Brownfield sites located near major freight markets.

Land use assessments performed for areas surrounding freight facilities typically identify strategies to achieve mutually supporting freight facility operations and surrounding land uses. In most cases, such efforts are led by the public agency responsible for the zoning, land use and transportation coordination in the area. Public agencies and communities working together can enhance the freight and land use relationship by implementing any of the following techniques:

- Identify areas where freight transport and adjacent land uses may be in conflict
- Conduct site visits and collect data on freight and traffic volume at peak use times
- Examine interactions among different land uses and assess any existing freight transportation and land use connections

- Provide incentives to enhance existing connections between freight transport needs and redevelopment or reuse opportunities
- Develop freight-supportive land use guidelines, such as requiring buffers or transitional zones between incompatible land uses, or protecting/reserving undeveloped land adjacent to freight facilities for future expansion though zoning, easements, or land acquisition.

A number of variables can alter the process of land use planning near freight transit operations, which makes it difficult to apply a uniform method or process across a variety of freight facility settings. A more standardized option to consider for coordinating land use and freight transport is a combined freight and land use concept popular in Europe known as the “Freight Village.” In the U.S., Freight Villages are sometimes known as “Integrated Logistics Centers” (ILC). Freight Villages are defined as a cluster of freight-related businesses located inside a secure perimeter operated under single management structure. Freight Villages usually offer intermodal transfer options, logistics services, integrated distribution, warehousing capabilities, showrooms, and support services. Such support services might include: security, maintenance, mail, banking, customs and import management assistance, cafeterias, restaurants, office space, conference rooms, hotels, and public or activity-center transportation.

2. Objectives

The main objective of this thesis is to evaluate impacts of city logistics on the urban traffic functions and environment by considering Addis Ababa as the case city.

The specific objectives are to:

- study main freight entry corridors and attraction centers of the city and determine the current level of congestion, pollution and safety problems caused by freight transport on the intersections in these areas;
- discuss the freight transport management and traffic operation practices of the city;
- identify different constraints that may hinder the proper management of freight transport and related land use improvements; and
- discuss possible logistics options in relation to land use and congestion.

Scope and limitation of the study

The scope of this thesis is, determining level of impacts of freight and land use patterns on traffic mobility and urban environment, development of recommendations on effective freight and land use improvement practices and development of appropriate city logistics options based on the basic principles of urban goods distribution, socio economic condition and current land forms of the case city.

Because of resource and time limitations the study is based on the data collected from some selected freight destination areas which are under considerable impacts by freight vehicles than other respective areas of the city. These areas were carefully selected after document analysis; field observation and interviews made with some stake holders. However collecting and analyzing data all over the city areas may result in more accurate values to determine the level of the impact, development of recommendations and effective logistics options that alleviate these problems.

Impact evaluation was carried out by indirect analysis of networks and interviews with sample stakeholders rather than using specific evaluation models. The few existing models on city logistics and urban transport were built for developed cities where availability and collection of relevant data is not a problem. For developing cities like Addis Ababa it is very difficult to adopt such models where majority of goods movement is carried out in an informal ways and the general urban travel behavior is very complex. This problem necessitates the development of new models for evaluation of the performance and level of impact of city logistics in developing cities.

3. Methodology

3.1. Research strategy

In this thesis both qualitative and quantitative research strategies in a deductive manner were used to draw the hypothesis based on the available theories in the study area. Qualitative data collected through interviews and questioner was analyzed. In addition to this quantitative data collection through field measurements and their analysis were carried out. The hypothesis drawn on the study area by the deductive approach based on the available theories was further examined in the subsequent empirical study.

3.2. Research design

This thesis project was mainly the question of how and what.

- ***How*** does freight transport and land use pattern affect the city traffic environment?
- ***What*** is the extent of the impact currently in the study area? and
- ***What*** are the remedial measures to be implemented to alleviate these problems?

Furthermore the problems that initiated the research question are up to date which demands detailed investigation and development of remedial measures that alleviate these problems.

Yin (2009) suggested that researchers can use case study design when:

- The research questions include *how* and *why*,
- Researchers have limited control on events,
- The events are contemporary within the real-life circumstance.

Based on Yin's definition on the nature of the research question, researcher event interaction and the timeliness of the events, among several research designs case study was adapted as an appropriate research design where a single case, the case of Addis Ababa is studied to examine the hypothesis.

3.3. Data collection

In this thesis literature studies, survey through questioner and direct interviews, site observations and field measurements were carried out to collect necessary data for the research.

3.3.1. Literature studies

In this thesis different literatures were studied as a source of information or secondary data. Among them journals and reports prepared focusing on the city's transportation system at different times collected from either government offices or individuals were the major ones. Documents like city land use map, road network map, transport network map and other related reports were collected from the city administration library. Document having data concerning transporters (freight carriers) of the country and in particular the city was collected from the federal transport authority. Accident records, consultancy reports and other relevant documents were collected from the city transport office and sub city traffic departments. Besides the documents collected from the above mentioned governmental institutions different documents relevant to the city freight transport and land use behavior were collected from freight transporters, individuals and from websites. All these documents were studied and analyzed accordingly to meet the objective of the thesis.

3.3.2. Survey

Survey was conducted in two major approaches to collect qualitative data. These are direct interviews or face to face interviews and questioner distribution.

Direct interview

Direct interview was carried out with carefully selected interviewees that have a direct or indirect involvement with the research question or theme of the thesis. Among these; government administrative officials at different level, individuals and some freight carriers in particular were found. Government administrative officials like federal transport authority representatives, Addis Ababa city transport office public relations officer, Addis Ababa City administration master plan revision project team, Addis Ababa environmental protection authority representative and traffic polices were those who were directly interviewed based on streams of question on a guided conversation approach.

Questionnaire

Besides the direct interview carried out with the above listed bodies, a list of questions were prepared in questioner format and distributed to the selected stake holders in the freight transport industry. Four major stake holders were selected. These are; transporters (freight carriers), traffic polices, freight drivers and the public. A total of 80 samples 20 from each stakeholder were interviewed through this questioner. The sample size was determined based on the basic principles of sampling, the level of accuracy planned, type of research design and the scope and limitations of the thesis work.

In principle there are different types of sampling techniques to be used during sample selection processes. These are; simple random, stratified random, cluster, stage, purposive, quota, snowball and volunteer or accidental or convenience.

Different sampling techniques for respective stakeholders selected to be interviewed through the prepared questioner were adopted. In the case of transporters purposive sampling techniques was applied intentionally to accommodate all variety of transport in the industry. Some of the characteristics of selection were their business or registration category (whether they are associations, plc, or privately registered), their current activity in the market, the number of vehicles they currently run and their locational distribution in Addis Ababa city. This transporters characterizing information were collected from the federal transport authority during the direct interview together with supportive documents. So based on the above mentioned characteristics a total of 20 transporters were selected and interviewed through the questioner.

Traffic polices were selected in a stratified random manner. However strata were applied at two stages one was at stakeholder selection stage and the second was selection of sub cities with dominant freight mobility. Based on these, 20 traffic polices were randomly selected and interviewed. In the case of drivers, similar to the traffic police two stage strata were applied, one at the stage where drivers were considered as one stakeholder and the other was a further strata created in between drivers based on the type of freight vehicles (whether it is heavy or light/medium) that they are driving and 20 drivers were randomly selected and interviewed. The case of the public was also similar with further strata of focusing on the freight destination or vulnerable areas. Based on this 20 community members living in the vicinity of major freight mobility areas of the city were randomly selected and interviewed.

The questioner was designed in two ways incorporating general and stakeholders' specific questions. The first 15general questions were answered by all the stakeholders and each stakeholder had its respective specific questions. This was intentionally done to later analyze and discuss responses generally and separately as appropriate.

Finally the total of 80 filled questioners were collected from each respondent and separately filed to later identify the grouping between stakeholders and analyze the general and specific questions separately.

3.3.3. Field measurements

Besides the qualitative data collected through direct interviews and questioner quantitative field measurements were carried out to meet the objectives of this thesis. Field measurements carried out were, classified traffic count and geometric measurements on selected intersections in major freight mobility areas. The selected intersections are found in high freight movement areas of the city. Several candidate intersections were observed during the preliminary site selection process of the research and fine tuned to the most severely vulnerable intersections to the freight impacts. Accordingly two intersections namely Kality-Gumruk intersection and 18-Mazoria intersections were selected to carry out the field measurement.

The main field data collected from the mentioned intersections was total traffic volume by vehicle category and some geometric elements of the intersection. Traffic counts were carried out based on AASHTO (American Association of State Highways and Transport Officials) recommendation of traffic count in urban areas and Addis Ababa roads authority (AACRA) recommendations on vehicle category with some modifications that enables separation of freight related vehicles from others during capacity analysis. Accordingly 10vehicle categories were created to easily separate during analysis. These are; cars/taxis, pickups, utilities (Jeeps, vans,), small bus, large bus, light truck, medium truck, heavy truck, truck with trailer and others (tractors, graders and etc). Count was made on both intersections based on this vehicle category.

Besides vehicle category the other important factor in traffic count is the selection of appropriate days of a week and hours of a day. Careful selection that optimizes the scope and limitations of the thesis work and the basic recommendations of either AACRA (Addis Ababa City Roads Authority) or ERA (Ethiopian Roads Authority) manuals was carried out at this stage. Two week days and one weekend, totally three days of a week namely Monday, Thursday and Saturday were selected after preliminary on site observation to account the variation in freight traffic flows on a weekly basis. To account the hourly variation of traffic flow in the area, in addition to field observation, information was gathered from traffic polices and communities living in the area. Accordingly, 8 hours of a day were selected with a distribution of 7: AM to 12: AM in the morning and 5: PM to 8: PM in the afternoon. This time distribution accommodates majority of the day time traffic and some night time traffic. Unlike the other urban traffic, freight vehicles are mostly affected by seasonal variations. So this field measurement was repeated three times at different seasons to account the seasonal variation in freight traffic flow. Accordingly the first traffic count was made in mid December, the second count at the end of March and the third at the end of April. The first count helps to understand the characteristics of freight traffic flow before the Ethiopian harvest season of January and February while the second and the third counts characterize the freight flow just after the harvest season. The traffic volume was counted by identifying the three movement patterns of the intersection; Left, Through and Right turning vehicles separately for the purpose of analysis. From the traffic volume data collected in this ways, the average hourly traffic volume (Veh/h) was computed and peak hour flow time was estimated later during the data analysis stage.

As another quantitative data, measurements of some intersection geometric elements were carried out for the purpose of analysis. The measured geometric elements of the intersection are; island diameter, number of rotating lanes, width of the rotating lane, and number and widths of approach and exit lanes. Besides measurement of these elements professional estimations have been made on other relevant geometric and traffic flow characteristics of the intersections such as entry angle and entry radius.

3.4. Data analysis

3.4.1. General

The data collected from different sources were analyzed to meet the general and specific objectives of the research. Different analysis techniques were adapted based on the type of data and relevance of techniques to be used. Two main approaches were used during the course of the process. The first was problem analysis based on detailed literature studies in the subject area and understanding of existing conditions in the area of study. The second was use of different application softwares such as aaSIDRA 5.1, SPSS 16, Microsoft Excel and ArcGIS to ultimately meet the intended objectives of the thesis.

3.4.2. Traffic volume analysis along the entry and exit corridors of the city

Average daily traffic at five entry/exit corridors of Addis Ababa as indicated on Urban Transport Study report (UTS, 2005) and average daily traffic at these corridors made in 2010 by Ethiopian Roads Authority were used. Based on the freight vehicles data collected from these sources at the specified years the percentage distribution of each freight vehicle categories were analyzed with respect to each other. The percentage share of the total freight traffic volume entering and leaving Addis Ababa along each entry/exit corridors was analyzed to identify the major entry and exit corridor of the city. The total freight traffic volume increment between the years 2004 and 2010 was analyzed. Analysis on the proportion among freight vehicular traffic categories was made. The percentage increase or reduction in their share of freight vehicles on each entry/exit corridors of the city between the years 2004 and 2010 was calculated to identify the recent condition of each corridor in terms of freight vehicular volume with respect to each other. In addition to the analysis made above on the freight volume data, freight tonnage at the five corridors on the year 2004 as indicated on (UTS, 2005) and freight tonnage at these corridors on the year 2010 as indicated on Addis Ababa traffic management report, 2012 were used to identify the entry/exit corridor of Addis Ababa which is under a considerable freight impact and to know the percentage share of freight movement along these corridors of the city.

Furthermore, statistical analysis on the responses of sample stakeholders interviewed through questioner was carried out to figure out their opinion on the major freight corridor of the city. Frequency and percentage analysis of respondent's opinion on the main road corridors under freight vehicular traffic were analyzed using SPSS 16.0.

3.4.3. Identification of main freight attraction areas of the city

Assessment on potential freight destination areas of the city was made during the data collection process. Different documents and study reports were also reviewed. Data collected through field observation and document revision were analyzed to identify the potential freight centers of the city. Documents like city land use map, road network map, advisory report on Addis Ababa city traffic management, 2012 and urban transport study report, 2004, were used in conjunction with field observation made.

The current land use map of the city depicts the structural classification of the city land among different functions. Customer based sites like large market areas, goods distribution centers and business areas has been marked as main and sub centers of the city. On the other hand the industrial and storage sites of the city have also been identified. The information on the land use characteristics of the city gathered from the land use map was analyzed to identify the location of freight attraction centers of the city. In addition to this other documents like Urban Transport study, (UTS, 2005) and advisory report on the city traffic management, 2012, were reviewed to identify the main freight destinations of the city. Traffic volume survey data of freight related vehicles entering and exiting the selected Addis Ketema and Arada sub cities studied by UTS, 2005 was discussed. Consequently, technical advisory report on the city traffic management carried out in 2011 revealed that the freight traffic volume in Mercato and Piassa areas which helps to identify the relevance of these areas with respect to freight mobility. The information gathered from these sources was analyzed with respect to the field observation made in the study area.

Besides the document analysis on the subject matter, the data collected through questioner from the four major stakeholders were statistically analyzed to point out the required results based on the respondent's opinion. Data from the direct interview with the community members and administrative bodies were analyzed in line with the observed facts and information gathered from different documents listed above.

3.4.4. Analysis of freight vehicular traffic impacts

3.4.4.1. Statistical analysis

Statistical analysis on the responses of sample stakeholders was carried out. For the purpose of statistical analysis SPSS 16.0 was used. The collected data was qualitative in nature. The first step was then preparation of the raw data in such a way that it was understandable by SPSS 16.0. Each question containing a certain answer was considered as a variable and its respective answer was a value associated to this variable. These variables should initially been defined with unique attributes related to the variables to make it easily understandable by the software. Coding the names of the variables, definition for descriptive value labels for numeric codes, identification of missing value codes, assignment of measurement level (nominal, ordinal or scale) were some of the major activities carried out during data entry process. Name of variables were shortly coded for the data view and labeled briefly in the label column of the variable view. Descriptive values of each variable were numerically coded in a variable view. Similarly possible missing values in the responses of the survey were coded during data entry.

Level of measurement

Different summary measures are appropriate for different types of data, depending on the level of measurement. In SPSS 16 level of measurements are discussed as follows:

Categorical: - data with a limited number of distinct values or categories also referred to as qualitative data. Categorical variables can be string (alphanumeric) data or numeric variables that use numeric codes to represent categories (for example, 1 = congestion and 2 = Pollution). There are two basic types of categorical data:

- Nominal. Categorical data where there is no inherent order to the categories. For example, impact category congestion is not higher or lower than an impact category of accidents.
- Ordinal. Categorical data where there is a meaningful order of categories, but there is not a measurable distance between categories. For example, there is an order to the values high, medium, and low, but the "distance" between the values cannot be calculated.

For such data the most typical summary measure is the number or percentage of cases in each category. The mode is the category with the greatest number of cases. For ordinal data, the median (the value at which half of the cases fall above and below) may also be a useful summary measure if there is a large number of categories.

Scale: - data measured on an interval or ratio scale, where the data values indicate both the order of values and the distance between values. For example, average fleet utilization of 85% per year is higher than average fleet utilization of 75%, and the distance between the two values is 10%. Such data is also referred to as quantitative or continuous data. There are many summary measures available for scale variables, including:

- Measures of central tendency. The most common measures of central tendency are the mean (arithmetic average) and median (value at which half the cases fall above and below).
- Measures of dispersion. Statistics that measure the amount of variation or spread in the data include the standard deviation, minimum, and maximum.

The levels of measurements used for almost all variables analyzed in this thesis are categorical with majority of nominal type and some ordinal types. These categorical variables are defined as numeric using numeric codes to represent categories. The coded names, labels, values and other parameters used in this thesis are given in Appendix B. The Frequencies procedure provides statistics and graphical displays that are useful for describing many types of variables. For this thesis also, frequency analysis was carried out to figure out the percentage distribution of cases on each variable values.

3.4.4.2. Capacity analysis of selected intersections

The capacity of the selected intersections was analyzed using SIDRA INTERSECTION5.1 software. First the classified traffic volume data collected on each intersection was analyzed using Microsoft Excel 2007 to get the average vehicle per hour (veh/h) data on each legs of the intersection with their distinct movement directions. ERA'S average daily traffic analysis method was adapted to calculate the hourly flow of vehicular traffic on each leg and movement directions of the intersection. Traffic volume considered for this analysis was a 60minutes or hourly value of total traffic where 15minutes were considered to be a peak flow period. The average value of the three repetition counts was calculated as a final (veh/h) data to be used for the capacity analysis.

The percentage share of heavy vehicles in this particular case freight related vehicles (from small trucks to truck and trailers) from the total traffic has been separately computed for use in the analysis software. According to US HCM, 2010 (Highway Capacity Manual), the three options available for specifying the heavy vehicle data are (using the same numerical example for each option):

- Separate LV(light vehicles) & HV (heavy vehicles): Separate volumes for light vehicles (LVs) and heavy vehicles (HVs) will be specified, e.g. LVs 900 veh/h and HVs 100 veh/h
- Total Vehicles & HV (%): Total volume and per cent heavy vehicles will be specified, e.g. total 1000 veh/h and 10 per cent HV, and
- Total vehicles & HV (veh): Total volume and heavy vehicle volume will be specified, e.g. 1000 veh/h and 100veh/h.

For the purpose of intersection analysis, SIDRA INTERSECTION defines a heavy vehicle as any vehicle with more than two axles or with dual tyres on the rear axle. Thus, buses, trucks, semi-trailers (articulated vehicles), cars towing trailers or caravans, tractors and other slow-moving vehicles are classified as Heavy Vehicles. All other vehicles are defined as Light Vehicles (cars, vans, small trucks). The US HCM (Highway Capacity Manual) defines a Heavy Vehicle as "a vehicle with more than four wheels touching the pavement during normal operation".

In case of this particular research heavy vehicles were defined as freight related vehicles (Small trucks, Medium trucks, Heavy trucks and Truck with trailers) and their percentage shares calculated from the total traffic volume for the purpose of analysis. In doing so among the above listed options the second one, the total volume and percent heavy vehicles HV (%) have been specified and used during the analysis.

Unit time for volumes

The volume data given in the volumes and pedestrians dialogs of aaSIDRA software are actual volume counts (*vehs* or *peds*) as measured during a time interval specified as the *Unit Time for*

Volumes (minutes). The program converts the volume counts (V_a) to hourly flow rates (q_a) according to the Unit Time for Volumes (T_v):

$$q_a\ (veh/h) = 60\ V_a\ (veh) / T_v \quad \text{Eqn 1}$$

However in this research, the hourly volume (q_a) was priorly analyzed from the total traffic V_a counted at the site of interest within selected days of a week and selected hours of a day as discussed in section 3.4.3. The computed values of hourly traffic on each leg of the intersection were further analyzed and the percentage share of heavy vehicles was computed. These values of total vehicle per hour and percentage of heavy vehicles were used directly during analysis by SIDRA INTERSECTION software.

Peak flow factor

In this thesis the intersections in question were analyzed using the PFF value of 90% based on the recommendation given by HCM 2010, as the total entering volume for almost all legs of the intersection is <1000 and the peak demand volume was not distinctly known.

Peak Flow Factor (PFF) is the ratio of the average arrival flow rate during the Total Flow Period (q_a) to the average arrival flow rate during the peak flow period (q_p) [HCM, 2010]:

$$PFF = 100\ q_a / q_p \quad \text{Eqn 2}$$

Where both q_a and qp are flow rates (veh/h) converted from volume counts to flow rates.

HCM 2010, Chapter 18 recommends 92 percent if total entering volume ≥ 1,000 veh/h and 0.90 if total entering volume < 1,000 veh/h.

Vehicle occupancy

In SIDRA INTERSECTION analysis vehicle occupancy values are used for calculating various performance statistics in terms of persons rather than vehicles or pedestrians (e.g. total travel time in person-hours per hour), and are important in determining the operating cost per vehicle allowing for the number of persons per vehicle in calculating time cost per vehicle. For this particular research the default vehicle occupancy value of 1.2person/veh was directly used as it do not affect the major output parameters that are needed to meet the objective of the research.

Flow scale (constant)

A quick analysis of increased demand flow levels for the intersection is possible using this parameter by applying the same value to all movements. The exact value of traffic volume data were used for this analysis without increasing or decreasing. The flow scale (constant) of 100% is used during the analysis. The Flow scale (constant) is specified as a percentage value. The demand volume will be increased or decreased using flow scale (constant) given for each movement converting it to a factor calculated as [flow scale (constant) / 100]. For example, volume = 200 veh/h, flow scale (constant) = 110 % will result in increased value of volume =

1.10 x 200 = 220 veh/h to be used by the program. Flow scale (constant) = 90 % will result in decreased value of volume = 0.90 x 200 = 180 veh/h.

Growth Rate

Growth rates specified as percentage values are used when design life or flow scale analysis is carried out through the demand & sensitivity dialog in SIDRA INTERSECTION analysis. The demand volume will be increased using the growth rate given for each movement converting it to a factor calculated as [1 + Growth Rate / 100]. In this particular thesis the analysis was neither design life nor flow scale to apply grow rate. Rather normal analysis based on the current traffic volume was carried out.

Geometric data of the intersections were used during the analysis. Generally the following roundabout geometric data were measured and used during the analysis: the island diameter, circulating lane width, number of circulating lanes, entry and exit lane width and number, entry radius and entry angle. The default values for other parameters of geometry were used. The following pedestrian data were collected and used for analysis. Pedestrian volume per hour on each legs of the intersection, approach travel distance and downstream distance. Peak flow factor of 90% was applied similar to the vehicular traffic volume. Default values of other pedestrian related parameters were used.

Movements on each lane of all legs of the intersection were defined based on the observation made on the site and traffic counts were done classifying movements to specific directions of left, through and right. Other movement, path and gap acceptance data as per HCM 2010 were used for analysis. The general model setting of delay and v/c (HCM 2010) level of service method with the delay and performance measure were used. US HCM 2010 round about capacity was used for the analysis. Other model parameters were used directly as default values of HCM 2010. Similarly, the default values of HCM 2010 cost parameters like vehicle operating costs, vehicle mass and power and time costs with their respective factors were used directly. In the case of gap acceptance the critical gap and follow-up head way parameters estimated by the program were used.

Generally the data collected on the areas of the study together with default values based on HCM 2010 given in SIDRA INTERSECTION software enabled this analysis successful to meet its intended objective of identifying the impact of freight vehicles (heavy vehicles) on these intersections. Capacity analysis on these intersections was carried out twice, one with the total traffic volume and existing percentage of heavy vehicles and the second was by limiting or reducing the percentage of heavy vehicles on each legs of the intersection to a value of 6% for Kality intersection and 4% for 18-Mazoria intersection. The level of impact of freight vehicles (heavy vehicles) can be clearly observed by comparing the analysis results of these two cases. Summary of major parameters used with their respective values is given in table 3.1.

Table 3-1Summary of major parameters used in SIDRA INTERSECTION software

	Kality Intersection	**18- Mazoria Intersection**	**Remark**
Geometry Data			
Island Diameter	80m	20m	Measured
Circulating width	14m	10.5m	Measured
Circulating lanes	4	3	Measured
Entry radius	30m	20m	Measured
Entry angle	30degree	30degree	Measured
Lane length	500m	500m	default
Lane type	Normal	Normal	Measured
Lane width	Max.3.5m and Min. 3m	Max.3.5m and Min. 3m	Measured
Volumes			
Total (Veh/hr)	See Appendix A1	See Appendix A1	Measured
HV (%)	See Appendix A1	See Appendix A1	Measured
Volume Factors			
Peak flow factor	90%	90%	HCM,2010
Vehicle occupancy	1.2per/veh	1.2per/veh	default
Flow scale constant	100%	100%	default
Growth factor	7.8%/year	7.8%/year	UTS, 2005
Path Data			
Approach cruise speed	65km/hr	65km/hr	default
Exit cruise speed	65km/hr	65km/hr	default
Approach travel distance	500m	500m	default
Movement Data			
Queue Space (LV)	7.6m	7.6m	default
Queue Space (HV)	14m	14m	default
Vehicle Length (LV)	5.1m	5.1m	default
Vehicle Length (HV)	11m	11m	default
Pedestrians			
Peak flow factor	90%	90%	HCM,2010
Flow scale constant	100%	100%	default
Growth factor	5%/year	5%/year	Estimated
Walking speed	1.3m/s	1.3m/s	default
Queue space	1m	1m	default
Model Setting			
Level of service method	Delay and v/c(HCM, 2010)	Delay and v/c(HCM, 2010)	default
Performance measure	Delay	Delay	default
HV method for gap acceptance	Include HV effect for all percentages	Include HV effect for all percentages	default
Capacity model	US HCM 2010	US HCM 2010	default
Round about LOS method	Same as signal control	Same as signal control	default
Cost	HCM,2010	HCM,2010	default
Analysis method	Neither design life nor flow scale	Neither design life nor flow scale	
Environment factor	1.2	1.2	default

3.4.5. Traffic accident analysis

Accident analysis was carried out based on five years accident record data. From the total accidents occurred, those caused by freight vehicles were identified and the percentage share of accidents caused by freight related vehicles was computed. The data collected from Addis Ababa transport office, traffic department was analyzed to know the percentage share of freight related accidents in the whole Addis Ababa. In addition to this, based on the information obtained from this office and results of previous analysis, the Akaki kality sub city was selected to figure out the level of accident impact of freight vehicles as this sub city is sited in Bishoftu exit/entry corridor of Addis Ababa which entertain majority of freight movement in and out of the city.

The vehicle types considered for this analysis were those who have a carrying capacity of <10quintals to truck with trailers. This is given in Appendix-A2 of this thesis. Simple accident trend analysis using Excel 2007 was made in both cases to figure out the percentage share of freight related accidents during the past five years. Besides this the trend of accident projection both in the case of Addis Ababa and the selected sub city of Akaki kality were analyzed to know how far the level of accident impact goes in the past five years.

3.4.6. Freight management and land use structure analysis

Different documents were revised to understand the freight management policies, rules and regulations related to freight mobility in Addis Ababa. Urban transport studies and traffic management advisory reports were assessed. The documents from the federal transport authority and Addis Ababa transport office were assessed to understand the current freight management practices of the city. In addition to the document analysis, the data collected through direct interview with the transport administrative officials and traffic polices were examined in depth. The management practice of the study area was analyzed with the general principles of freight management to figure out the shortcomings of the subject matter in the study area. In line with the study of the administrative frame work of freight transport, the city structural land use plan was also assessed to identify the impact on the city traffic function caused by freight and its related land use behavior.

Besides this the data collected through questioner was analyzed using SPSS 16.0 to point out managerial and land use related problems associated to freight transport in the city and recommendations to overcome these problems based on the opinion of the respondents.

3.4.7. Location analysis of logistics terminals

Locations of existing freight ware houses distributed in different parts of the city were assessed through field observation, land use and road network maps study. The city was mapped based on its existing industry and storage sites, future reserved storage and industrial areas, freight attracting centers and sub centers and other transport terminals using ArcGIS software.

Based on their current location in the city and the problems they caused on the overall social and environmental aspects of the city, relocation of the existing warehouses, distribution centers, factories and freight related service providing institutions like garages were proposed. In addition to those to be relocated, the construction of new integrated logistics terminals along each entry corridors at city peripheries have been proposed. The selection of locations for these integrated logistics terminals depends on factors like availabity of infrastructure, accessibility for delivery, availability of labor, proximity to suppliers and markets and service facilities and population.

Ultimately the city was mapped based on the existing freight attracting nodes and the newly proposed logistics terminals using ArcGIS.

3.5. Summary of the research process

The research processes starts with the evaluation of the general research question in terms of relevancy, adaptability and possibility of data availability in the limit of the reach of the scope of the work. Parallelly preliminary study of possible cases and selection of the case was carried out. Once it was approved that the general research question was relevant to the selected case city, detailed theoretical study to tighten the research question has been carried out. Based on the specific research question and scope of the work target sites and target groups has been selected. After targets groups have been selected, the necessary data was collected, analyzed and interpreted to come up with the findings of the research. The general research process is presented in Figure 3.1.

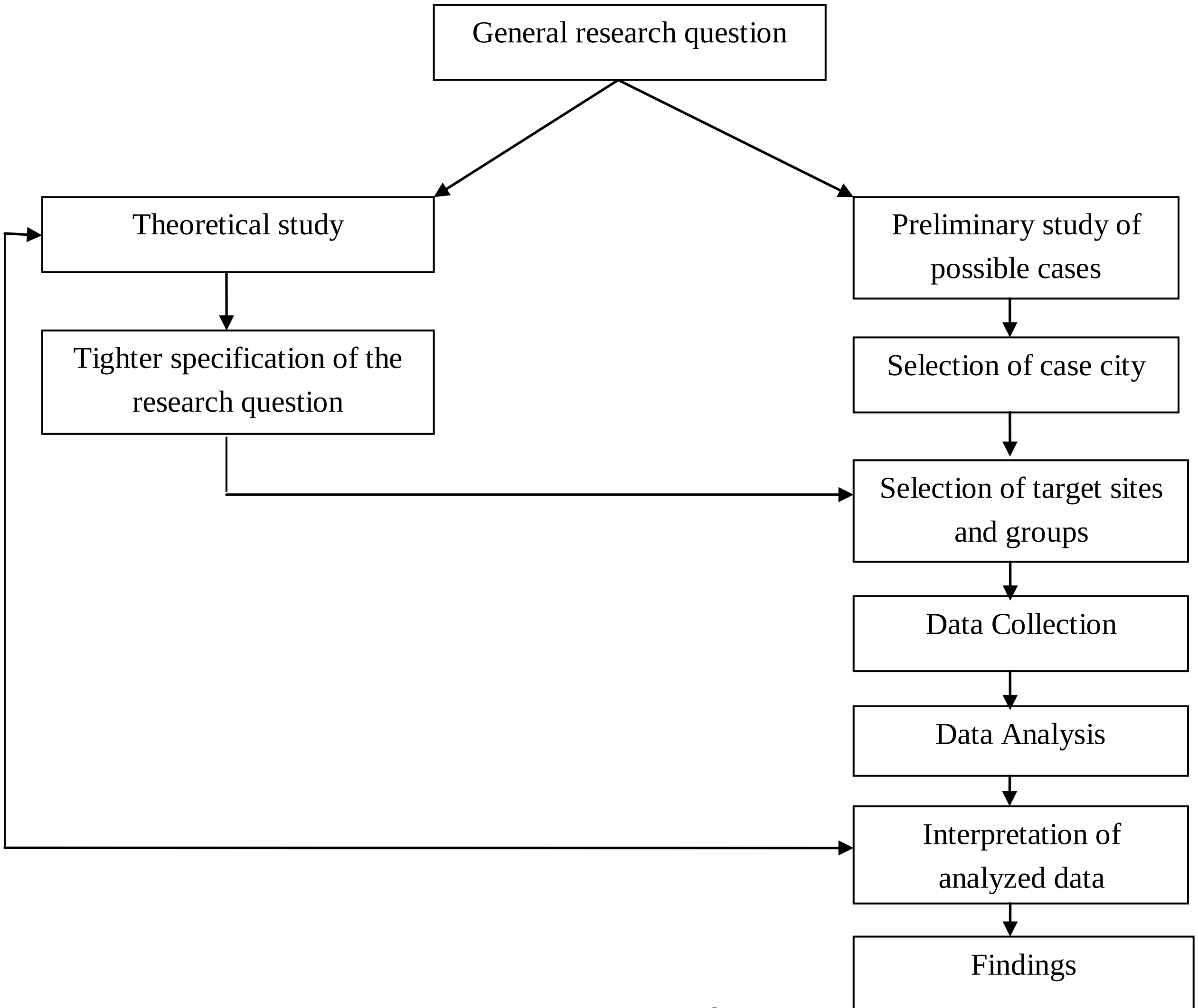


Figure 3-1 Research process

4. Results

4.1. Volume of freight vehicles along entry and exit corridors of the city

According to the UTS report of the year (2005), a total of around 9400 freight vehicles entered and exited from Addis Ababa daily along the main five corridors of the city in the year 2004. Considering each entry/exit corridors, Bishoftu road is leading by 48.2% of the total freight vehicles recorded in the same year. Ambo road and Jimma road follows Bishoftu by 19% and 17% respectively. In terms of vehicular composition small trucks take the lead with 60.8% of the total freight traffic with medium and heavy truck following it. Table 4.1 reports the summary of average daily freight traffic data in the mentioned year.

Table 4-1 Average daily freight traffic at five entry/exit corridors of Addis Ababa in 2004

	Freight traffic by mode					
Entry and Exit	S/Truck	M/Truck	H/Truck	Truck & Trailer	Total	Percentage
Bishoftu	2469	1369	448	224	4510	48.2%
Dessie	547	171	94	17	829	8.9%
Gojjam Road	438	150	28	9	625	6.7%
Ambo Road	1035	526	179	36	1776	19.0%
Jimma Road	1203	366	33	21	1623	17.3%
Total	**5692**	**2582**	**782**	**307**	**9363**	**100%**
Percentage	**60.80%**	**27.60%**	**8.40%**	**3.30%**	**100%**	

Source: UTS (2005)

According to Ethiopian Roads Authority (ERA), traffic count report of the year 2010, a total average daily freight traffic at all entry/exit corridors of the city was around 20700 vehicles. Considering entry/exit corridors Bishoftu road was again leading the other corridors by a value of 75.9% of the total freight traffic entering and leaving the city. Jimma and Dessie roads follow Bishoftu by 8.4% and 6% respectively. In terms of vehicular distribution Medium truck takes the lead with a value of 29.5% followed by heavy truck and truck with trailers. Table 4.2 summarizes these values.

Table 4-2 Average daily freight traffic at five entry/exit corridors of Addis Ababa in 2010

	Freight traffic by mode					
Entry and Exit	S/Truck	M/Truck	H/Truck	Truck & Trailer	Total	Percentage
Bishoftu	3745	4060	3914	3975	15694	75.9%
Dessie	311	443	329	157	1240	6.0%
Gojjam Road	163	385	351	130	1029	5.0%
Ambo Road	64	368	245	304	981	5.0%
Jimma Road	222	833	559	114	1728	8.4%
Total	**4505**	**6089**	**5398**	**4680**	**20672**	**100%**
Percentage	**21.80%**	**29.50%**	**26.10%**	**22.60%**	**100%**	

Source: ERA (2010) Data

In addition to the analysis of freight traffic in terms of their volume, further analysis was carried out in terms of tonnage by different modes of truck entering and leaving the city along each corridor in the year 2004 and 2010 based on the data collected from UTS, (2005) and Addis Ababa city traffic management advisory report, (2012).

A total of 81947 tons per day of freight entered and left the city of Addis Ababa in the year 2004. Out of this about 55% entered and left across Bishoftu corridor. Ambo and Jimma roads follow by 19.7% and 11.5%. Freight tonnage at the five entry/exit corridors of the city in the year 2004 is indicated in Table 4.3.

Table 4-3 Freight tonnage at five entry/exit corridors of Addis Ababa(2004)

	Tonnage, by different modes of trucks						
Entry and Exit	Pick up	LCV	2/3 axle	Truck & Trailer	Multi axle	Total	Percentage
Bishoftu	1934	4806	16593	14291	7414	45039	55%
Dessie	476	989	2103	2999	563	7129	8.70%
Gojjam Road	300	922	1845	893	298	4258	5.20%
Ambo Road	924	1834	6470	5710	1192	16129	19.70%
Jimma Road	1178	1965	4502	1053	695	9392	11.50%
Total	**4812**	**10515**	**31513**	**24946**	**10162**	81947	**100%**
Percentage	**5.90%**	**12.80%**	**38.50%**	**30.40%**	**12%**	**100%**	

Source: UTS, (2005)

The data obtained from Addis Ababa city traffic management advisory report, (2012) depicts that a total of 414574 tons of freight has entered and left the city along all corridors. Out of this Bishoftu road takes the lead by entertaining 76.2% of the total freight by tonnage with Jimma and Ambo roads following by 8% and 5.4% respectively. Freight tonnage at the five entry/exit corridors of the city in the year 2010 is indicated in Table 4.4.

Table 4-4 Estimated freight tonnage in to and out of Addis Ababa in 2010

	Tonnage, by different modes of trucks					
Entry and Exit	S/Truck	M/Truck	H/Truck	Truck & Trailer	Total	Percentage
Bishoftu	9737	49938	129553	126803	316031	76.2%
Dessie	809	5449	10890	5008	22156	5.3%
Gojjam Road	424	4736	11618	4147	20924	5.0%
Ambo Road	166	4526	8110	9698	22500	5.4%
Jimma Road	577	10246	18503	3637	32963	8.0%
Total	**11713**	**74895**	**178674**	**149292**	**414574**	**100%**
Percentage	**2.80%**	**18.10%**	**43.10%**	**36.00%**	**100%**	

Source: Addis Ababa city traffic management advisory report, (2012) Besides the analysis carried out on the data collected from the mentioned sources and shown above, analysis was carried out on the response of interviewees to select the major freight vulnerable entry/exit corridor of the city. Around 90% of the respondents believe that Bishoftu road is currently under severe impact of freight mobility problems with Ambo and Jimma roads following with 7.5% and 3.8% respectively. Appendix B and D shows the questionnaire and how it was analyzed.

4.2. Main freight attraction centers

The results indicating the main freight generating centers of Addis Ababa city were compiled from the analysis of different kinds of data. Visual observations in different parts of the city were carried out parallel to the data collection process. Another source indicating the main freight attracting centers of the city was the results of the interviews carried out with different administrative officials and stakeholders. The other main source of information to come up with a tangible result in this regard was analysis carried out on different documents like land use map of the city, road network map of the city and study reports carried out on the city's transport system at different times.

4.2.1. Large market areas

According to the onsite observation conducted throughout the city area, and study made on the city land use map, the main market areas attracting freight vehicles in the city are; Merkato, Piassa (Atikilt tera), Messalemia, Kolfe, Teklehaimanot, Shola gebiya, Kirkos and Ayertena. The above listed business areas are parts of the main and sub centers of the city. All these listed areas are locally known market and business areas of the city where dominantly small to medium trucks are moving. Some of these areas are shown on Figure 4.1.

Based on UTS, (2005) report the freight vehicular traffic movement to and from the central areas of the city covering Addis Ketema and Arada sub cities are as follows. The volume of freight vehicles into and out of these areas mainly Merkato and Piassa was observed to be 19,533 vehicles per day of which 66% were pickups, 26% LCVs and 6.75%trucks. A total of 53,490 tons of goods per day was transported in and out of these areas with a large share of (48%) carried by pickups and 25% carried by LCVs.

According to Technical advisory report for Addis Ababa city traffic management (2012), in the year 2011 about 7049, out of which (49%) pickups and (40.6%) LCVs entered and left Merkato on average daily basis. While 15, 186 out of which (82%) pickups and 14.8% (LCVs) freight vehicles entered and left Piassa area each day. In terms of quantity, 21,530 tons were transported in and out of Merkato area while 38,570 tons moved in to and out of Piassa each day.

4.2.2. Freight terminals and warehouses

In Addis Ababa, freight vehicles coming from different directions of the country are either loaded or unloaded in warehouses distributed in different directions of the city. Most of these warehouses are owned by private companies or government institutions. In the city there are no freight terminals which meet the minimum requirements like loading and unloading, parking and vehicular service facilities that a modern logistics terminal should fulfill. Majority of the existing facilities serve only storage purposes. There are very few terminals owned by transport companies like Comet transport, Weyra transport and Ethiopian grain trade enterprise which have some parking spaces to accommodate freight vehicles. However warehouses of large capacity are concentrated in Akaki Kality sub city of Addis Ababa.

Most of the large sized warehouses in the city are owned by government institutions like Ethiopian grain trade enterprise and NGO's like World food program (WFP). Ethiopian grain trade enterprise owns warehouses of a total capacity of 8,000,000quintals all over the country for grain storage purposes. Around 22% in storage capacity warehouses are found in Addis Ababa distributed in different directions of the city as shown in Table 4.5 below.

Table 4-5Ethiopian grain trade enterprise warehouses locations and their capacity

Location	Saris (Abo)	Kality M.Church	Gofa	Megena gna	Kolfe	Saris (Adey Abeba)	Gojam Berenda	Kebena (Shell)	Kechene
Storage capacity (quintals)	950,000	200,000	200,000	160,000	80,000	40,000	40,000	20,000	20,000
Percenta ge	55.6%	11.7%	11.7%	9.4%	4.7%	2.3%	2.3%	1.2%	1.2%

Source: Ethiopian grain trade enterprise, 2012

The ware houses in kality and Saris adey abeba are mainly dedicated to export coffee. In most of the remaining warehouses food grains of different types have been stored for use by the city except that of WFP to be redistributed to different parts of the country.

There are also lots of medium to large sized ware houses owned by private and companies distributed in different directions of the city. Most of the food grain temporary storage and distribution centers are concentrated in Messalemia, Ihilberenda, around Kolfe and Teklehaimanot areas. In Bole sub city around Megenagna, between Imperial and Megenagna and in the areas towards Gurd Shola there is large concentration of warehouses and industries of various scales. Almost all factories and industries in Ethiopia have distribution centers of their products in Addis

Ababa. It is difficult to cover them all in the scope of this thesis, however some of them are; cement factories around Gotera, beer factories, soft drink factories, steel factories, different building materials and petroleum products are some among many factories which own distribution centers of their own or by rental in the central areas of Addis Ababa.

In Akaki Kality sub city particularly around Kality intersection there are lots of privately owned, company and government warehouses in addition to the grain trade enterprise warehouses. The field observation, response of majority of the interviewees and document analysis made on this subject revealed that Akaki kality, Addis ketema, Nifas silk lafto and Bole sub cities of Addis Ababa are sub cities with larger concentration of warehouses and distribution centers of different bulk agricultural and industrial products.

4.2.3. Factories and service providing institutions

There are several small scale to medium factories which demand raw materials from either inside or outside the city areas. These factories also distribute their products to different areas of the city and outside the city to different parts of the country. Among many such factories; soft drink (Koka, Moha), beer (St. Gorge), flour factories, abattoirs (Kera), food complexes and so many other partially processing and value adding factories are located in the city centers. Most of these factories were established many years before now. At that time their current locations were the peripheries of the city. With the city rapidly developing in all direction through time, the areas where most of the factories found turned to be city centers. As mentioned earlier this factories collect raw material and distribute their products using variety of freight vehicles ranging from small truck to truck with trailers.

The other freight attraction areas of Addis Ababa are service providing institutions like Ethiopian customs authority and various service garages distributed in the city. Ethiopian customs Authority (Gumruk) located at saris Abo near kality intersection is one of the major freight attraction centers of the city. Previously that area was like city periphery, however in its current situation it is no more be a city periphery as there is one sub city (Akaki Kality) behind that location as part of Addis Ababa. Many of the truck service providing garages and spare part shops are also located in city centers like Kera and Gofa. The main attracting and generating centers of Addis Ababa city was mapped by ArcGIS 10 using Arc map and shown in Figure 4.1.

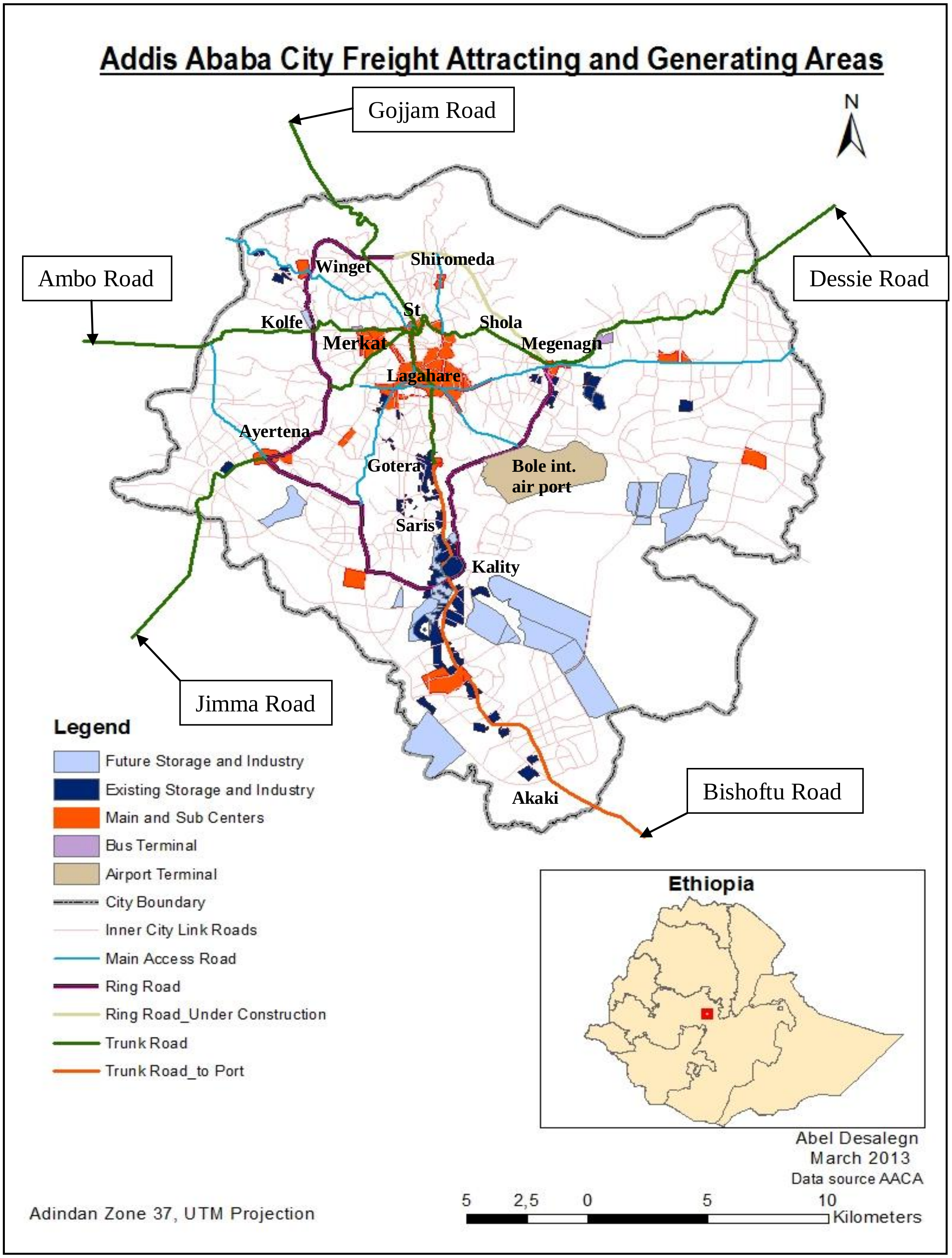


Figure 4-1 Addis Ababa city freight attracting and generating areas

4.3. Sample intersections and associated freight impacts

4.3.1. Selected intersections

Based on the results of Section 4.2 of this thesis, Akaki kality, Addis ketema and Kolfe Keraniyo sub cities were given a due concern and investigated in depth to come up with best representative sites with dominant freight movement. The selection of representative sites that can clearly demonstrate the level of congestion impacts caused by freights in the city was carefully carried out.

All the sample stakeholders interviewed through questioner were given an open ended question to discuss all the intersections they know and believe that are congested because of freight vehicles movement in the area The responses of interviewees analyzed using SPSS 16.0 and depicted that Kality intersection found in Akaki kality sub city on the main Bishoftu exit road between Ethiopia Customs Authority (Gumruk) and Addis Ababa transport authority’s drivers training center is one of the most congested intersections by freight vehicles in the city. Around 68.8% of the respondents believe that this intersection is number one intersection which is under freight vehicles impact. An intersection locally named as 18-mazoria intersection found to the west of Addis Ababa in Kolfe keraniyo sub city close to the entry towards Messalemia and Merkato areas is selected to be the number one congested intersection in its freight movements by 25% of the respondents. Ayertena intersections and others account for the remaining 7%. The result is summarized in Figure 4.2as shown below.

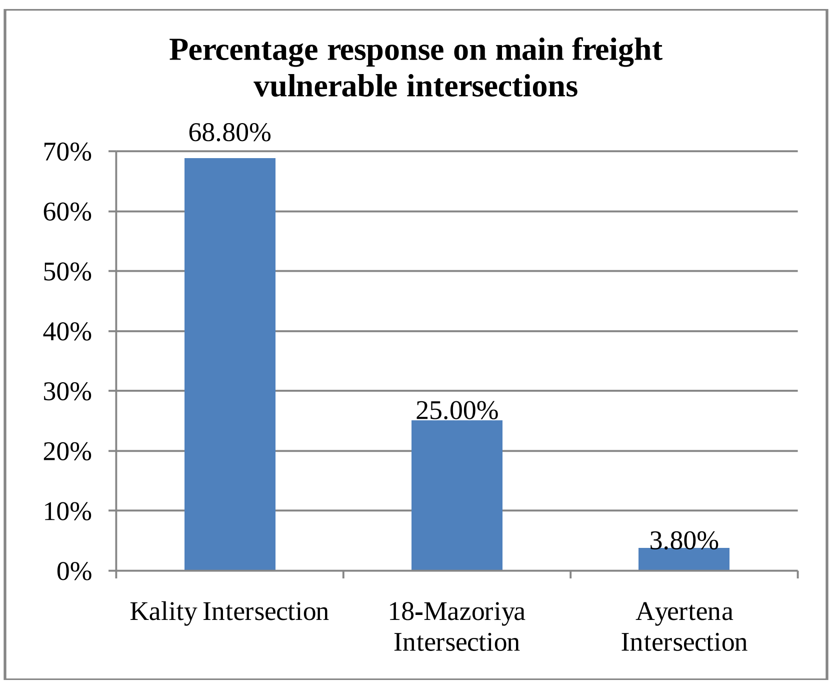


Figure 4-2 Main vulnerable intersections to freight vehicles

4.3.2. Major freight impacts

4.3.2.1. General

There are several freight related impacts in urban areas which highly affect the efficiency of the general urban traffic and environment. In developing cities like Addis Ababa where complex travel behavior and informal goods distribution governs, the problems associated to freight is much more significant. Highly noticeable impacts currently affecting the socio economy and environment of the city are congestion, pollution, accidents and poor city aesthetics. Understanding the level of impact caused by freight transport was one of the goals of this thesis.

4.3.2.2. Congestion

Impacts like congestion is mainly pointed out through parameters like Level of service, Delay, travel time, travel speed and degree of saturation. The relationship between travel speed and flow and the level of service on the road network as given by Addis Ababa City Roads Authority geometric design manual is presented in figure 4.3.

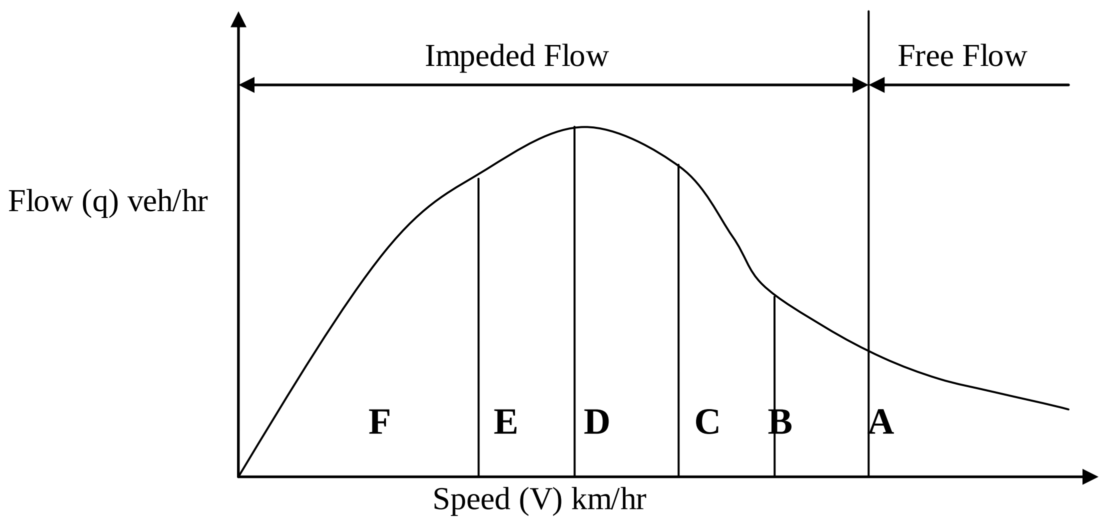


Figure 4-3 Speed-Flow relationship and Level of Service

Source: AACRA (Addis Ababa City Roads Authority) Geometric design manual

AACRA geometric design manual defines each category of LOS for arterial roads like the one considered in this analysis as described in Table 4.6 below.

Table 4-6 Level of service characteristics

Level of Service	Arterial roads
A	Average travel speed of about 90%of free flow speed. Stopped delay at signalized intersection is minimal.
B	Average travel speed drop due to intersection delay and inter vehicular conflict, but remain at 70% of free flow speed. Delay is not unreasonable.
C	Stable operations. Longer queues at signals result in average travel speed of about 50% of free flow speeds motorists will experience appreciable tension.
D	Approaching unstable flow. Average travel speed down to 40% of free flow speed. Delays at intersections may become extensive.
E	Average travel speed 33% of free flow speed. Unstable flow. Continuous back up on approach to intersections
F	Average travel speed between 25 and 33% of free flow speed. Vehicular backups and high approach delays at signalized intersections.

Source: AACRA (Addis Ababa City Roads Authority) Geometric design manual

Traffic volume and intersection geometry data as discussed in data analysis section of this thesis were used by the SIDRA INTERSECTION software to come up with these results. The raw traffic volume data is given in Appendix-A1 of this thesis report where the summary of the traffic volume and heavy vehicle percentage are given before each analysis.

The analysis was carried out:

i. By using the total average counted traffic and the actual percentage of heavy vehicles (freight vehicles in the case of this thesis)

ii. By using reduced percentage of heavy vehicles to a value of 6% for all legs of Kality intersection and 4% for all legs of 18-Mazoria intersection.

This category of analysis was made to observe and evaluate the change in parameters that are indicators of those impacts on the intersections in question. For the purpose of this thesis heavy vehicles were defined as all freight vehicles except pickups and other delivery vehicles like vans as they are easily maneuverable vehicles. The percentage of heavy vehicles (HV %)(freight vehicles in the case of this thesis) used in the second analysis is the unavoidable traffic which is the deduction of possibly diverted traffic and possibly decentralized traffic from the total heavy vehicles percentage which was estimated based on the origin destination survey carried out by Ethiopian Roads Authority (ERA) for the purpose of understanding the diversion potential of traffic along the Bishoftu corridor of the city as part of the newly constructed Addis-Adama road project which is connected to the city around Akaki and the possibility that majority of freight vehicles can be controlled at the city fringes assuming integrated freight centers are constructed at the city peripheries so that major freight attracting and generating nodes can be decentralized and relocated in these areas. Summary of the diversion potential is presented in Table 4.7.

Table 4-7 Ratio of Diverted Traffic to Project Roads from the Kality – Akaki Section

No.	O/D of Diverted Traffic		Proportion of Traffic to (%)				Existing Alternative Road
	Origin	Destination	East	West	North	South	
1	Addis Ababa	Elsewhere	7.4%	7.6%	11.3%	22.1%	Kality – Akaki
2	Elsewhere	Addis Ababa	10.0%	7.7%	9.7%	23.2%	Akaki –Kality
Total Diversion Potential (%)			17.4%	15.3%	21%	45.3%	

Source: Ethiopian Roads Authority

Based on the traffic count carried out on Kality intersection, freight vehicles account for around 37.1% including pickups. Based on the above table about 22.1% of the total traffic originates from and about 23.1% is destined to the southern section of Addis Ababa where Kality intersection is the main entry point in the current traffic flow condition along Akaki kality road. The remaining traffic can possibly be diverted to the other sections of the city provided that new external orbital road is constructed. Among the destined traffic to the southern section of the city, about 8.61% which is the 37.1% of 23.2% total traffic in this area is the share of freight vehicles. It is assumed that heavy trucks with three to four axels and truck with trailers can be controlled at the entry areas around Akaki provided that freight terminals are constructed. Based on the survey made, these vehicles account for about 35.6% of the total freight vehicles entering Kality intersection. This is around 3.1% from the share of freight vehicles destined to the southern section of the city which is 8.61% as discussed above. Therefore, the unavoidable possible freight traffic is about 5.5% which is the deduction of 3.1% from 8.61%. It is approximated to 6%, where within this 6% limit of heavy vehicles, it is assumed that the remaining types of freight vehicles which needs to enter the city for special purposes like construction, waste disposal and others can be accommodated. For further simplification of the stress on the intersection, diversifying their mobility times from other vehicles (for example construction and waste materials to be damped during night times and etc) can also be implemented.

For 18-Mazoria intersection the HV% for the second analysis was estimated from the proportion of heavy vehicles movement between Kality and 18-Mazoria intersections as per the traffic count data. Accordingly the average percentage of heavy vehicles on all legs of Kality intersection is 26% when that of 18-Mazoria intersection is 16.25%. This means that Kality intersection exceeds 18-Mazoria intersection by around 60%. Applying the same proportion, the 6% HV% tolerance on Kality intersection can be 3.7% on 18-Mazoria intersection. This is approximated to 4% for the purpose of analysis.

Accordingly, the results of the capacity analysis by SIDRA INTERSECTION for both selected intersections are presented as follows.

Kality Intersection

Actual traffic volume and percentage heavy vehicles

The intersection is part of the main ring road where the north east and south west running road passes under the roundabout. The under pass is a wide multi lane road which accommodate a traffic from and to Megenagna and Lafto side legs of the intersection. This under pass was treated as a wide median of 21m width and only left and right movements were defined for these legs of the intersection. The traffic volume count and percentage share of freight volume is summarized in Table 4.8 below.

Table 4-8Traffic volume and percentage heavy vehicles of Kality intersection by actual traffic volume

Traffic Volume	Direction of flow (Intersection legs)			
	Akaki side	Megenagna side	Saris side	Lafto side
Total traffic(veh/h)	1100	522	723	650
percentage (HV)	25%	29%	16%	34%

The parameters used as measures of congestion were, travel time total (veh-h/h), travel speed (Km/h), degree of saturation (v/c), delay (sec) and level of service. The results of the analysis are summarized in Table 4.9.

Table 4-9 Results of congestion measures of Kality intersection by actual traffic volume

Measuring Parameters	**Direction of Flow**				
	Southeast (Akaki side)	**Northeast (Megenagna side)**	**Northwest (Saris side)**	**Southwest (Lafto side)**	**Intersection**
Travel time total (veh-h/h)	38.7	49.0	12.1	32.0	131.8
Travel speed (Km/h)	20.5	8.9	43.2	15.4	17.1
Degree of Saturation(v/c)	1.04	1.52	0.54	1.22	1.52
Delay average (Sec)	73.9	250.8	14.1	114.7	99.2
LOS (Level of Service)	F	F	B	F	F

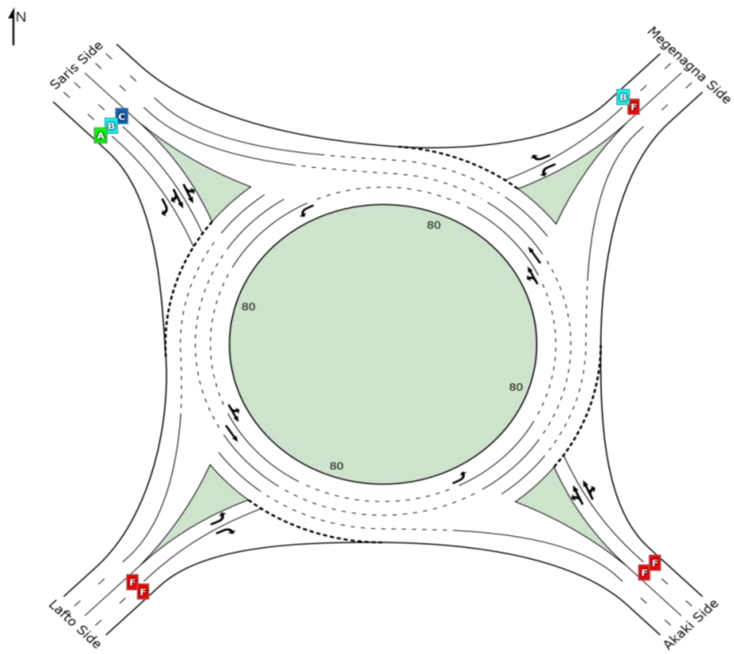


Figure 4-4 Level of Service summary of Kality intersection by actual traffic

Heavy vehicles reduced to Max. 6%

Summary of traffic volume after heavy vehicles reduced to 6% is given in the Table 4.10.

Table 4-10 Traffic volume and percentage HV reduced to 6%-Kality intersection

Traffic Volume	Direction of flow (Intersection legs)			
	Akaki side	Megenagna side	Saris side	Lafto side
Total traffic(veh/h)	881	394	646	452
Percentage heavy vehicles	6%	6%	6%	6%

The data was reanalyzed by reducing the actual values of heavy vehicles percentage (HV %) to a maximum value of 6% on each legs of the intersection keeping all other input values constant Table 4.11 shows the summary of the results of the analysis.

Table 4-11 Results of congestion measures of Kality intersection, heavy vehicles reduced to 6%

Measuring Parameters	**Direction of Flow**				
	Southeast (Akaki side)	**Northeast (Megenagna side)**	**Northwest (Saris side)**	**Southwest (Lafto side)**	**Intersection**
Travel time total (veh-h/h)	15.0	9.0	10.1	8.8	42.9
Travel speed (Km/h)	42.2	36.6	46.2	39.2	41.4
Degree of Saturation(v/c)	0.63	0.69	0.43	0.60	0.69
Delay average (Sec)	15.3	20.9	10.5	18.0	15.4
LOS (Level of Service)	C	C	B	C	C

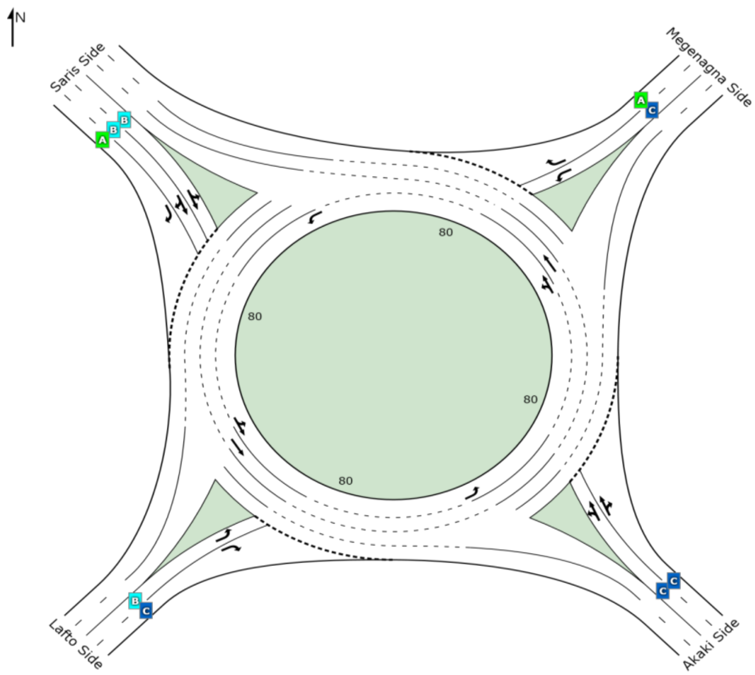


Figure 4-5 Level of Service summary of Kality intersection heavy vehicle reduced to Max.6%

18-Mazoriya Intersection

Actual traffic volume and HV %

Similar analysis was carried out to know the level of congestion impact on this intersection. As discussed in earlier sections this intersection is part of the city ring road which is found in the west side of Addis Ababa. It serves as a main entry spot to the city main commercial center Merkato and Messalemia. The summary of total traffic volume per hour and percentage heavy vehicles is given in Table 4.12.

Table 4-12 Traffic volume and percentage HV of 18-Mazoria intersection by actual traffic volume

Traffic Volume	Direction of flow (Intersection legs)			
	Torhailoch side	Messalemia side	Winget side	Likuanda side
Total traffic(veh/h)	833	489	722	535
Percentage (HV)	19	16	16	14

This data was analyzed and congestion measuring parameters is summarized in Table 4.13 as shown below.

Table 4-13 Results of congestion measures of 18-Mazoria intersection by actual traffic volume

Measuring Parameters	**Direction of Flow**				
	South (Torhailoch side)	**East (Messalemia side)**	**North (Winget side)**	**West (Likuanda side)**	**Intersection**
Travel time total (veh-h/h)	16.8	14.1	13.6	11.6	56.1
Travel speed (Km/h)	34.2	23.8	37.1	31.5	31.7
Degree of Saturation(v/c)	0.65	0.95	0.66	0.82	0.95
Delay average (Sec)	23.6	53.1	17.7	29.9	28.8
LOS	C	F	C	D	D

The level of service of the intersection has been summarized in the figure 4.6 as shown below.

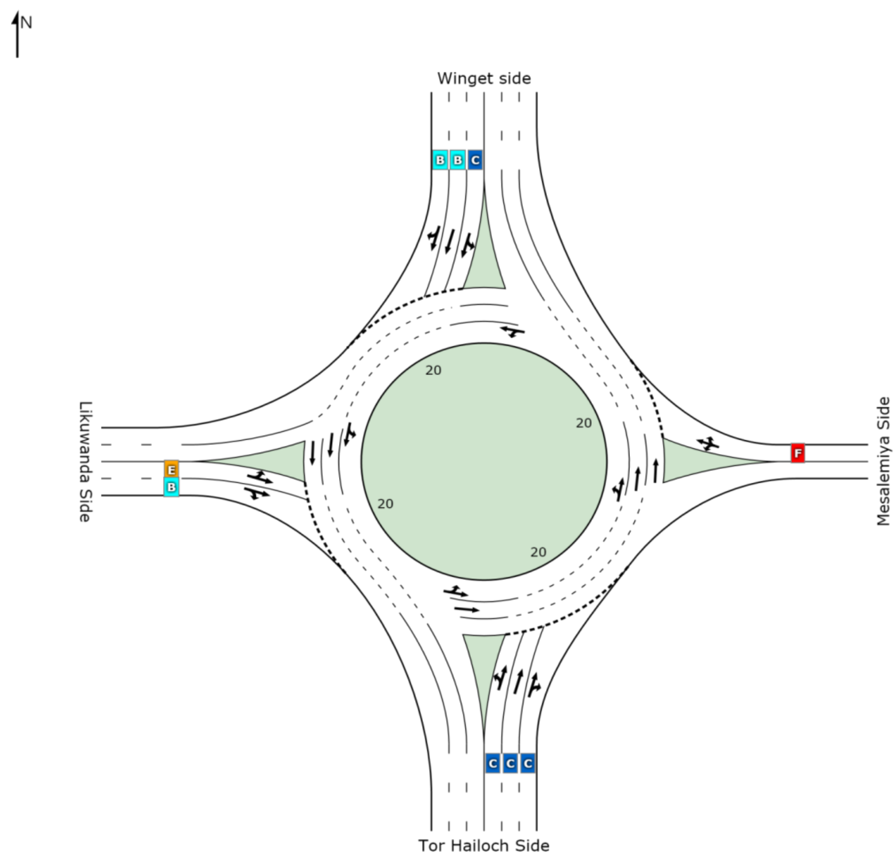


Figure 4-6 Level of service summary of 18 Mazoria intersection by actual traffic

Heavy vehicles reduced to Max. 4%

The percentage of heavy vehicles on each leg of this intersection was reduced to a maximum value of 4% to understand the variation in congestion measuring parameters. The total traffic volume and percentage heavy vehicle reduced is summarized in Table 4.14.

Table 4-14 Traffic volume and percentage heavy vehicles reduced to 4%- 18-Mazoria intersection

Traffic Volume	Direction of flow (Intersection legs)			
	Torhailoch side	Messalemia side	Winget side	Likuanda side
Total traffic(veh/h)	707	429	629	479
percentage (HV)	4%	4%	4%	4%

Using the data shown above analysis was made and the new results of those parameters are as indicated in Table 4.15 below.

Table 4-15 Results of congestion measures of 18-Mazoria intersection after HV reduction to 4%

Measuring Parameters	**Direction of Flow**				
	South (Torhailoch side)	**East (Messalemia side)**	**North (Winget side)**	**West (Likuanda side)**	**Intersection**
Travel time total (veh-h/h)	11.9	7.8	10.5	8.3	38.5
Travel speed (Km/h)	40.9	38.0	41.7	39.7	40.3
Degree of Saturation(v/c)	0.44	0.66	0.47	0.60	0.66
Delay average (Sec)	12.7	17.5	10.8	15.1	13.6
LOS	B	C	B	C	B

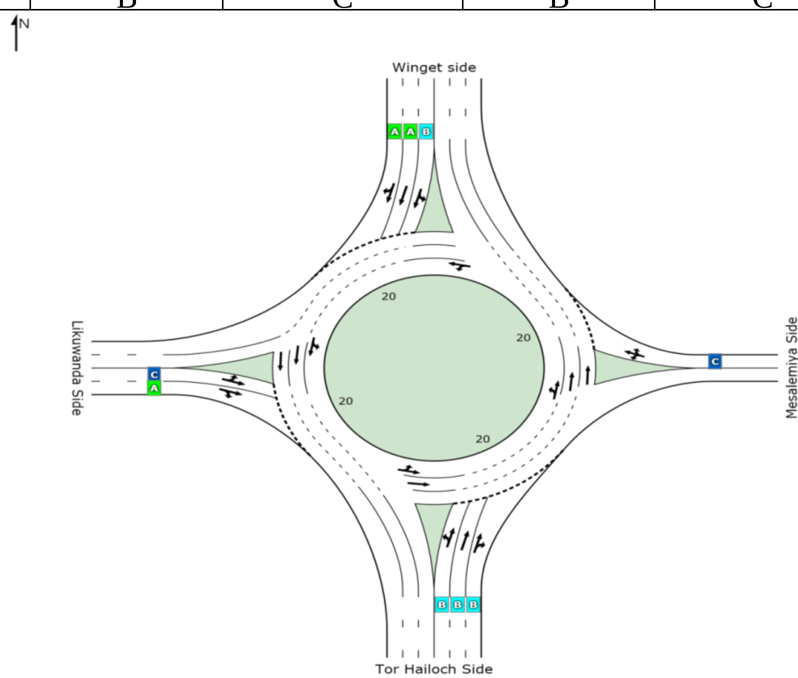


Figure 4-7 Level of service summary of 18 Mazoria intersection after percentage HV reduction

Besides the field measurement made on selected hotspot areas, to figure out to what level freight affected those areas, interviewees response on issue of congestion in the city was analyzed. Around 70% of the respondents agree that the number one brutal challenge associated to freight transport in the city in current time is congestion followed by traffic accidents and environmental pollution. The respondents claimed that freight vehicles congest most of the major streets of the city especially in those hotspot areas, the ring road and areas outside the ring road of the city.

Most of the roundabouts on the ring road are currently highly congested. Some of the main examples are Kality, 18-Mazoria, Bole Michael, and Imperial roundabouts. These intersections and links outside the ring road of the city are congested mostly as there is no restriction in movement for freight vehicles on and outside the ring road areas of the city. Among the respondents the transporters claimed the impacts that the city congestion caused on their business while the public mostly claimed the social and economical impacts that this congestion caused. Most of the drivers argued that the current level of congestion really tempt their tolerance and affect their driving behavior which in turn caused considerable safety problems in the city. Traffic polices mostly responded that the problem reached beyond their control where they can't regulate the traffic in the way it should be especially during peak flow periods. They claimed that the problem is not only associated to the transport system rather it is multi dimensional which requires the coordination of all concerned bodies in city planning and development. Summary percentage of respondents in severity order of freight challenges in the city has been presented in the chart below.

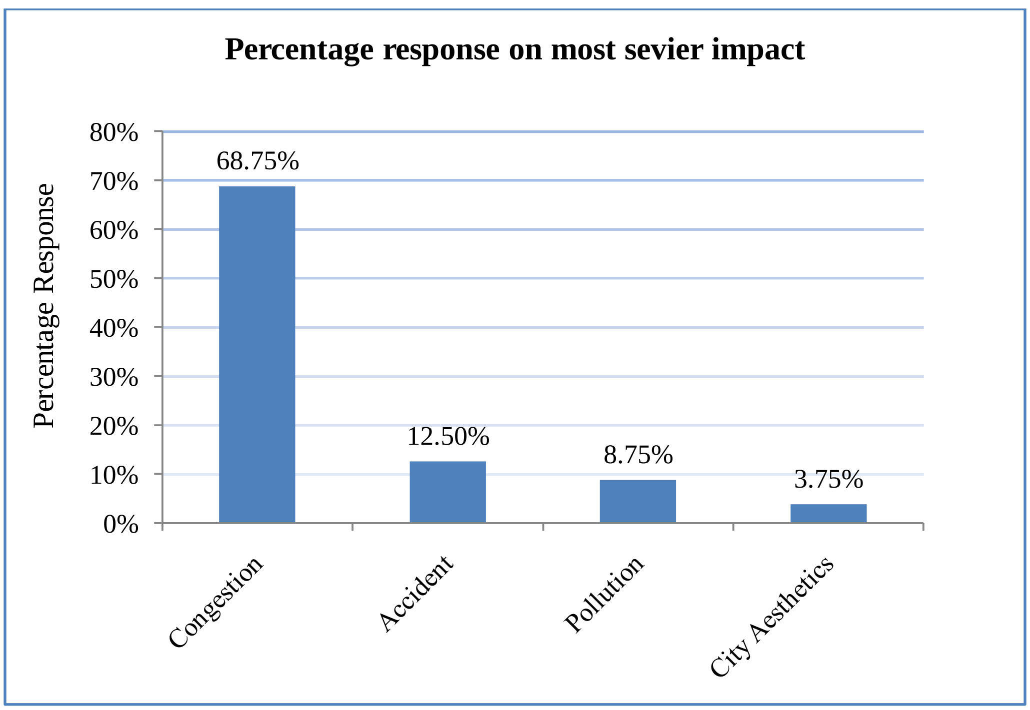


Figure 4-8 Severity order of freight challenges in Addis Ababa

4.3.2.3. Pollution

Freight vehicles pollute cities in different ways. Among these; emission, sound pollution, dust and leak of oil and other petroleum residuals are the most common ones. All of these environmental pollution problems related to freight vehicles exist in Addis Ababa at different level of intensity.

In recent years, societal and environmental issues have become a concern in developing cities like Addis Ababa. More than 55% of the respondents of the interview made on this regard argued that emission and dust is the major environmental pollution problem in Addis Ababa city while around 45% believes that noise is the main challenge in terms of environmental pollution.

The result from the capacity analysis by SIDRA INTERSECTION software made on the selected roundabouts of Kality and 18-Mazoria revealed the following results of emission. All parameters like vehicle data, fuel and other cost parameters that results in the outputs related to pollution were kept the default values given in the software as recommended by HCM 2010. This was because of the fact that the objective of this thesis was not to calculate the amount of emission in these areas rather it is to understand to what level freight vehicles have contributed to the problem in question. So keeping the default values of these parameters, comparative analysis was made between the two output values of emission, the first analysis was made by using actual traffic volume data and the second was the analysis made by reducing the percentage of heavy vehicles to 6% and 4% for Kality and 18-Mazoria intersections respectively. The results of the analysis are presented in tables as follows.

Kality Intersection

By actual traffic volume

Table 4-16 Results of Emission at Kality intersection by actual traffic volume

Emission(kg/h)	Direction of Flow				
	Southeast (Akaki side)	**Northeast (Megenagna side)**	**Northwest (Saris side)**	**Southwest (Lafto side)**	**Intersection**
NOx (Total)	1.387	1.406	0.507	1.002	4.301
CO2 (Total)	548.0	541.1	209.5	416.7	1715.3
CO (Total)	45.5	38.2	15.4	32.5	131.5
HC (Total)	0.830	0.726	0.291	0.618	2.466

Heavy vehicles reduced to Max. 6%

Table 4-17 Results of Emission at Kality intersection after heavy vehicles reduced to 6%

Emission(kg/h)	Direction of Flow				
	Southeast (Akaki side)	**Northeast (Megenagna side)**	**Northwest (Saris side)**	**Southwest (Lafto side)**	**Intersection**
NOx (Total)	0.468	0.437	0.346	0.281	1.532
CO2 (Total)	200.9	150.5	145.4	117.1	614.0
CO (Total)	13.9	11.0	10.3	8.9	44.0
HC (Total)	0.307	0.180	0.220	0.186	0.893

18-Mazoria Intersection

By actual traffic volume

Table 4-18 Results of Emission at 18-Mazoria intersection by actual traffic volume

Emission(kg/h)	**Direction of Flow**				
	South (Torhailoch side)	**East (Messalemia side)**	**North (Winget side)**	**West (Lafto side)**	**Intersection**
NOx (Total)	0.736	0.436	0.587	0.426	2.185
CO2 (Total)	287.8	180.3	230.4	170.5	869.0
CO (Total)	23.9	14.3	19.1	13.8	71.1
HC (Total)	0.425	0.285	0.344	0.264	1.318

HV reduced to Max. 4%

Table 4-19 Results of Emission at 18-Mazoria intersection after HV reduction to 4%

Emission(kg/h)	**Direction of Flow**				
	South (Torhailoch side)	**East (Messalemia side)**	**North (Winget side)**	**West (Lafto side)**	**Intersection**
NOx (Total)	0.410	0.250	0.363	0.276	1.299
CO2 (Total)	165.1	102.0	146.4	111.7	525.2
CO (Total)	13.5	8.2	11.9	9.0	42.5
HC (Total)	0.274	0.170	0.243	0.185	0.872

4.3.2.4. Accidents

Similar to the other impacts discussed above the cause of traffic safety problems are multi sectoral. Among many, significant number of accidents has been caused by freight vehicles moving in the city and its surrounding. Even most of the accidents caused by the other vehicles are one way or another connected to freight vehicles. To figure out the level of accidents caused in the city by freight vehicles, analysis on accident record data of five years was carried out. The accident record data of the whole Addis Ababa which was collected from the city's transport office traffic department was first analyzed and in particular the level of accident in Akaki kality sub city was analyzed based on the accident record collected from the sub city's traffic office.

Addis Ababa

The result of the analysis at the city level is presented in Table 4.20 as shown below.

Table 4-20 Summary of accident record in the past five years in Addis Ababa

Year	Total no of accidents	Accidents Caused by freight	Percentage
2007/2008	8169	2207	27.0%
2008/2009	7523	1693	22.5%
2009/2010	6285	1689	26.9%
2010/2011	9134	1934	21.8%
2011/2012	11529	3036	26.3%

The trend of freight caused accidents in the whole Addis Ababa in the past five years was analyzed and presented in Figure 4.9 as shown below.

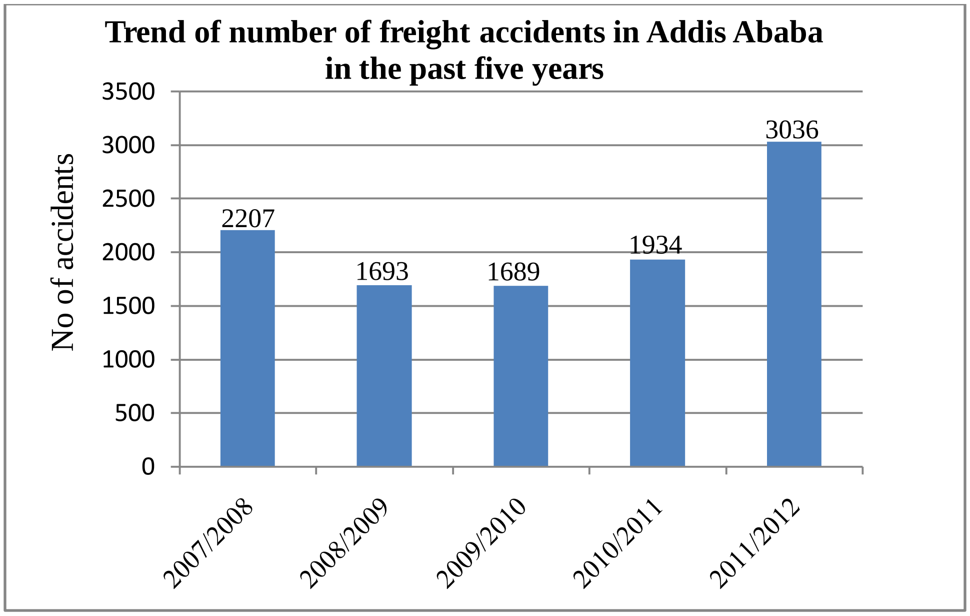


Figure 4-9 Trends of accidents caused by freight vehicles in Addis Ababa

Akaki Kality sub city

Besides the analysis carried out to figure out the trend in total number and share of freight caused accidents, for the past five years for the whole Addis Ababa, analysis for the selected sub city (Akaki Kality) was carried out and its results has been presented in Table 4.21.

Table 4-21 Summary of accident record in the past five years in Akaki kality sub city

Year	Total no of accidents	Accidents Caused by freight	Percentage
2007/2008	484	213	44.0%
2008/2009	543	257	47.3%
2009/2010	558	274	49.1%
2010/2011	768	395	51.4%
2011/2012	1057	595	57.4%

The summary of the trend in number and percentage of accidents caused by freight vehicles in the past five years in Akaki kality sub city are discussed as shown in Figure 4.9 and 4.10 as below consecutively.

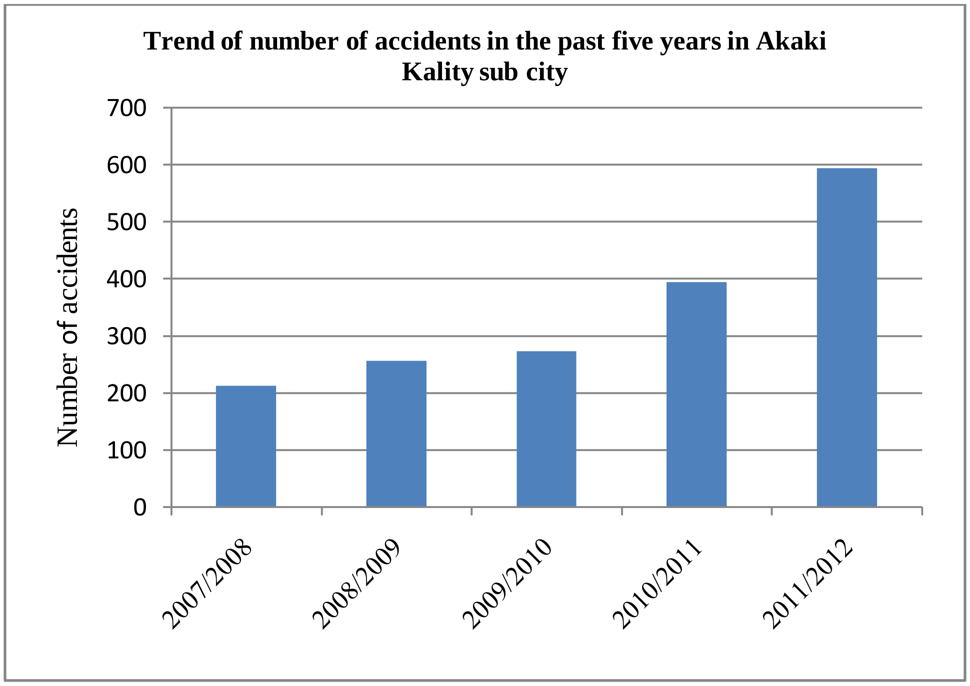


Figure 4-10 Trend of number of accidents caused by freight vehicles in Akaki Kality sub city

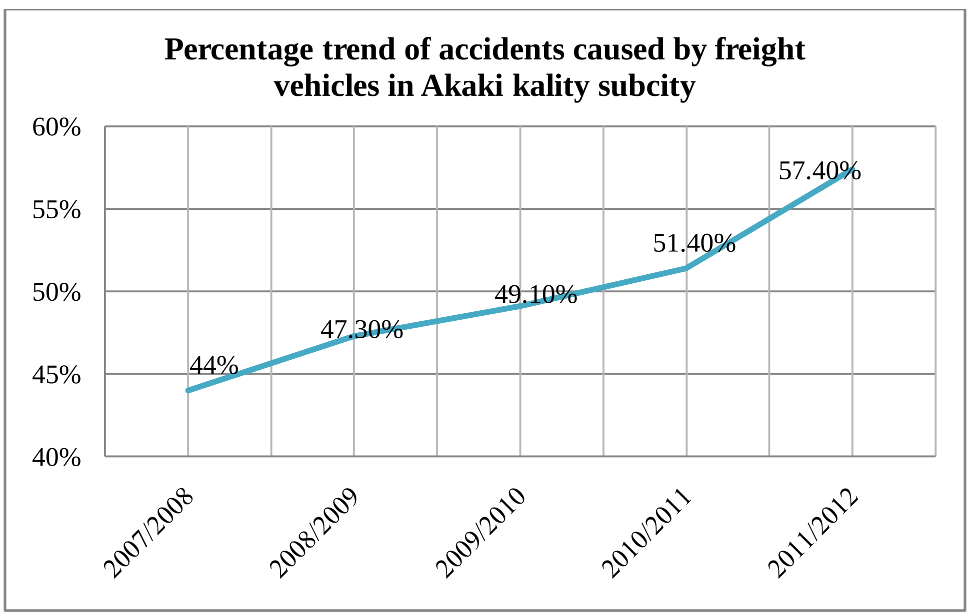


Figure 4-11 Trend of percentage of accidents caused by freight in Akaki kality sub city

4.3.2.5. City aesthetics

Significant number of interviewees responded that goods distribution in the city of Addis Ababa, considerably affected the aesthetic value of the city. Besides the transport of goods, storage areas lack neatness and the warehouses are old and their walling is mostly made from corrugated iron sheets which affect the city aesthetics. Majority of the goods transported especially agricultural products are bulk and non- processed which do not reflect the standard of modern city. Typical example of such products affecting the city aesthetics are Piassa (Atikilt tera) and in Merkato (Ihil berenda) and Kibe berebda. These areas are aesthetically unpleasant and stinky, which in any way do not fit the modern living style.

4.4. Freight transport management and traffic regulation practices

The analysis carried out on different types of documents and interviews carried out by respective stakeholders revealed that, there is no well structured and coordinated freight management system either from the private sector or from the government side in Addis Ababa and in general in Ethiopia. The efficiency of freight both in terms of cost reduction and socio environmental improvement is very minimal. As per the interview made with the federal transport authority officials, majority of the country's freight issues including Addis Ababa are managed centrally in one office which makes the freight management activity to be highly inefficient. Currently the federal transport authority is attempting to implement the framework of modern fleet management system in the industry. However, this centralized effort of the authority alone cannot solve several problems ingrained in the system. The private sectors should thoroughly involve in implementing efficient freight management system as part of their daily businesses.

According to the survey made on this subject, only 55% of the transporters in the city have a fleet management system in their organizational structure. Even those transporters having fleet management systems are mainly concerned on the operational aspects of the system rather than the wide perspective that the system should fulfill. This has resulted in lack of accountability in caring for social and environmental assets of the community. Consequently the social, economical and environmental problems discussed so far have been aggravated.

In Addis Ababa city one of the main operational challenges of the freight industry is the lack of proper management system and lack of stakeholder coordination running the industry. About 45% of the interviewees argued that lack of coordination between stakeholders is the major challenge hindering the proper freight management and traffic operation systems in Addis Ababa. Poor infrastructure and corruption follows lack of coordination between stakeholders respectively. The response of interviewees on factors mainly hindering proper implementation of freight management and traffic operations in Addis Ababa is summarized in Figure 4.11 shown below.

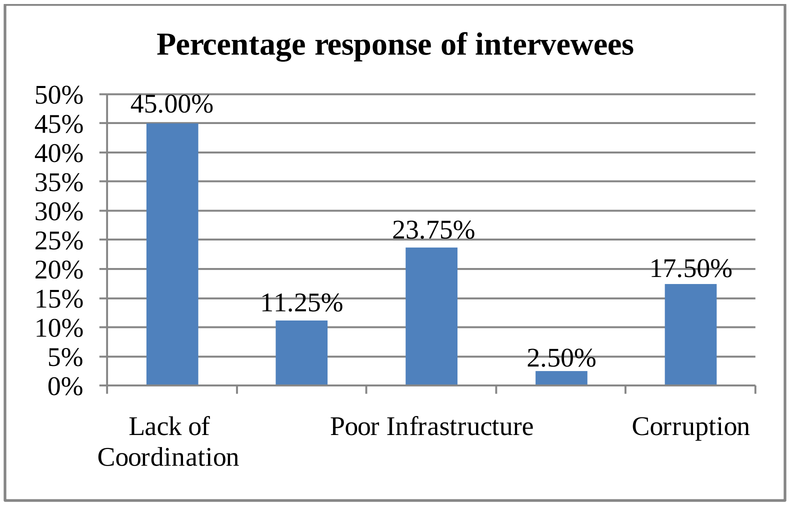


Figure 4-12 Percentage responses of interviewees on factors hindering implementation of freight management

The interview made with respective stakeholders in the industry depicted that there is no strong traffic regulation practices in Addis Ababa, especially in area of freight transportation. The information gathered from the city traffic departments depicted that there is a time and place restriction of movement on heavy freight vehicles in the city centers, especially inside the roundabout areas. In the areas on and outside the roundabout no place and time restriction exists. The time of free mobility in day times is from 10: AM to12: AM in the morning and from 2: PM to 4: PM in the afternoon and the whole night. Among several feasible freight management options that may ease the impacts of freight mobility in urban areas, the following are presented based on the respondents opinion. About 46.25% responded that managing freight transshipment at the city peripheries can solve the impacts. Enforcing the freight rules and regulations and freight coordination follows transshipment as indicated in Figure 4.12. Below shown are only some of the many freight management options.

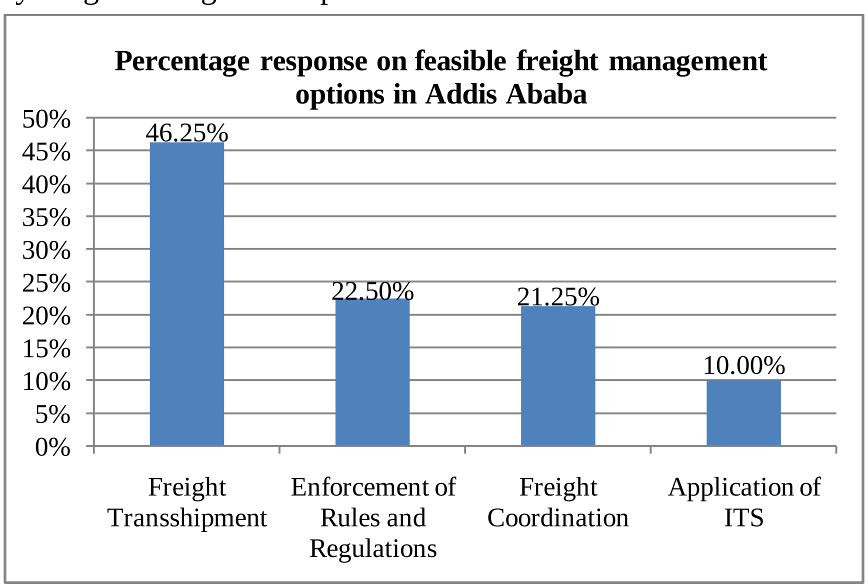


Figure 4-13 Responses on feasible freight management options in Addis Ababa

4.5. Transportation and land use interaction

4.5.1. Land use challenges and city travel behavior

The dominant land use pattern of Addis Ababa city is mixed land use. Major problems related to land use which in turn affect the travel behavior of the city are mainly;

i. **Zoning: -** Some heavy manufacturing activities are mixed with residential area, which creates in efficiency in the supply of infrastructure and environmental management.
ii. **Centralization:** - Transport centers are concentrated at the city center
iii. **Land utilization: -** Old settlements have irregular plot subdivision. As a result of this land is inefficiently utilized. In general manufacturing and government establishments occupy large urban land area thus resulted in inefficient land utilization.

According to Addis Ababa structural plan – 2010, the road network and transportation covers only 3.8% and 1.9% of the total land in hectare, respectively. The structural land use plan as part of the city master plan (200-2010) as presented on UTS, 2005 is shown in table below.

Table 4-22 Land use proportions of the city

Major components of the structural plan	Area(ha)	Percentage
Mixed use(Housing) built up	16,274	31.3
Mixed use(Housing) expansion area	6,974	13.4
Existing industry	1,244	2.4
Proposed industry	1,777	3.4
Center (CBD’s and sub CBD’s)	1,276	2.4
Existing social services	495	1
Proposed social services	600	1.2
Road Network	1,975	3.8
Transportation	989	1.9
Forest open space	12,176	23.4
Agricultures	7,175	13.8
Reserved area	1,045	2
Total	52,000	100

Source UTS, 2005

About 82.5% of the respondents during the interviewing process of this thesis argue that the current land use pattern of Addis Ababa city has significantly affected the traffic mobility of the city. More than 70 % of this stake holder responded that decentralization of the warehouses and distribution centers residing in the city center will significantly solve the problems associated to current traffic condition of the city. So it is very important to keep on considering decentralization as a major policy direction and finding the way to its immediate implementation.

4.5.2. Freight transport and land use

The previous city master plan of Addis Ababa has not considered freight terminals or stations. However efforts have been made to decentralize big ware houses and depots to the suburb or out of the ring road area of the city. Because of the lack of infrastructure in these suburb areas, lack of coordination between institutions and lack of implementation strategy; the intended plan has failed to be implemented and resulted in today's freight related problems. Information gained from the city administration depicted that there are some areas planned to be developed for truck freight depot particularly in Akaki Kality sub city. However they are occupied by informal settlements in the city.

4.6. Logistics practices of the city

4.6.1. Freight coordination and consolidation practices

In Addis Ababa, there is no separated intra city and intercity goods distribution scheme. As a result there are no consolidation centers for the urban delivery activities. Long haul trucks either from the port or other parts of the country deliver goods directly to each storage facilities or distribution centers located in city centers. Freight transporters have not developed working in coordination for the common goal of creating safe and congestion free urban environment. Analysis made on the responses of the interviewees on this matter pointed out that, the about 70% of the transporters have a work relation with one another. However this relation is only business oriented like subcontracting works when it gets beyond ones capacity rather than it is to solve urban problems associated to lower load rate practices.

As the interview made with stakeholders of the industry depicted, different agricultural and industrial items transported either from the port or from other regions of the country are mostly distributed through the city directly by the long haul trucks. This clearly indicated that there are no consolidation and transshipment practices for the goods delivery. Similarly, for items moving out of Addis Ababa either to the port or to other parts of the country, there is no coordinated distribution framework. Most of the time different industrial and home use commercial items are distributed to regional markets from Addis Ababa. This makes the city commercial centers like Merkato, very busy and congested. As per the interview made with some drivers of light and medium trucks in Merkato and Messalemia (Ihil Berenda) area depicted, some retailers found in different regions of the country who collect their business items from Addis Ababa have practices of hiring transporters in coordination. Although their collaboration is primarily aimed to optimize their own business efficiency, somewhat it also benefits the city in reducing the number of entering trucks to the city.

Freight vehicles operating in Ethiopia ranges from pickups to multi axel truck trailers. Freight vehicles with a carrying capacity of over 70 quintals are registered by the federal transport authority while vehicles with lower capacity are registered by the regional transport bureaus. Knowing the ownership, loading category and accountability to the administrative frame work of the sector can help to discuss the future coordination potential of freight transporters to alleviate their mobility impacts on the urban environment. Summary of the ownership and fleet characteristics of the higher and lower capacity vehicles whose main operational centers located in Addis Ababa city are presented in Table 4.23.

Table 4-23 Ownership of higher capacity freight vehicles by their number and total fleet size

Cargo type	Ownership type	Number of owners	Total fleet size	Percentage of fleet
Dry Cargo	Association	162	12328	50.3%
Dry Cargo	Enterprise	199	6414	26.1%
Dry Cargo	Private	301	2054	8.4%
Liquid Cargo	Association	6	597	2.4%
Liquid Cargo	Enterprise	44	1944	7.9%
Liquid Cargo	Private	20	1192	4.9%
Total		**732**	**24529**	**100%**

Source: Federal Transport Authority, 2012

Table 4-24 Ownership of lower capacity freight vehicles by their fleet size in Addis Ababa

Ownership type	<11 quintals	11-70 quintals	Dual purpose	Total	Percentage
Private	6671	8013	6217	20901	57.6%
Organization	3642	3398	8330	15370	42.4%
Total	**10313**	**11411**	**14547**	**36271**	**100%**

Source: Addis Ababa traffic advisory report, (2012) based on the city transport bureau data

4.6.2. Decentralization and relocation

The current Addis Ababa city master plan outlined decentralization as a main urban policy direction. However it lagged behind in terms of implementation. The general decentralization policy covers, distribution of the population to reduce densities in central area, relocation of manufacturing activities consuming large extent of land to industrial uses areas, shift of market places, shift of storages facilities and relocation of freight terminals to the city peripheries.

As discussed in Section 4.2 of this thesis, lots of factories and small scale industries, ware houses and distribution centers are still located in city central areas. As interview made with the city master plan revision team depicted, several attempts have been made to relocate those freight nodes from the city center. However majority of them failed and resulted in the current mobility problems. Transporters and the public strongly argued that, although decentralization and relocation of facilities are set on the master plan as the policy direction of the city development, necessary attention was not given from the government side to execute the plan. Much attention was only given to other investment sectors than the freight transport and its related facility.

5. Discussion

5.1. Main entry/exit corridors of the city

From the results of all analysis indicated in Section 4.1 of this thesis, the total volume of freight traffic that entered and left the city has increased by more than 100% in between six years time. This indicates that how freight vehicular volume is rapidly growing in the city and in the country as well. Among the five entry exit corridors Bishoftu corridor shows a large increase in its percentage share of freight vehicular traffic volume from 48.2% to 75.9% compared with other corridors. While considering the freight by tonnage between the years 2004 and 2010 the total tons of freight moving in and out of the city has increased by more than 400% which means more than four times of its value in 2004. This indicates how the city is becoming a huge freight hub in the recent years. From this non- proportional growth of freight vehicular volume and freight quantity in tons one can conclude that the volume of heavy truck and truck with trailers entering and leaving the city has been increased in recent years. The total tonnage along all corridors has significantly increased. However in terms of their percentage share among each other Bishoftu road has shown large increase than the others. Bishoftu corridor has grown both in terms of size (freight volume and tonnage) and in terms of its percentage share compared with other corridors of the city. This indicates that this corridor is inevitably the main freight entry corridor of the city. Apart from this, the result indicates that, part of the city along this entry corridor is under significant freight impact.

Considering each freight vehicles separately the share of heavy trucks and truck with trailer has significantly increased in the six years time. This is an indication of the increase in number of heavy duty vehicles inside the city area and total freight by tonnage. One of the possible reasons for this road corridor to show such significant increase than the others is that, this road corridor remains the only import export corridor of the country for years and most of the industries and business interactions have been concentrated in the eastern and south eastern directions of the city that mainly uses this corridor to enter and exit the city.

In most of other entry/exit corridors of the city, the total freight traffic volume has significantly increased except Ambo road which shows some reduction in volume in recent years. The reason in reduction of freight vehicular volume entering Addis Ababa along this corridor is possibly because of the fact that Oromia commodity exchange center has been recently established in Burayu town in area locally named as Ashewa meda where light and medium sized trucks mostly destined. This has currently assisted the city significantly by prohibiting most of the freight vehicles coming from the western part of the country loading different agricultural products not to enter the city center. This result is one of an indication of the advantage of decentralization of warehouses and terminal from the city center. However the result of analysis of freight by tonnage in (2010) indicates that this corridor is still the second most vulnerable corridor of Addis Ababa by freight movement. This non-proportional growth of freight vehicles volume and tonnage is an indication of large increase in the volume of heavy and truck with trailers in this corridor. These heavy vehicles mostly are loaded with coffee, sugar, export crops like sesame, cement and marble from western area of the country and enter the city to unload at their respective warehouses. Because of the fact that commodity exchange center mentioned earlier mostly serves other crop types and agricultural products to be used in the local markets rather than export items.

Similar to the Ambo road, dominant freights moving across Jimma corridor are agricultural items like coffee, flower and fruits and vegetables from south western part of the country and southern part of the country along Alemgena Butajira road joined to the main Jimma road at Alemgena. Along Gojjam corridor both agricultural and industrial products has shown significant increase in recent years. Dessie roads mostly entertain industrial products and construction materials that come from the northern part of the country with most of the agricultural products moving towards there across this road corridor. So with the recent development in terms of industrialization and booming construction activities all over the country the northern exit and entry corridors of the city are also under significant impact and this effect will also be expected to highly increase in the future.

5.2. Main freight attraction centers

Results shown in Section 4.2 of this thesis give some indications about the volume of freight vehicles moving within the city. While this represents the freight demands in a few areas of the city, there is currently no detailed information about the total demand for the intra city freight transport covering all areas of the city. However it is possible to identify the potential freight attraction centers of the city through observation in the city and other indirect methods to plan and execute city logistics strategies that can ease the challenges related to goods distribution in the city centers. Those listed local areas of the city in this section are only some which are mainly recognized during the field investigation process, interview results and document analysis. Currently in line with the development activity carried out in the city, lots of sub centers are being introduced which inevitably turned out to be potential freight attraction centers in the near future. These discussed main and sub centers of the city are mainly composed of distributions centers of variable magnitude and form, temporary storage areas, retail centers, shops with variety of items, malls, hotels and open (on street) vending areas.

All these mentioned activities are concentrated in some localized areas and attract both customers and respective goods and services for those customers in need. In contrary with such concentrated activities physical infrastructures like road networks, storage areas, loading unloading facilities and parking lots are very scarce in these areas. This situation highly aggravates the problem and resulted in the current congestion, safety and pollution problems. The existing scarce infrastructure resources are mostly occupied by street venders, vehicles parked on streets and different service providing shops like garages and etc. This indicates that the freight movement is not the only problems causing factor in these market areas, rather the problem is multi sectoral which necessitates the coordination of different institutions to come up with a sustainable solution.

Furthermore, in these mentioned city centers detailed study on the sources and magnitudes of the impacts should be carried out by coordination among institutions like city planners, infrastructure administrators, traffic operators, private sectors and community members. After problem identification and analysis it is possible to come up with multi sectoral solution that sustainably alleviate the problems in question.

The other main freight attracting centers of the city other than market places and mixed business areas as discussed above are warehouses and terminals located in the city. One of the major bottlenecks for the efficiency of freight transport and logistics in urban areas is the availability and location of storage and related facilities. Logically these facilities should be located in close proximity to markets and business areas which are invariably found in city centers. The paradox to this phenomenon is the scarcity of infrastructure resources like road networks resulting in congested streets in city centers which limits the accessibility of this area. Major solutions to solve the problems associated to storage facilities are to decentralize and relocate them and to upgrade their standards from simple storage purposes to a well organized logistics terminals that can provide variety of services beyond storage. The existing warehouses should be in depth studied in terms of their particular location, capacity, ownership, specialty of storage and surrounding land use. The studied warehouses should be categorized in priority order in terms of their relevance, severity of their impact on the city traffic functions and their flexibility of movement. Finally relevant measures should be taken according to the classifications and priority order set before. These measures can be one of the following;

i. On spot improvement and facilitation
ii. Simple decentralization and
iii. Decentralization and upgrading of their standards

These concepts will be discussed in depth in section 5.6 of this thesis.

Similar to the warehouses and market centers factories and service providing institutions attract significant amount of freight vehicles. Even though the Modjo dry port has currently started its services, all the custom clearance and other related services has not totally moved there yet, which still attracts freight vehicles to the previous location of ECA. As a result majority of import items coming along Bishoftu roads come to Saris area to get customs clearance for the items imported.

This activity can be simply given outside Addis Ababa without coming this long inside the city and causing trouble on the city streets. So, total relocation of ECA (Gumruk) and the adjacent Comet terminal from its current location to somewhere outside the city or to the Modjo dry port is something which needs an immediate action. Truck service garages and shops should also need to be decentralized and located close to the freight terminal areas.

5.3. Sample intersection and associated freight impacts

The result of this analysis strengthened the previous study of the identification of main freight attraction areas. Kality intersection, lies on the Bishoftu road which is the main import export corridor of the country. This intersection is part of the Addis Ababa ring road which is geometrically sound. Considering the geometry of the intersection, it is a very large roundabout with underpass road headed north east - south west directions. The island diameter of the intersections is around 80m with four rotating lanes. Except the South east leg (Akaki side) which is narrow and structurally deteriorated road the remaining legs of the intersection are relatively sound both in terms of Geometry and structure. The main reason for the roundabout of this size and additional under pass road to be congested is that excessive traffic using the intersection. The share of freight related vehicles using this intersection are also very high which worsen the problem. Around 60% of the interviewees responded that excessive freight traffic volume is the main cause of congestion on this intersection while 26.2% believe that it is geometry related problem.

The main freight attracting centers in this area is the Ethiopian Customs Authority (Gumruk) which is found just near the intersection to its north side. Customs related activities have been carried out in the large compound near the intersection. In addition to that the comet terminal and many other large ware houses mentioned in the earlier sections are concentrated in this area up to Gotera interchange. As there is no another road network departing from and entering Addis Ababa from the east and south east direction all vehicles moving this direction must use this intersection either to enter or leave the city. So based on all these facts and findings of the previous sections it is found to be logical to select this intersection for the capacity analysis to meet the objective of this thesis.

The 18-mazoria intersection is located to the west side of the city in Kolfe keraniyo sub city in a particular area named as Asrasimint. The intersection is part of the Addis Ababa ring road which runs from north to south from Winget to Torhailoch and it is the critical entry spot towards the main commercial center of the city Merkato and Mesalemia Ihil berenda areas for the traffic coming from the west and south west directions of the city. This intersection mainly serves the west side traffic of the main Ambo road corridor to enter and exit the city along the new Ambo road. In addition to this the intersection mainly serves the traffic coming along Jimma road and seeks to enter Merkato or Mesalemia areas. As the information gathered from the traffic polices in this area depicts, freight drivers coming from Jimma road corridor and seeks to enter Mesalemia or Merkato areas, prefer to use the main ring road along Torhailoch towards 18-Mazoria rather than moving along Torhailoch-Koka-Abinet-Sebategna and finally Merkato. This is because of the fact that they have the right to move 24 hours of a day on the ring roads and they can reach their destination departing at this intersection in short distance without being penalized by traffic polices. This intersection also serves a freight traffic coming from north direction across winget and needs to either enter the mentioned market areas or pass towards the south west direction of the city. In recent times drivers coming from and moving towards the north side corridors of the city shows a tendency to use this intersection as an entry and exit departure point towards the main commercial areas of Merkato and Messalemia as the ring road from Adisugebiya and Winget is already completed and open for traffic. So this intersection is one of the main spots serving majority of freight vehicles to enter and exit main freight destination areas like Merkato and Messalemia. So based on the existing facts and analysis made so far this intersection is selected to the second place for the capacity analysis.

As discussed above two of the most sensitive and relevant spots among the many road networks in Addis Ababa namely Kality and 18-Mazoria intersections are selected for the capacity analysis to characterize the level of impacts imposed on the city by freight vehicles and to draw some logical recommendations that need to be implemented to solve the problems.

Congestion

Currently one of the major traffic problems in Addis Ababa city is congestion. It is difficult to find a road network in Addis Ababa which is congestion free almost in all times of the day. This problem is worse in intersections than links of the road networks. The causes of congestion on Addis Ababa streets are so many. In this thesis one of the cause for the city roads congestion, freight transport or goods distribution moving into, out of and within the city were studied, analyzed and discussed.

Kality Intersection

From the results given in Section 4.3.2.2, the share of freight causing a congestion impact on the intersection in question is clearly visible. The second analysis result shows, with a reduced percentage volume of freight vehicles from its actual counted value to the maximum of 6% all measures of congestion travel time, travel speed, degree of saturation, delay and level of service have significantly improved. Before the reduction the level of service of the intersection is in the category F and it is improved to the level of service C with the reduced percentage of heavy vehicles. Level of service is one of the main indicators of capacity of the road network. Level of service relates to the operating conditions encountered by traffic. It is a qualitative measure of such factors as speed, trip time, interruptions, interference, freedom to overtake, ability to maneuver, safety, comfort convenience and vehicle operating cost.

So according to the general characteristics of Level of Service values described in the table 4.6, level of service changed from F to C means that average travel speed changes from its value of 25%-33% of free flow speed to 50% of the free flow speed which is very significant.

The improvement in the level of service is the cumulative improvement value of all the other measuring parameters of congestion discussed above. As a result of reducing only the percentage of heavy vehicles to the maximum of 6%, all these parameters have shown improvement at a rate of more than 100%. Travel time, degree of saturation and delay has significantly reduced by more than 100% and travel speed has increased similarly by more than 100%. The reduction in average delay is much higher than the others which is more than 500% which means more than five folds reduction in delay time. The summary of improvement gained by reducing the percentage of heavy (freight) vehicles from the total vehicular traffic using the intersection is summarized in Table 5.1.

Table 5-1 Percentage improvements of congestion indicators at Kality intersection

Measuring Parameters	**Values before HV% reduction**	**Values after HV% reduction**	**Percentage improvement**
Travel time total (veh-h/h)	131.8	42.9	207.2%
Travel speed (Km/h)	17.1	41.4	142.1%
Degree of Saturation (v/c)	1.52	0.69	120.3%
Delay average (Sec)	99.2	15.4	544.1%
LOS	F	C	

This result proves the hypothesis that says Kality intersection is highly congested because of excessive freight traffic rather than the geometry or orientation of the intersection. Although the intersection is geometrically sound in its current condition one of its leg the south west (Akaki side) is currently under major geometric and pavement related problem which intensifies the congestion on the link from Kality intersection to Akaki check point (Addis Ababa entrance). This road segment is the only road network serving all traffic entering and leaving Addis Ababa. Starting from Akaki check point to Kality intersection there is no alternative road network which distributes traffic coming in to and out of the city. Kality intersection is a departure spot for all traffic leaving and entering Addis Ababa. All vehicles coming from all directions of the city depart there and enter the Kality-Akaki check point road network. Similarly all vehicles entering the city from the south east direction use this road network up to Kality intersection. This road network is about 10km in length and it is very narrow and structurally deteriorated. The geometric and structural problems that this road network has, together with excessive vehicular traffic, makes this road a traffic hell of the city. The roads coming from Megenagna and Lafto side mostly serve heavy vehicles as they are part of the ring road of the city. The result of the analysis also indicates this. The through traffic in this direction uses the under pass road beneath the roundabout so it does not have an impact on the intersection. The road in the Saris side is a multi lane new road which is currently in good geometrical and pavement condition.

18-Mazoria Intersection

The level of service of an intersection has improved from D to B with the reduction in the percentage of heavy vehicles to 4% on all legs of the intersection. Based on the general definition of level of service given by AACRA (Addis Ababa City Roads Authority) and discussed in Table 4.2, this means the travel speed changed from 40% of the free flow to 70% which is very significant. Other parameters which are indicators of congestion have also shown significant improvement as summarized in Table 5.2.

Table 5-2 Percentage improvements of congestion indicators at 18-mazoria intersection

Measuring Parameters	**Values before HV% reduction**	**Values after HV% reduction**	**Percentage improvement**
Travel time total (veh-h/h)	56.1	38.5	45.7%
Travel speed (Km/h)	31.7	40.3	27.1%
Degree of Saturation (v/c)	0.95	0.66	43.9%
Delay average (Sec)	28.8	13.6	111.7%
LOS (Level of Service)	D	B	

Travel speed has increased by about 27.1% while the rest has reduced significantly as shown in the table. Compared to Kality the percentage improvement of this intersection is relatively lower in value. This is an indication of the fact that the problem of congestion on this intersection is not only the volume of freight traffic, rather factors such as geometry and orientation of the intersection should also need to be evaluated. In terms of geometry this intersection has several problems as observed on site during data collection. Its size is very small with island diameter of only 20m, the south-north road from Torhailoch to Winget is connected to the roundabout at large grade which is a challenge for heavy vehicles to apply a break, and the east – west direction roads from Messalemia to Likuanda are very narrow and poor pavement road which affects smooth traffic flow. Especially the leg of the intersection in Messalemia side is only a two lane road for the two way movement of traffic without median. No walk ways as houses and different kinds of shops are located just near the road. This problem on this site dictates that the need for road geometric solutions and expansion of additional networks that connect to the commercial areas of the city.

So the result of the analysis made on the two sample sites is an indicative of the fact that pulling out heavy vehicles from city centers will result considerably in relieving the roads from their current congestion problems.

In general, currently the problem of congestion in Addis Ababa city is very rigorous which affects the overall social needs, economy and efficiency of the freight operation by itself. The causes of congestion in the city are multi directional which concerns different sectors. However those causes of congestion which are directly related to freight transport and land use are majorly categorized in to two. These are;

i. Infrastructure related challenges and
ii. Freight transport management challenges

Both challenges contributed significantly to the city's current condition of congestion. However their level and relevance to the problem in question varies from one another. Survey on the existing freight facility areas like warehouses and loading and unloading areas of the city were made during the data collection. It was observed that there is a huge shortage of various freight infrastructures in the city that contributed a lot to congestion problem besides their mobility and excessive increase in volume. The other major challenge in freight operation today in the city is poor management and traffic operation practices that in any way are not compatible with the current booming transport demand and city development. According to the response of stake holders interviewed around 67.5% argues that the current problems associated to freight transport in the city of Addis Ababa emerges from lack of freight related infrastructures or facilities. The remaining 32.5% believes that poor freight management practice is the main cause of these problems. This figure indicates that improving freight facility needs immediate attention to solve the problems. Improving the operational characteristics of freight should also be carried out parallel to providing the city with necessary freight infrastructures that fits the city master plan and current developmental activities in the industry.

Among many infrastructures related challenges lack of parking areas, lack of sufficient road networks, lack of loading and unloading facilities, lack of sufficient storage facilities and land use pattern are the main ones. Survey was carried out in the city to figure out the availability and standards of freight facilities. Most of freight mobility areas of the city like commercial and warehouse areas discussed in earlier sections are located in city centers where land is very scarce and human settlement is very dense. As a result, freight related infrastructures are limited to very narrow areas mixed with other commercial activities of the area. Narrow and deteriorated roads are observed in these areas. Most of the warehouses do not have loading and unloading facilities; as a result, this activity is mostly carried out on the nearby roads which in turn aggravate the congestion problem of the city streets. The selected stakeholders have also been interviewed on this issue and their responses are summarized in Figure 5.1.

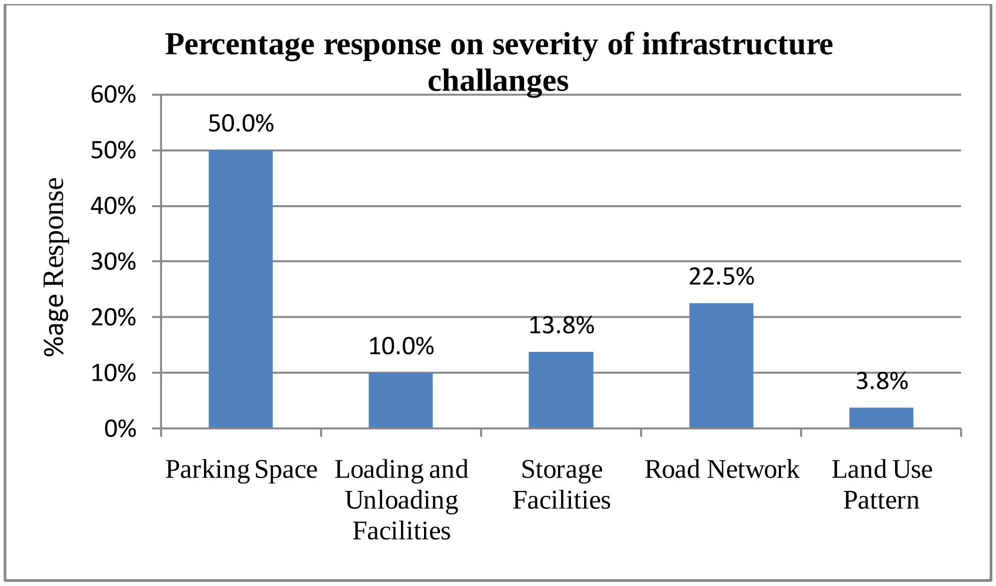


Figure 5-1 Summary of percentage response on infrastructure challenges

The result of the interviewee's response indicated that among the above listed challenges lack of parking area is the most brutal problem in the city of Addis Ababa currently. As indicated on the chart above half of the respondents argue that lack of freight parking space is the major problem causing congestion in the city. Freight vehicles in the city are mostly parked on streets because of the lack of terminals. Most of the freight transporters argues that they don't have freight terminals and parking areas where their vehicles to be parked when they are off duty. More that 75% of the transporters responded that they don't have terminals (compounds) to park their vehicles. Some of them responded that they have garages which serve dual purpose parking and vehicular services. As a result around 60% of the transporters answered that they park their vehicles mostly on streets, around 30% on company and private garages and the rest on rental terminals or private compounds. This indicates that how serious on street parking has become in causing congestion problems in the city.

The second most fatal problem of infrastructure causing congestion in the city is associated to road networks. The problems associated to the road networks of Addis Ababa are mainly three. These are;

i. Lack of networks: - road networks in the city are in sufficient to accommodate the current traffic within reasonable level of service.
ii. Quality of road networks: - the available networks mostly of poor quality both in terms of geometry and pavement which results in poor traffic flow and accidents.

iii. Orientation of road networks: - orientations of road networks in the city are mostly north-south while the traffic flow is dominantly east-west which imposes a huge impact on east-west roads.

Others like storage and associated loading, unloading facilities and land use pattern of the city are infrastructure challenges causing congestion in the city. The other main causes of congestion, poor operational management will be in depth discussed in later sections while discussing the management aspect of the city freight.

Pollution

Environmental pollution is one of the major challenges of urban freight distribution. This problem is worse in developing cities like Addis Ababa where there is no strong societal demand for clean environment and where administrative initiatives are at infant ages. The environmental pollution caused by freight vehicles is much more intense in freight destination areas than other parts of the city. Freight vehicles by nature release large amount of emission to the environment than other vehicle types. They also cause high sound pollution especially when they are moving loaded.

Kality Intersection

The comparative analysis made on the two analysis values described in Section 4.3.2.2 of this thesis are summarized and presented in Table 5.3.

Table 5-3 Percentage improvement of emission at Kality intersection

Emission(kg/h)	Values before HV% reduction	Values after HV% reduction	Percentage improvement
NOx (Total)	4.3	1.53	180.7%
CO2 (Total)	1715.3	614	179.4%
CO (Total)	131.5	44	198.9%
HC (Total)	2.46	0.89	176.1%

This result shows that if the total percentage of heavy (freight) vehicles around Kality area can be reduced to a maximum of 6% of all vehicular traffic using this intersection, the emission of harm full gases like NOx, CO2, CO and HC can be reduced by more than 100%. This result indicates that how heavy vehicles affect the area by emitting harm full gases to the environment.

18-Mazoria intersection

The results from the two cases have been comparatively analyzed to come up with the percentage improvement possibly gained by reducing the total HV percentage to maximum of 4%. The values of percentage improvement of the emission levels have been presented in table below.

Table 5-4 Percentage improvement of emission at 18-mazoria intersection

Emission(kg/h)	**Values before HV% reduction**	**Values after HV% reduction**	**percentage Improvement**
NOx (Total)	2.18	1.29	68.2%
CO2 (Total)	869	525.2	65.5%
CO (Total)	71.1	42.5	67.3%
HC (Total)	1.32	0.87	51.1%

The result of the analysis shows that significant improvement will be gained if the total percentage of HV can be reduced to 4%.

The comparative analysis carried out on the two cases on both intersections of the city indicates how freight vehicles significantly affect the environment of the city by emitting harm full gases. And it also indicates if the volume of freight vehicle moving in the city can be reduced to some tolerable limits, significant emission reduction can be attained which consequently improve the environment of the city.

Besides their volume, one of the main causes of environmental pollution caused by freight vehicles is associated to their ages. The interview made with the sample transporters depicts the fact that most of the vehicles used for freight transport in Addis Ababa and in Ethiopia in general are aged which is one of the case for their huge emission of gases and sound pollution in freight areas. Around 55% of the transporters responded that the average age of their vehicle is between 10 and 20 years and about 25% of them responded that average ages of their vehicles is >20%. This indicates that the city streets are mostly covered by aged vehicles which pollute the environment. It is not only their ages that aggravates the problem but also their models. In Addis Ababa even the remaining 20% of freight vehicles with average ages of <10years are mostly old model vehicles which are not environmental friendly. This problem is caused because of the lack of enforcing law from administration side that restricts aged vehicles not to move on city streets. Most of the transporters in the country also have no vehicle replacement policy. According to the survey made on this issue about 85% of the transporters in Ethiopia do not have vehicle replacement policy. The current pollution problem is the city is the cumulative impact of all these facts.

Accidents

Traffic accident is one of the major freight related challenge in urban areas. Because of their large size freight vehicles accommodate wide portion of the road. Their height is larger than other vehicles in the road which affect clear visibility of the road and its surrounding. As a result collision problems mostly occurred; this in turn results in life and property damages. In cities like Addis Ababa where most of the roads are narrow and directional flows are not separated by medians, the problem is very significant. According to the information from traffic departments of the city, Ethiopia in general is one of the leading countries in the world by the number of road traffic accidents per year. Most of these accidents have occurred in the capital city Addis Ababa where majority of the vehicles concentration are found.

According to the Table 4.18 the percentage share of freight caused accidents goes up and down between the mentioned years. However it shows the tendency of increment in the past two years from 21.75% to 26.33% which is significant. Considering the number of accidents caused directly by freight vehicles in the city, it has increased by 37.6% in between the years 2007/2008 to 2011/2012. The trend of increment in number of freight caused accidents seems to reduce in the first two years of analysis, however in the past three years it starts to increase by a rapid rate.

According to the information from the Akaki kality sub city traffic police department, the accident record data collected from the office does not include the fatal (death) accidents because of the fact that fatal accidents were not recorded by the sub city level until recently. However the data can depict the trend of accident growth in the area and the percentage share of freight caused accidents in the sub city in the past five years. As per the information from the sub city's traffic department majority of these accidents were caused on the main Bishoftu exit road network from Kality intersection to Akaki check point. The number of accidents caused by freight vehicles has increased by more than 179% in the past five years. Similarly the percentage share of freight caused accidents has increased from 44% in the year 2007/2208 to 57.4% in the year 2011/2012 which is very significant.

Both the total number of accidents caused by freight and their percentage share among other accidents has increased continuously in the past years. The percentage share of accidents caused by freight vehicles in this sub city is significantly larger than that of the whole Addis Ababa. This is another indication that Akaki kality sub city is highly vulnerable to freight mobility challenges when compared to the overall city.

Generally the result of the analysis clearly indicates that it is impossible to ensure road safety without giving necessary attention to the freight transport while planning traffic safety. So immediate measures need to be taken to alleviate the current safety problems associated to freight mobility in the city as part of the general plan to reduce traffic accidents in the city and in the country as a whole.

City aesthetics

City aesthetics has become one of the concerns of the society in recent times. The society demands safe, convenient, environmentally healthy and aesthetically pleasant urban environment from time to time. The rapid commercial and economic activities taking place in urban areas somehow affected their aesthetic values. As part of rapid commercial activity and service giving sector the freight transport sector by itself causes significant effect on city aesthetics. This problem is considerably observed in developing cities like Addis Ababa where majority of the transported goods are bulk agricultural products using road freight mode by aged vehicles and other non vehicular modes of transports. These old model aged vehicles affect the city aesthetics while moving and parked on the roads in the city. The unprocessed bulk agricultural products distributed in the city negatively affected the city aesthetics. These entire problems are caused because of the lack of modern logistics terminal and distribution centers which receive these bulk products, add some values like cleaning and sorting in their types and distributing to the retail centers where the customers can easily get.

5.4. Freight transport management and traffic regulation practices

Freight Management is a strategic system to optimize the efficiency of freight and commercial transport. The concept of logistics has a great role in freight management practices. Logistics considers wider issues in the distribution of goods like shipment sizes, storage and packaging, vehicle types used, modes of transportation, facility sites and sizes and frequency of shipping. Although the prior objective of freight management is to minimize costs in the freight industry, it should also need to attain goal of assuring social needs and environmental safety of the community through planning and executing freight distribution strategies that alleviate traffic congestion, accidents and environmental pollution challenges. Traffic regulations are part of transport administrative frame works mostly carried out by governments.

As indicated in Figure 4.12 there is lack of coordination between stakeholders that significantly affected the freight operation activity. This is because of the fact that there is no smooth communication chain between these stakeholders to strive towards common goals. Each of the stakeholders act from their own interests only; transporters only run to maximize their profit, the public needs to safe and clean environment and administrative bodies need to mediate the public and transporters need by enforcing rules and regulations. No common ground has been reached so far in the industry, up on which solutions for the associated problems have been established. Lack of infrastructure in this context means mostly the communication infrastructure and lack of information technology related infrastructures. It is highly connected to the economic standard of the country as a whole. Corruption in the system at different level is the other major bottleneck that affects freight management and traffic operation efficiencies in the city. This may be caused as a result of lack in ethics and economical burden in the community. Poor land use behavior both from the private and government sides and lack of transportation professionals have also contributed a lot to this problem. The above listed factors are only the major ones. Others like lack of awareness in the community and only business oriented interests of other private sectors have also contributed to the challenges in implementing efficient freight transport and traffic operations in the city.

Traffic regulations in the city mostly focused on public and passenger transports sidelining the movement of freight vehicles that currently caused a huge problem in traffic controlling systems of the city. Most of the rules and regulations are drawn for public and passenger transports. Only few and inefficient regulations concerning freight are currently in action in the city. Even these existing rules and regulations lack proper implementation practices that aggravate the social, economical and environmental impacts of freight transport in the city. Currently the place and time restriction rule on freight mobility has several problems. The major ones are;

i. This rule have a timing problem
ii. The area of restriction is only confined to the center
iii. The system of permission giving for mobility is exposed to corruption
iv. There is lack of implementation and enforcement of the rules

Majority of the drivers claims that the timing of free mobility in day time is very poor that aggravates the problem of congestion rather than solving it. This is because of the fact that the current congestion problem in the city and inefficiency of the loading and areas like warehouses do not let the freight drivers to reach their required destination, load or unload and get out of the restricted areas in the time frame of 2hours either morning or in the afternoon period. So, as there is no enforcing parking rule in the city drivers prefer to park on the city streets to wait for their next free time of mobility rather than being penalized, which in turn causes another congestion problem. So this free mobility timing of freight vehicles should be re evaluated and given immediate measure which is consistent with the current traffic conditions of the city. As it is very common in the city to see freight vehicles queued in front of the warehouses and waiting their turn, so warehouses and loading or unloading facilities in the city should increase their efficiency of serving the coming vehicles on time before the free mobility time window expires.

The spatial analysis made on the city current land use and development shows that the areas of restriction for free mobility is narrow which needs to be reconsidered. As the rule says freights vehicles can move twenty four seven on and outside ring road areas of the city. In its current situation the existing ring road of Addis Ababa city can no more be a city periphery. The newly established developments in the area make the road to be considered as a city center rather than periphery. The areas outside the ring road are also highly developing and urbanized especially with the current housing development both from government and private sides that change the areas to the residential districts from open agricultural and industrial areas. As a result the community leaving in these areas is highly exposed to freight related impacts than other communities of the city. Typical example for this case is the Akaki kality sub city.

As per the information from traffic departments and drivers there is a special circumstance where drivers will be given a free mobility permission from the administration side to move anywhere at any time in the city. This system is highly exposed to corruption and biased working systems which aggravates the problem. So especial treatments should be totally banned or made under very strict surveillance.

The other major problem associated to this rules and regulations is the lack of implementation from traffic regulators and transport offices. Most of the time traffic controllers carelessly avoid when rules are broken. Besides, some drivers prefer to move in the city being penalized rather than staying their free mobility time. This approach may be profitable for the freight carriers as time is money; however its consequence on the efficiency of the overall urban transportation system is very detrimental. This indicates that the existing rules and regulations lack enforcing power in addition to the existing implementation problem.

As indicated in Figure 4.12 among several effective freight management options managing freight at city peripheries is believed to ease the problems associated to freight vehicles in urban areas. Next to freight transshipment at city boundaries, enforcing the existing traffic rules and regulations and modifying them in such a way that they can efficiently regulate the traffic environment of the city were options that significant percentage of the interviewed stakeholders agreed on. So parallel to developing freight infrastructures, working on improving its management system is a very wise step towards ensuring sustainable and efficient freight transport system in urban areas without affecting the socio environmental assets of the community.

5.5. Transportation and land use

Transportation and land uses are two interconnected systems, where the changes occurred on one inexorably affects the other. In developing cities like Addis Ababa where the dominant informal land use systems do not dictate the transportation systems, estimating the travel demand and behavior is mostly difficult. In this section the impacts of land use on the city travel behavior and the practices of freight transport land uses have been discussed based on the field observation carried out during data collection, document analysis and analysis of interviewees response made with concerning stakeholders.

Problems associated to the land use make the modeling and estimation of travel demand in the city complex. The existing land use structure is not evenly distributed among different services.

The land covered by road networks and transportation facilities are very less compared to other components of the city land structure.

As indicated in Table 4.22, the proportion land in the city for transport and road network is scarce. This causes the travel behavior to be concentrated in areas where road and transport facilities are available which in turn causes congestion and other social impacts in some localized areas.

Major challenges of implementing modern land use behavior in Addis Ababa are;

- Concentration of services in one particular area
- Complexity of the travel behavior

As services are concentrated in certain areas, the demand to access that area gets above the supply. So it is difficult to implement modern land use with decentralized and classified in zones without first providing the new establishment areas with necessary services and facilities. Complexity in travel behavior results from poor travel demand estimation which by itself is the result of complex and informal land use pattern. So the transport behavior should be integrated with the land use pattern by gradually decentralizing services and facilities that are concentrated in certain areas only.

In general it is difficult to implement the land use and general master plan of Addis Ababa city mainly because of the following reasons.

i. Poor organizational structure and logistics
   - Frequent change in plan executing offices
   - Lack of man power
   - Insufficient logistics
   - Inter and Intra institutional information exchange and registration.

ii. Illegal land occupation

iii. Lack in experience and corruption related to plan preparing personnel

iv. Executive bodies (Administration)
   - Lack of awareness on the use of plan
   - Giving focus only for service related issues
   - Concerned only on short term solutions for raised problems

v. community related problems
   - Illegal land invasion
   - Poor waste disposal practices
   - Unawareness of importance of land use

All these problems associated to land use and in general master plan implementation of the city, contributes significantly to different social and environmental challenges of the city like congestion, traffic safety and Environmental pollution. So stakeholders in transportation, city planning areas and private sectors should closely work together to solve these problems from the route. As part of the general transport planning of the city, freight transport planning should be given a due concern to come up with the required solution of mitigating traffic functions and travel behaviors of the city. Prior infrastructure development in the areas where freight terminals planned to be moved should be carried out to encourage users of the facility. Inter institutional coordination should be made to solve the problem sustainably. Private developers of logistics terminals should be encouraged similar to other investment areas.

5.6. Major logistics solutions

5.6.1. City logistics process

The impacts associated to the urban goods distribution can be minimized through the initiatives of city logistics, if properly planned and implemented in accordance with the general city development plan and socio economic conditions that are specific to each cities. The general city logistics framework should incorporate the policy and strategy setting, plan preparation and implementation processes. Each stage in the process may vary in contents of the details from city to city based on their level of development and freight transport practices. The city logistics process that shows the major stages in the process and its detail have been presented in Figure 5.2.

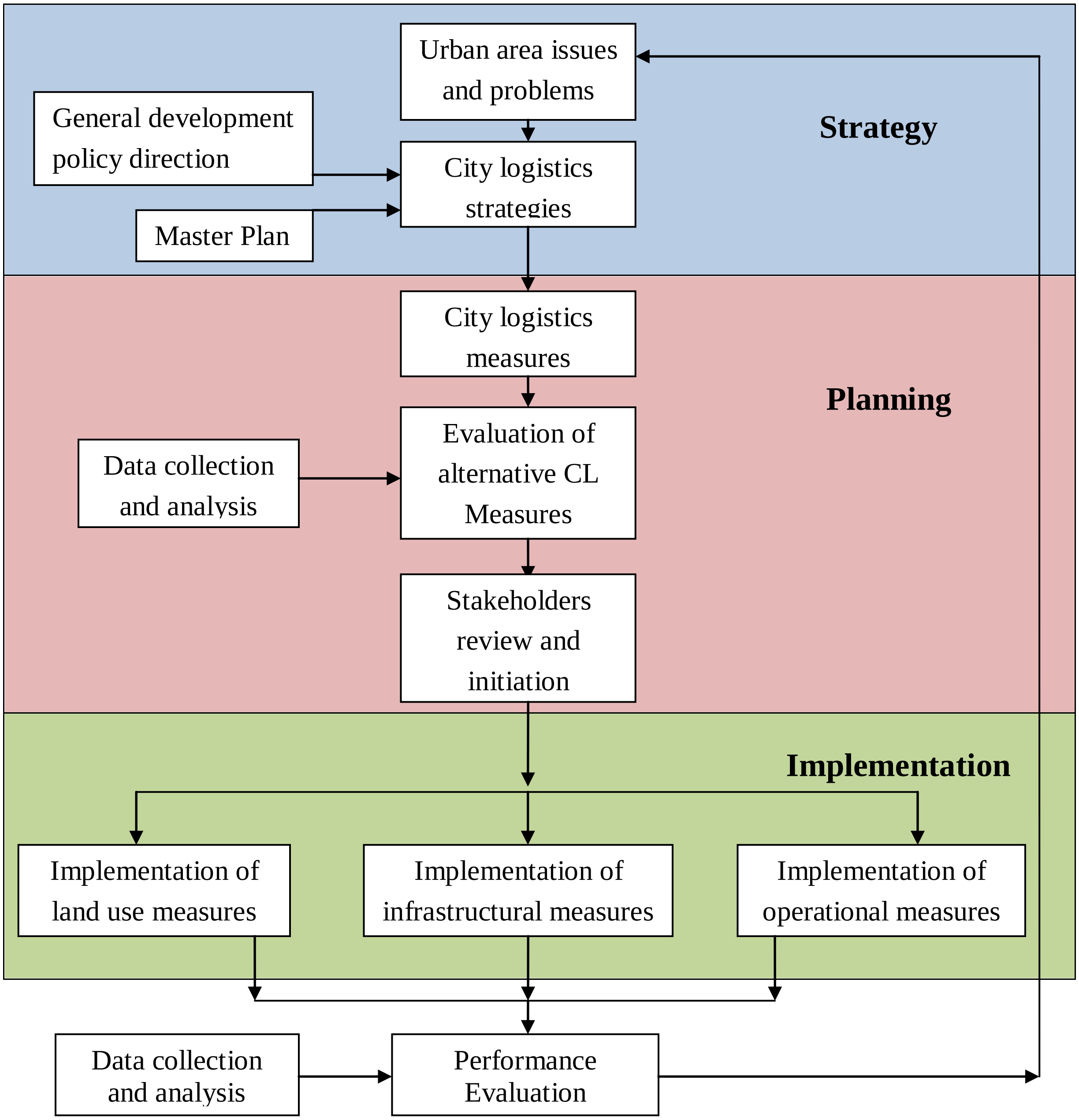


Figure 5-2 City logistics process

In the strategy stage of the process, general urban problems and those associated to goods distribution have to be identified by assessing the area through feed backs from the community and operators of the sector. City logistics management unit (CLMU) under the general freight management framework needs to be established. This unit routinely monitors the societal, economic and environmental impacts caused in urban areas by the urban goods distribution activities and uses it for predicting when these impacts could possibly pass the acceptable limits. At which time it becomes necessary to trigger freight management plans for implementation.

These would also help to monitor the business efficiency of the sector. Considering the current condition and tendency in growth of freight impacts, threshold tolerable limits for those impacts should be set based on the development and economic level of the city. This threshold limit can be set referring to the percentage share of the sector among other sectors causing the impacts in question.

Having understood the problems and their causes, it becomes necessary to identify the various strategies which can be adopted to mitigate the problems in the short, medium and long term. The strategies identified should then be tuned with the general city development plan, master plan, transport plan and priorities of the city. Each strategy could require a package of city logistics measures to be implemented to achieve the desired objectives. Each of these measures needs to be clearly identified and listed to enable a comparative evaluation and to select most acceptable strategy and measures for implementation. In order to select the most effective package of measures for implementation, a comparative evaluation of each city logistics strategy needs to be done against a common set of criteria. The most common method adopted for such evaluation is the cost benefit analysis. To enable such an analysis, appropriate data needs to be collected.

After the appropriate package of city logistics strategies have been selected, stakeholders need to be reviewed and initiated for the implementation of the plan. Each stakeholder should involve in its area of responsibility and also need to work in coordination with other stakeholders in the industry. Effectiveness of the city logistics measures need to be monitored and evaluated to ensure that the desired objectives are being met. There could be circumstances wherein the implemented measures may have to be modified or reversed if the impacts are observed to be ineffective. To evaluate the performance of the city logistics measures which have been implemented, post implementation data should be periodically collected and analyzed. In case there arises a need for modifying or changing the implemented package of measures, the entire logistics process should be repeated before implementing the modified package of measures.

5.6.2. City logistics in developing cities context

In developing cities like Addis Ababa, the idea of city logistics is not well understood either from the administration side or public and private transporters side. Lack of awareness in the advantages of city logistics and its application strategies is one of the drawbacks of the current freight management practices in developing cities. Both urban and cross urban goods distribution takes place in a non coordinated manner. The share of informal and non vehicular goods distribution using animal packs and human labor is also significant which need to be considered during policy making, planning and implementation stages. The inner urban goods distribution should be separated from long haul goods movement. The policy direction should clearly specify modes of transport to be used for the inner city goods delivery in such a way that the long haul goods movement is identified and managed at city peripheries. Besides the delivery modes, the items to be transported should also given a due concern while making policies related to city logistics in developing cities. This is because of the facts that, in developing cities like Addis Ababa the movement of bulk unprocessed agricultural products is dominant than the industrial products like in developed cities. Such bulk unprocessed products demand large space for storage and also have high potential to pollute urban environments. The case of Atikilt tera in Piassa, Kibe berebda and Ihil berenda in Merkato areas are strong indicators of this fact. The reverse logistics activities like solid waste collection and disposal activities take place using human labor by hand pushed carts which is highly inefficient and polluting. As there are no sufficiently developed underground waste collection pipes, liquid waste collection is mostly carried out by home to home moving waste collecting vehicles from individual's septic tanks. This has highly increased the movement frequency of waste collecting vehicles which in turn contributed to the city congestion and pollution problems.

Although the general objectives of city logistics both in developed and developing cities is to optimize the efficiency of good movement in urban areas, there are distinct features of the subject matter that need to be fine tuned specific to each city based on the level of development of the city, urban policy directions, awareness on the issue, goods distribution practices, social and environmental concerns of the public. Comparison of the city logistics practices and related issues in developed and developing cities has been presented in Table 5.5.

Table 5-5 City logistics practices in developed and developing cities

Comparison parameters	**Developed cities**	**Developing cities**
Awareness on the issue	High	Low
Administrative concern for the freight sector	Relatively high	Low
Freight management practices	Strong	Weak
Freight infrastructure	Developed	Less developed
Land use structure	Mostly structured	Less structured
Societal demand	High	Low
Environmental issues	Highly sensitive	Less sensitive
Freight services and facilities	Mostly decentralized	Mostly centralized
Dominant land freight modes	Vehicular	Both vehicular and non vehicular
Items transported	Mostly processed (Industrial)	Mostly non processed (Agricultural)
Inner urban delivery versus long haul goods movement	Mostly separated	Un separated
Freight Impacts	Relatively low	High

5.6.3. Coordination and consolidation

As the result in Section 4.6.1 indicated, even though there is no strong coordination between transporters currently in Addis Ababa, there is some potential which could be helpful if developed through strong freight management practices. The business oriented work relations among transporters and private business sectors could be broadened in such a way that it also insures societal and environmental needs of the urban community. The data from federal transport authority and Addis Ababa transport bureau indicated that majority of the high capacity freight vehicles are owned by associations and enterprises. This scenario could help if coordination among those transporters is planned as one logistics solution to solve the current prevailing problems associated to the sector. Associated transporters provide a good potential of coordination than that of individually running businesses. The government should encourage and motivate transporters to associate not only for the purpose of business, rather to make them part of the solution for urban challenges. The general idea and advantages of coordinated goods delivery should be discussed with all stakeholders. The benefits of coordinated goods delivery is not only for the public and administration, it is also for the transport company themselves, in such a way that they can reduce empty back haul and lower load rates which in turn enhance efficiency of their business by reducing fuel consumption and unnecessary vehicle operation costs. In another way they can also benefit from the reduced congestion, safe traffic flow and clean environment. So the idea of coordination should be planned and implemented based on the mutual interest and benefit of all stakeholders in the business.

5.6.4. Decentralization and Relocation

Decentralization of warehouses, factories and terminals was the main policy direction of the previous Addis Ababa city master plan, even though its implementation has lagged behind other sectors of the city development. As the information gathered from the city master plan revision team depicted, this policy direction will also be followed for the coming master plan of the city. The success of previous decentralization attempts was only partial. City peripheries planned for this purpose were occupied by new industries in almost all directions of the city. The failures in decentralization policy according to UTS, (2005) are:

- Absence of an effective follow up program with investment and institutional support
- Absence of developed land supply at new locations
- Less access to developed land at economic price
- Non-development of envisaged transport infrastructure facilities resulting in relatively low accessibility levels of the new locations
- Absence of package of incentives to shift and disincentives for continued location in central area

- Incremental growth and absorption in existing locations at reduced levels of service and efficiency
- Missing of established backward and forward linkages at the new locations.

The decentralization and relocation process need to be carried out carefully by involving all relevant stakeholders. To solve the problems associated to the inefficiency of implementation in decentralization, there should be a policy model change. The planning and implementation of decentralization program should change its policy package towards, holistic package of integrated planning, land development, incentives and disincentives, transport infrastructure and services, other physical and social infrastructures, financial, organizational and legal arrangements (UTS, 2005).

The model change in policy is to plan and develop an integrated logistics centers at different locations of the city. The concept of ILC (Integrated Logistics Center) is, simply replication of central areas, in terms of function and facilities at smaller scale at the new locations identified for relocation of activities (UTS, 2005). The ILC need to include other central area activities, closely related to trade like financial institutions, administrative services, business entrepreneurships, physical and social infrastructure facilities and services, facilities for users and employees. The other important component of ILC is the transport network. It should be connected to the city center and other regions through adequate transport networks with parking, loading and unloading facilities. It also needs to be serviced by public mass transport systems of the city. High accessibility and availability of extensive land are critical requirements. Private sectors need to be given a wide opportunity in developing the integrated logistics centers either separately or in joint venture with the city government.

According to UTS, 2005 report the city government needs to take initiatives. It needs to promote the idea of ILC amongst stakeholders. It needs to conduct studies to prepare ILC plans including study of its financial and economic viability. It needs to identify the location, allocate and develop land. It needs to develop the transport, social and other physical infrastructures. It needs to finance and facilitate financial and technical supports from other sources.

Integrated logistics centers should be developed in conjunction with truck terminals and rail depots. Distribution centers, whole sale markets, storage, utilities and services and parking are the main components of the ILC, while warehouses, loading/unloading facilities, service industry (Fuel station, garages, weigh bridges, etc), commercial, public and parking areas are the major components of freight terminals. Freight terminal and rail terminals are integrated but to be developed as adjacent parts of ILC.

As part of the sustainable solutions for the problems associated to urban goods distribution, the city of Addis Ababa need to plan and implement integrated logistics centers. The city government should establish a city logistics division or a management unit under the transport bureau that is responsible for planning and promoting policies and strategies related to city logistics, executing and administering logistics projects like ILC and other issue related to city logistics. The UTS, 2005 report also suggested the establishment of Addis Ababa Integrated Freight Complex Corporation (AAIFCC) by Addis Ababa city government, even though it is not given a due concern until today. However, such reluctance from the government and private sectors side on this matter may cost the city steep price if it is not given an immediate solution.

As part of the city logistics solutions, for the current problems associated to freight transport the city government of Addis Ababa need to take immediate action in decentralizing the existing warehouses and factories to the city peripheries. However prior to the decentralization process the potential areas where these facilities to be moved, have to be carefully selected and provided with necessary facilities as discussed above. Step by step action needs to be taken. Prioritization of activities is also important. The newly selected areas need to be planned in such a way that they can accommodate the integrated logistics complexes to be developed in the future. As part of the integrated logistics center, the city government should develop freight terminals with its associated facilities at the selected areas of city peripheries. Later with economic development of the city, the other components of ILC will be developed and moved out of the city.

As freight generating activities and truck terminals for parking of goods modes need large extent of land, formulating appropriate policies, identifying suitable locations and allocating adequate extent of land is the critical step in bringing about rationality and efficiency. These locations need to be linked with consumption activities through the transport network system. A high degree of policy coordination and integration between land use and transport system planning and development is required.

Based on the land use characteristics of the Addis Ababa city, in this thesis integrated logistics complexes locations were proposed at all entry and exit corridors of the city. The land use characteristics where these complexes were proposed are those open agricultural areas, forests and future mixed use reserve areas. The city map based on the newly proposed logistics terminal locations and existing freight attracting and generating sites in such a way that is shows the land use behavior of the city peripheries was prepared using Arc GIS 10, Arc map and presented in Figure 5.3 as shown below.

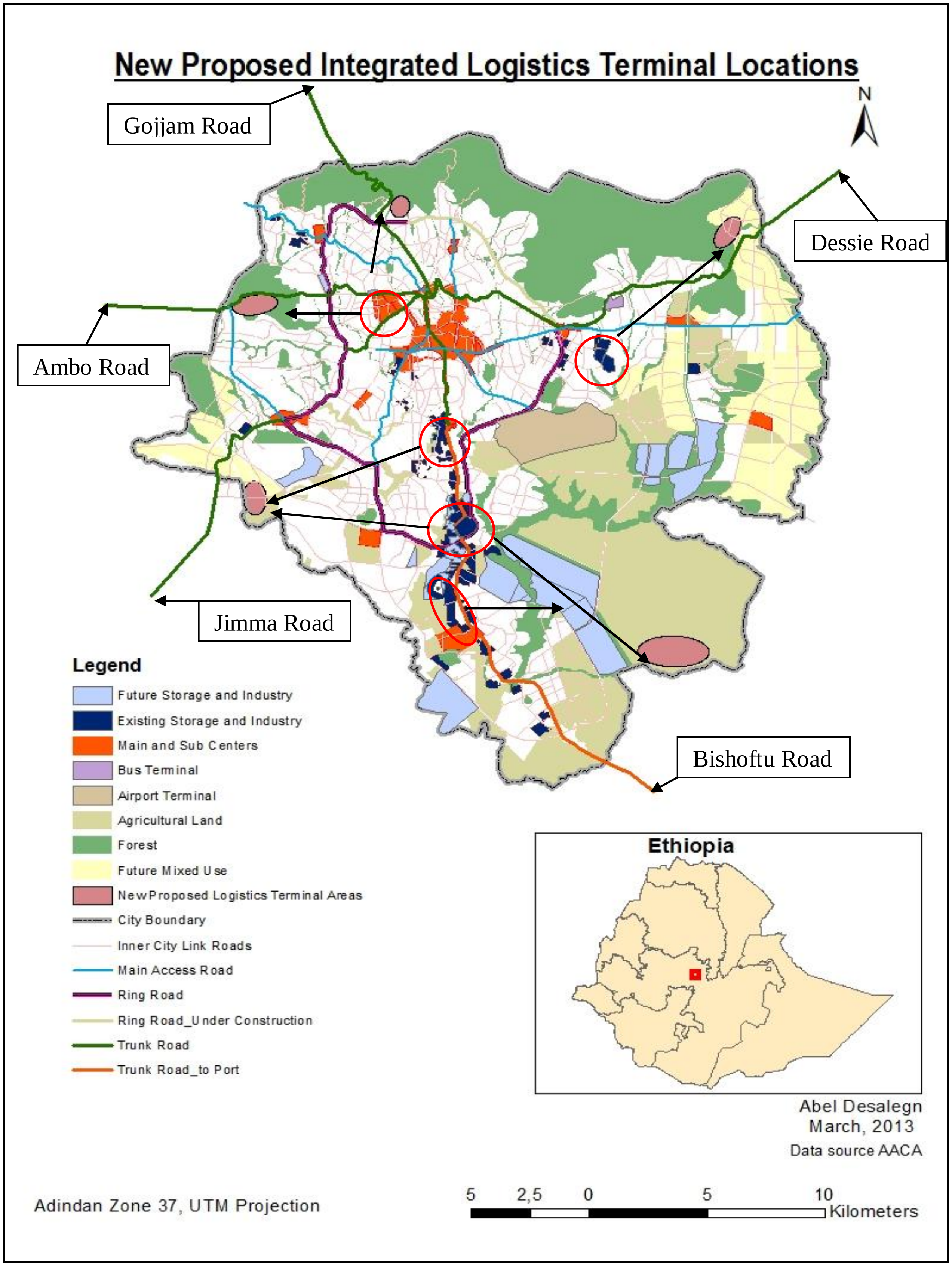


Figure 5-3 New proposed locations for integrated logistics terminal

Each proposed sites were located close to the main trunk roads connecting Addis Ababa to the Port of Djibouti and other regions of the country. The proposed site along Bishoftu road is pushed to the right from the current road deliberately, as the currently construction Addis – Adama toll road is connected to the city across that area. On the other entry corridors, the land use characteristics of the area and proximity to the main roads dictate the location proposal. In this study where in general these facilities to be developed is proposed. The total number of required freight terminals, the exact location in the city and the size of the land to be used need to be decided based on multi sectoral detailed study and analysis once decentralization and relocation is selected as appropriate city logistics measure during the planning phase of the city logistics process.

The main recommendations related to decentralization of industries and storages facilities in Addis Ababa include:

- Relocation of Ethiopian customs authority (Gumruk) from its current location at Saris Abo to the either previously reserved terminal site found at the southern part of the city or, the newly proposed site on Bishoftu road.
- Relocation of cement depots, Kera abattoir and grain silos at Gotera either to the Jimma or Bishoftu road peripheries.
- Relocation of warehouses like Kibe berenda, ihil berenda and chew berenda in Merkato area and vegetables market in Atikilt tera to either the nearest Ambo or Gojjam road proposed sites.
- Relocation of big warehouses in Bole sub city around Gerji imperial to thenearest Dessie road proposed site.
- Relocation of ware houses of Ethiopian grain trade enterprise distributed in different areas of the city to the nearest city periphery proposed sites.
- Relocation of different factory distribution centers like, Pepsi around Gotera, Koka between Lideta and Abinet, St gorge Brewery factory and all other remaining distribution centers and semi processing centers to appropriate locations as relevant.

The above listed are only the main facilities that can be reached by the scope of this study and proposed to be decentralized and relocated. Further study and prioritization of the facilities to be decentralized is required while implementing decentralization and relocation as an appropriate city logistics measure to solve problems associated to those facilities.

6. Conclusion

The following conclusions can be drawn from this study:

- Bishoftu corridor is found to be the main entry/exit corridor of freight among all other corridors with larger share both in terms of volume and tonnage. The study also identified the main freight generating land uses of the city and discussed their characteristics in terms of their current traffic and environmental aspects. Large markets like Merkato and Piassa, big ware houses in Akaki Kality and Nifas silk Lafto sub cities, small and medium scale factories were identified. The spatial distribution of these freight nodes and their interaction with other land forms were mapped using Arc map 10 to give a clear picture of the subject.
- At Kality intersection both congestion and emission indicator parameters have shown improvement by more than 100% of their values before reduction in HV percentage to maximum of 6%. As a result the level of service of the intersection has improved from F to C.
- Similarly at 18-Mazorial intersection, significant percentage improvements have been attained both in terms of congestion and emission releases of detrimental gases like NOx, CO2, CO and HC. Consequently the level of service of the intersection has been improved from D to B.
- This result can be a good ground to understand the congestion and emission impact caused by freight movement in major freight movement areas of Addis Ababa and to estimate the possible extent of improvement that can be attained by pulling out heavy freight vehicles from city centers to suburbs and diverting their movement by additional external orbital roads.
- The total number of accidents caused by freight vehicles in Addis Ababa city has increased by 36.7% in the past five years.
- In Akaki Kality sub city in the past five years the total number of accidents caused by freight vehicles has grown by 179% and the percentage share of accidents caused by freight has also grown from 44% in the year 2007/2008 to 57% in the year 2011/2012.
- The study revealed that the poor freight transport management and traffic operation practices of the city significantly contributed to the congestion, safety and pollution problems caused by freight vehicles.
- Generally the study showed that managing freight vehicles outside the city areas by decentralizing freight generating and attracting facilities, by developing new freight facilities, by constructing adjoining road networks for through traffic, by improving the land use practices and by improving freight management and traffic operation characteristics of the area, it is possible to alleviate the current impacts associated to freight mobility in the city.

7. Recommendation

Based on the results of the study and literature review made on the subject matter, the following recommendations have been drawn.

- The intrusion of large freight vehicles to the city centers should be reduced by decentralizing and relocating freight attraction centers to city peripheries by providing new integrated freight centers in carefully selected areas of the city peripheries.
- The construction of external orbital road or outer ring roads in addition to the currently existing ones needs to be carried out to divert the through traffic at all entry/exit corridors before entering the city.
- The potential proposed peripheral areas of the city should be fulfilled with infrastructures prior to facility relocations to encourage customers.
- Inter institutional coordination between different stakeholders should be developed to plan sustainable solutions for the problems in question.
- Commercial activities like road side vendering and temporary storage of different construction materials on pedestrian walkways that aggravates the congestion and pedestrian safety problem should be managed properly.
- Activities like on street parking, loading and unloading needs to be well monitored to ease the current problems.
- Place and time restriction on freight vehicles should be re evaluated thoroughly and strict policy and implementation strategy of rules and regulation by which freight vehicles administered should be set.
- Besides relocation, the standards and working efficiency of warehouses should be improved.
- The government should encourage the private sector which needs to develop freight facilities like integrated logistics terminals.
- Traffic rules and regulations concerning parking, sound limit in cities, vehicle ages and mechanical requirements should be developed and strongly implemented.

Bibliography

Abderrahim BENJELLOUN, Teodor Gabriel CRAINIC, (2009), *Trends challenges and perspectives in city logistics*, Université du Québec, Montréal, Canada.

Addis Ababa Transport Authority, (2012), *Consultancy Services for Technical Advisory Service for Addis Ababa City Traffic Management, Final report.*

Alain Bertaud, *Transportation and Urban Spatial Structure*, (April 2002), ABCDE Conference, Washington.

Allen, J., & Browne, M. (2010). *Considering the relationship between freight transport and urban form.*

An overview of European research and policy, *Urban freight transport and logistics*, European Communities, 2006.

Azadeh Moazami, Sayeh Noroozi, (2011), *Urban Freight Transport in the context of Urban Development*, Chalmers University of Technology, Report No. E2011:090.

Cathy Macharis and Sandra Melo, *City Distribution and Urban Freight Transport*, Edward Elgar publishing limited, Cheltenham UK, 2011.

Crainic Teodor Gabriel, Ricciardi Nicoletta, Storchi, Giovanni; (2009), *Models for Evaluating and Planning City Logistics Systems*; Inter university research center on enterprise networks logistics and transportation.

COST 321, (1998), *Urban Goods Transport*, European Cooperation in the field of scientific and technical research.

Eiichi Taniguchi, Russell.G.Thompson, Tadshiyamada, Ron Van Duin. *City Logistics Network Modelling and Intelligence Transport Systems*, JAI Press, 2007.

Ethiopian Roads Authority, *Urban transport study and preparation of pilot project for Addis* Ababa, (December, 2005), Addis Ababa.

European Commission urban transport research project, *Inner urban freight transport and city logistics,* (2003), Research for sustainable mobility.

Jan Fabian Ehmke, *Integration of Information and Optimization of Models for Routing in City Logistics,* Volume 177, Springer New York, 2012.

Jean-Paul Rodrigue, (2009), *Urban land use and transportation*.

Laetitia Dablanc and Jean-Paul Rodrigue, 2009, *City Logistics*, French Institute of Sciences and Technology for transport, development and networks (IFSTTAR), Universite de Paris-Est.

LV Pu, WANG Yang, XU Fengwei, 2010 *Research on Evaluation System of City Logistics Development Level*; School of Management Dalian Jiaotong University Dalian China,116028.

Markus Hesse, *The City as a Terminal, the urban context of logistics and freight transport*, MPG Books Ltd, Bodmin, Cornwall, 2008.

Michael A P Taylor, (2005), *City logistics paradigm for urban freight transport*, Transport Systems Centre, University of South Australia.

OnTrackAmerica (OTA), *Freight Transportation Land Use Strategy to Maximize Efficiency While Limiting Sprawl and Pollution*, (2010), Pennsylvania.

Todd Litman, Rowan Steel, (August, 2011), *Land use impacts on transport*, Victoria Transport Policy Institute.

US Department of Transportation, Federal Highway Administration, *Freight and Land use Hand Book*, April 2012.

Victorian freight and logistics council, *Freight transport and urban congestion*, Bureau of Infrastructure Transport & Economic Research 2006.

Victoria Transport Policy Institute, TDM encyclopedia, *Freight Transport Management*, May 2011.

Yetnayet Ayalneh (*2012)*, *The Transport Network Structure, Case Study on Addis Ababa*, University of Twente, Netherlands.

Appendices

Appendix-A Data used and analysis out puts

Appendix-A1 Average traffic count data with (veh/h) and (HV %) computed

Kality Intersection

Average counted traffic with calculated Veh/h and HV%-SARIS leg

Days	Hours	Vehicle type										Total
		Cars/ Taxi	Pick ups	Utilities (Jeeps, 4 WD's,)	Small Bus (12 seats)	Large Bus (above 27 seats)	light trucks	Medium Trucks (2 axles)	Heavy trucks (3 - 4 axles)	Trucks with trailers	Others (Tractors, graders,)	
From Saris Side to Kality Intersection												
Monday	01:00 - 02:00	144.3	46.7	18	196.7	101	15	11	23	31	0	**587.0**
	02:00 - 03:00	177.0	8.0	8	302.7	65	37	12	11	30	1	**650.3**
	03:00 - 04:00	207.3	78.3	60	208.7	42	46	13	15	41	1	**711.3**
	04:00 - 05:00	197.7	72.0	71	185.3	24	33	7	20	38	-	**649.0**
	05:00 - 06:00	213.0	52.0	63	194.0	25	46	11	18	42	-	**663.7**
	11:00 - 12:00	137.3	48.0	38	181.3	46	32	10	16	32	1	**540.7**
	12:00 - 01:00	137.7	40.3	32	205.3	50	46	8	14	25	-	**559.0**
	01:00 - 02:00	134.7	36.0	26	193.0	44	39	8	16	25	-	**521.3**
	Total	**1349.0**	**381.3**	**316**	**1667.0**	**398**	**294**	**80**	**132**	**263**	**3**	**4882.3**
Thursday	01:00 - 02:00	100.0	61.3	64	303.3	122	25	14	23	13	1	**726.7**
	02:00 - 03:00	121.3	36.0	61	240.0	46	26	10	18	12	1	**572.3**
	03:00 - 04:00	177.0	72.7	75	213.0	48	55	10	15	29	1	**694.7**
	04:00 - 05:00	212.0	93.7	91	218.7	23	41	21	16	32	-	**749.0**
	05:00 - 06:00	241.3	80.0	80	218.3	42	48	19	16	36	-	**780.3**
	11:00 - 12:00	181.7	65.0	90	184.7	85	45	39	36	59	1	**785.3**
	12:00 - 01:00	154.7	55.0	50	222.7	55	30	12	14	46	0	**639.7**
	01:00 - 02:00	128.3	33.0	45	169.7	54	41	14	24	40	-	**549.7**
	Total	**1316.3**	**496.7**	**557**	**1770.3**	**474**	**310**	**138**	**163**	**267**	**4**	**5497.7**
Saturday	01:00 - 02:00	63.0	46.7	54	233.0	92	27	13	21	18	1	**568.7**
	02:00 - 03:00	151.7	64.0	54	318.0	61	40	23	15	14	2	**743.0**
	03:00 - 04:00	195.3	91.3	96	256.3	46	42	11	25	29	1	**792.0**

	04:00 - 05:00	193.0	73.7	68	214.3	32	45	14	17	31	1	**689.0**
	05:00 - 06:00	222.0	77.3	80	267.7	27	36			50		**796.0**
	11:00 - 12:00	143.7	51.7	71	222.3	25	42	13	26	48	1	**644.0**
	12:00 - 01:00	115.7	42.3	43	205.7	48	34	7	19	32	-	**547.3**
	01:00 - 02:00	124.7	42.0	52	234.3	43	43	8	15	38	-	**600.7**
	Total	**1209.0**	**489.0**	**519**	**1951.7**	**374**	**309**	**99**	**164**	**260**	**6**	**5380.7**
Total weekly Traffic		**3874.3**	**1367.0**	**1,392**	**5389.0**	**1,247**	**913**	**317**	**459**	**790**	**13**	**15760.7**
Weekly average Traffic-3days		**1291.4**	**455.7**	**463.89**	**1796.3**	**415.56**	**304.22**	**105.78**	**152.89**	**263.44**	**4.33**	**5253.6**
Average Veh/h-8hrs		**161.4**	**57.0**	**57.99**	**224.5**	**51.94**	**38.03**	**13.22**	**19.11**	**32.93**	**0.54**	**656.7**
(Veh/h) corrected for errors-10%		**177.6**	**62.7**	**63.78**	**247.0**	**57.14**	**41.83**	**14.54**	**21.02**	**36.22**	**0.60**	**722.4**
												723.0

For aaSIDRA use		
	Normal Traffic	HV% Reduced to 6%
Total Veh/hr	723	646
No of HV	114	39
HV (%)	16.0	6

Average Counted Traffic with calculated Veh/h and HV%-LAFTO leg

Days	Hours	Vehicle type										
		Cars/ Taxi	Pick ups	Utilities (Jeeps, 4 WD's)	Small Bus(12 seats)	Large Bus (27 and above seats)	Light trucks	Medium Trucks (2 axles)	Heavy trucks (3-4 axles)	Trucks with trailers	Others (Tractors, graders)	Total
From Lafto Side to Kality Intersection												
Monday	01:00 - 02:00	72	63	24	65	52	35	12	51	28	-	**401**
	02:00 - 03:00	141	83	43	55	61	44	16	43	48	0	**534**
	03:00 - 04:00	76	74	38	33	34	62	30	44	43	-	**435**
	04:00 - 05:00	80	76	25	40	21	78	23	44	51	-	**436**
	05:00 - 06:00	88	75	66	52	54	95	23	57	48	1	**559**
	11:00 - 12:00	73	58	26	45	41	55	15	33	29	-	**375**
	12:00 - 01:00	56	58	25	29	46	37	16	28	22	0	**318**
	01:00 - 02:00	72	50	44	25	78	61	12	46	38	-	**426**
	Total	**657**	**537**	**291**	**344**	**387**	**467**	**147**	**345**	**307**	**1**	**3,484**
Thursday	01:00 - 02:00	281	162	88	127	163	98	53	58	52	-	**1,083**
	02:00 - 03:00	337	181	89	132	89	147	53	110	52	-	**1,190**
	03:00 - 04:00	308	173	103	118	71	150	62	122	73	1	**1,180**
	04:00 - 05:00	253	116	84	87	52	89	49	92	56	-	**878**
	05:00 - 06:00	150	96	58	55	31	88	44	74	55	1	**652**
	11:00 - 12:00	176	63	57	81	96	81	26	59	72	1	**711**
	12:00 - 01:00	186	64	49	75	59	58	38	54	61	-	**645**
	01:00 - 02:00	128	49	54	65	37	59	57	35	45	-	**528**
	Total	**1819**	**906**	**582**	**740**	**598**	**770**	**382**	**604**	**466**	**2**	**6869**
Saturday	01:00 - 02:00	121	100	66	90	105	73	38	61	52	0	**706**
	02:00 - 03:00	191	91	42	65	60	72	42	71	40	-	**674**
	03:00 - 04:00	140	72	55	60	35	72	26	55	47	0	**563**
	04:00 - 05:00	151	63	50	43	34	97	28	60	33	1	**560**
	05:00 - 06:00	102	64	32	50	28	53	30	50	42	-	**452**
	11:00 - 12:00	67	41	28	29	37	62	13	53	33	1	**364**
	12:00 - 01:00	46	38	25	28	35	32	10	33	19	1	**266**

	01:00 - 02:00		35	20	30	33	32	9	22	22	-	**241**
	Total	**856**	**502**	**319**	**396**	**367**	**493**	**196**	**406**	**289**	**3**	**3826**
Total weekly Traffic		3,332	1,946	1,192	1,480	1,351	1,731	725	1,355	1,062	7	**14,180**
Weekly average Traffic-3days		1,110.7	648.6	397.4	493.2	450.4	576.9	241.6	451.7	353.9	2.3	**4,726.7**
Average Veh/h-8hrs		138.8	81.07	49.68	61.65	56.31	72.11	30.19	56.46	44.24	0.3	**590.8**
(Veh/h) corrected for errors-10%		152.72	89.18	54.65	67.82	61.94	79.32	33.21	62.10	48.66	0.3	**649.9**
Average Veh/h corrected												**650**

For aaSIDRA use		
	Normal Traffic	HV% Reduced to 6%
Total Veh/hr	650	452
No of HV	224	27
HV (%)	34.0	6

Average Counted Traffic with calculated Veh/h and HV%-AKAKI leg

Days	Hours	Vehicle type										Total
		Cars/ Taxi	Pick ups	Utilities (Jeeps, 4 WD's,)	Small Bus (12 seats)	Large Bus (above 27 seats)	light trucks	Medium Trucks (2 axles)	Heavy trucks (3 - 4 axles)	Trucks with trailers	Others (Tractors, graders)	
From Akaki Side to Kality Intersection												
Monday	01:00 - 02:00	336	153	76	306	103	90	54	99	72	1	**1,290**
	02:00 - 03:00	262	99	53	211	76	83	37	76	51	1	**949**
	03:00 - 04:00	213	91	36	161	35	70	24	70	36	0	**736**
	04:00 - 05:00	242	99	42	156	27	74	26	74	49	1	**790**
	05:00 - 06:00	272	141	72	247	74	76	58	82	75	2	**1,098**
	11:00 - 12:00	135	81	41	233	77	48	39	47	31	1	**735**
	12:00 - 01:00	190	93	44	251	73	48	42	53	29	1	**823**
	01:00 - 02:00	158	85	42	227	68	42	30	46	39	1	**737**
	Total	**1,809**	**842**	**405**	**1,791**	**532**	**531**	**310**	**547**	**383**	**8**	**7,159**
Thursday	01:00 - 02:00	293	166	89	351	129	95	37	99	60	2	**1,321**
	02:00 - 03:00	268	133	63	320	67	104	47	111	51	1	**1,165**
	03:00 - 04:00	260	114	72	298	53	62	34	120	81	1	**1,096**
	04:00 - 05:00	208	96	64	229	50	71	47	71	51	2	**888**
	05:00 - 06:00	208	97	65	173	45	57	24	71	44	1	**784**
	11:00 - 12:00	199	138	59	216	85	49	35	66	58	1	**906**
	12:00 - 01:00	206	145	82	271	95	71	36	70	74	-	**1,050**
	01:00 - 02:00	196	142	46	198	83	65	36	58	57	-	**882**
	Total	**1,838**	**1,031**	**541**	**2,055**	**607**	**574**	**296**	**666**	**476**	**7**	**8,091**
Saturday	01:00 - 02:00	260	161	85	338	124	112	27	103	65	2	**1,276**
	02:00 - 03:00	323	205	80	322	96	115	47	110	84	1	**1,384**
	03:00 - 04:00	278	162	75	314	45	96	54	132	69	1	**1,226**
	04:00 - 05:00	214	102	31	201	30	42	17	49	47	1	**734**
	05:00 - 06:00	194	91	38	209	37	54	24	52	31	1	**731**
	11:00 - 12:00	263	158	110	339	103	74	28	76	60	1	**1,212**
	12:00 - 01:00	266	136	118	278	142	115	24	79	42	1	**1,200**
	01:00 - 02:00	222	158	59	220	84	93	33	65	41		

	Total	**2,020**	**1,174**	**596**	**2,221**	**661**	**701**	**254**	**667**	**438**		
Total weekly Traffic		5,667	3,046	1,542	6,067	1,801	1,807	860	1,879	1,298	**24**	**23,991**
Weekly average Traffic-3days		1,888.9	1,015.4	514.11	2,022.33	600.2	602.3	286.8	626.44	432.56	**7.89**	**7,997.0**
Average Veh/h-8hrs		236.1	126.9	64.26	252.79	75.03	75.3	35.8	78.31	54.07	**0.99**	**999.6**
(Veh/h) corrected for errors-10%		259.7	139.6	70.69	278.07	82.53	82.8	39.	86.14	59.48	**1.08**	**1,099.6**
Average Veh/h corrected												**1100**

For aaSIDRA use		
	Normal Traffic	HV% Reduced to 6%
Total Veh/hr	1100	881
No of HV	269	53
HV(%)	25.0	6

Average Counted Traffic with calculated Veh/h and HV%-MEGENAGNA leg

Days	Hours	Vehicle type										Total
		Cars/ Taxi	Pick ups	Utilities (Jeeps, 4 WD's)	Small Bus (12 seats)	Large Bus (above 27 seats)	light trucks	Medium Trucks (2 axles)	Heavy trucks (3 - 4 axles)	Trucks with trailers	Others (Tractors, graders)	
From Megenagna Side to Kality Intersection												
Monday	01:00 - 02:00	105.7	65.7	99.0	108.7	51.3	59.3	55.7	70.3	37.7	1.0	**654.3**
	02:00 - 03:00	121.3	73.0	72.7	81.7	41.0	58.7	29.7	62.3	22.3	0.3	**563.0**
	03:00 - 04:00	109.7	78.0	73.3	62.3	56.0	41.3	45.0	55.3	34.3	0.7	**556.0**
	04:00 - 05:00	106.3	71.7	65.3	79.0	56.0	67.3	33.0	74.7	41.7	1.3	**596.3**
	05:00 - 06:00	88.0	79.7	64.7	72.3	24.3	30.7	23.3	47.3	33.3	1.0	**464.7**
	11:00 - 12:00	139.0	98.7	67.0	96.0	57.0	68.0	32.0	100.7	40.7	0.7	**699.7**
	12:00 - 01:00	81.7	29.7	41.7	61.3	23.0	33.0	13.7	38.0	25.7	0.3	**348.0**
	01:00 - 02:00	41.7	35.0	20.0	31.0	16.7	13.0	9.3	21.0	8.7	0.0	**196.3**
	Total	**793.3**	**531.3**	**503.7**	**592.3**	**325.3**	**371.3**	**241.7**	**469.7**	**244.3**	**5.3**	**4078.3**
Thursday	01:00 - 02:00	92.0	78.3	70.0	94.3	41.7	32.7	20.7	34.7	23.0	1.0	**488.3**
	02:00 - 03:00	120.7	95.0	83.0	84.0	31.7	55.0	22.0	68.7	23.7	1.3	**585.0**
	03:00 - 04:00	110.3	62.0	62.3	53.7	42.7	32.0	13.0	36.7	29.0	0.3	**442.0**
	04:00 - 05:00	107.0	61.3	64.7	81.0	18.0	42.7	14.3	72.0	11.7	1.0	**473.7**
	05:00 - 06:00	107.0	77.0	74.0	91.0	44.7	46.7	32.0	125.3	51.7	2.0	**651.3**
	11:00 - 12:00	87.7	63.3	48.7	54.0	12.3	25.7	15.0	29.7	28.7	0.3	**365.3**
	12:00 - 01:00	132.7	99.7	69.0	80.7	36.3	25.3	20.0	53.3	31.3	1.0	**549.3**
	01:00 - 02:00	81.0	35.3	28.3	44.0	23.7	16.3	15.0	28.0	26.3	0.0	**298.0**
	Total	**838.3**	**572.0**	**500.0**	**582.7**	**251.0**	**276.3**	**152.0**	**448.3**	**225.3**	**7.0**	**3853.0**
Saturday	01:00 - 02:00	152.0	85.0	73.3	126.0	46.0	27.3	15.0	70.3	15.0	0.7	**610.7**
	02:00 - 03:00	222.0	122.7	71.3	61.7	13.3	20.7	13.7	51.0	9.0	1.0	**586.3**
	03:00 - 04:00	147.3	59.7	51.0	57.0	18.0	33.0	8.7	41.0	9.3	0.7	**425.7**
	04:00 - 05:00	120.7	67.3	55.3	63.3	14.7	25.0	13.0	44.7	12.3	0.7	**417.0**
	05:00 - 06:00	153.0	77.3	53.3	43.3	10.0	34.7	14.7	93.3	27.7	0.0	**507.3**

	11:00 - 12:00	74.3	49.3	31.7	48.0	11.7	16.7	10.7	42.7	13.7	0.7	**299.3**
	12:00 - 01:00	91.3	49.7	33.3	57.3	20.3	26.0	12.0	34.3	16.3	0.3	**341.0**
	01:00 - 02:00	74.7	35.7	27.0	41.7	21.3	26.0	6.7	20.3	11.7	0.0	**265.0**
	Total	**1035.3**	**546.7**	**396.3**	**498.3**	**155.3**	**209.3**	**94.3**	**397.7**	**115.0**	**4.0**	**3452.3**
Total weekly Traffic		2667.0	1650.0	1400.0	1673.3	731.7	857.0	488.0	1315.7	584.7	16.3	**11383.7**
Weekly average Traffic-3days		889.0	550.0	466.7	557.8	243.9	285.7	162.7	438.6	194.9	5.4	**3794.6**
Average Veh/h-8hrs		111.1	68.8	58.3	69.7	30.5	35.7	20.3	54.8	24.4	0.7	**474.3**
(Veh/h) corrected for errors-10%		122.2	75.6	64.2	76.7	33.5	39.3	22.4	60.3	26.8	0.7	**521.8**
Average Veh/h corrected												**522.0**

For aaSIDRA use		
	Normal Traffic	HV% Reduced to 6%
Total Veh/hr	522	394
No of HV	150	24
HV(%)	29.0	6

18-Mazoria Intersection

Average Counted Traffic with calculated Veh/h and HV%-LIKUANDA leg

Days	Hours	Vehicle type										Total
		Cars/ Taxi	Pickups	Utilities (Jeeps, 4 WD's)	Small Bus (12 seats)	Large Bus (above 27 seats)	light trucks	Medium Trucks (2 axles)	Heavy trucks (3 - 4 axles)	Trucks with trailers	Others (Tractors, graders)	
From Likuanda Side to 18 Mazoria-Intersection												
Monday	01:00 - 02:00	111	52	31	171	30	51	34	13	9	-	**502**
	02:00 - 03:00	53	21	13	146	18	26	16	8	8	0	**310**
	03:00 - 04:00	113	23	8	142	34	62	29	17	9	1	**438**
	04:00 - 05:00	104	37	13	151	18	55	17	15	12	0	**422**
	05:00 - 06:00	115	34	16	186	24	41	16	11	8	0	**452**
	11:00 - 12:00	109	44	41	211	26	28	13	10	8	1	**491**
	12:00 - 01:00	64	25	45	182	17	14	12	6	8	-	**372**
	01:00 - 02:00	98	39	46	161	18	13	10	7	6	-	**397**
	Total	**768**	**275**	**214**	**1,348**	**185**	**290**	**147**	**87**	**68**	**2**	**3,383**
Thursday	01:00 - 02:00	155	62	53	252	41	25	14	11	8	1	**621**
	02:00 - 03:00	178	51	51	246	35	40	14	8	6	0	**631**
	03:00 - 04:00	114	58	45	166	31	38	15	10	7	-	**483**
	04:00 - 05:00	135	43	36	199	14	38	16	9	9	1	**501**
	05:00 - 06:00	114	44	31	202	14	35	20	11	8	-	**480**
	11:00 - 12:00	119	35	44	209	15	34	15	8	7	0	**486**
	12:00 - 01:00	94	41	47	213	20	32	10	9	5	-	**470**
	01:00 - 02:00	105	36	31	202	22	30	11	5	9	-	**452**
	Total	**1,014**	**370**	**338**	**1,689**	**192**	**271**	**115**	**71**	**60**	**2**	**4,122**
Saturday	01:00 - 02:00	113	62	43	271	33	35	23	9	11	-	**599**
	02:00 - 03:00	167	51	63	193	26	26	22	10	3	-	**561**
	03:00 - 04:00	150	47	52	230	26	47	16	12	5	-	**585**
	04:00 - 05:00	118	43	40	196	15	36	26	11	6	0	**491**
	05:00 - 06:00	122	50	30	203	22	41	20	9	8	-	**503**
	11:00 - 12:00	89	45	25	227	14	21	12	7	8	-	**447**
	12:00 - 01:00	109	51	49	203	23	18	9	5	4	-	**471**

01:00 - 02:00	112	54	41	223	19	25	9	3	3	-	**489**
Total	**979**	**403**	**344**	**1,746**	**177**	**248**	**136**	**66**	**47**	**0**	**4,147**
Total weekly Traffic	2,761	1,048	895	4,784	554	809	398	224	175	5	**11,652**
Weekly average Traffic-3days	920.22	349.2	298.44	1,594.56	184.78	269.56	132.67	74.78	58.22	1.67	**3,884.11**
Average Veh/h-8hrs	115.03	43.65	37.31	199.32	23.10	33.69	16.58	9.35	7.28	0.21	**485.51**
(Veh/h) corrected for errors-10%	126.53	48.02	41.04	219.25	25.41	37.06	18.24	10.28	8.01	0.23	**534.07**
Average Veh/h corrected											**535**

For aaSIDRA use		
	Normal Traffic	HV% Reduced to 4%
Total Veh/hr	535	479
No of HV	74	19
HV(%)	14.0	4

Average Counted Traffic with calculated Veh/h and HV%-TORHAILOCH leg

Days	Hours	Vehicle type										Total
		Cars/ Taxi	Pick ups	Utilities (Jeeps, 4 WD's)	Small Bus (12 seats)	Large Bus (above 27seats)	light trucks	Medium Trucks (2 axles)	Heavy trucks (3 - 4 axles)	Trucks with trailers	Others (Tractors, graders)	
From Tor Hailoch Side to 18 Mazoria-Intersection												
Monday	01:00 - 02:00	176	77	41	152	44	53	10	14	18	1	**586**
	02:00 - 03:00	355	122	44	245	84	48	16	32	44	1	**992**
	03:00 - 04:00	219	86	92	175	60	117	12	35	66	1	**863**
	04:00 - 05:00	183	99	60	136	29	66	23	43	34	0	**673**
	05:00 - 06:00	195	114	32	140	35	75	24	38	24	1	**678**
	11:00 - 12:00	260	154	34	193	35	88	17	29	24	0	**835**
	12:00 - 01:00	293	144	42	217	70	83	9	26	28	1	**912**
	01:00 - 02:00	304	94	45	213	30	62	8	17	18	1	**794**
	Total	**1,986**	**890**	**391**	**1,471**	**387**	**592**	**120**	**234**	**255**	**6**	**6,332**
Thursday	01:00 - 02:00	212	97	55	214	49	50	19	22	13	0	**731**
	02:00 - 03:00	286	90	38	213	37	58	14	25	13	1	**774**
	03:00 - 04:00	246	109	44	171	17	52	11	46	10	1	**707**
	04:00 - 05:00	270	93	35	167	15	78	10	47	21	0	**736**
	05:00 - 06:00	254	118	35	179	23	71	17	36	25	1	**758**
	11:00 - 12:00	209	113	69	212	29	96	3	42	15	-	**787**
	12:00 - 01:00	270	178	87	238	94	117	2	23	16	-	**1,026**
	01:00 - 02:00	161	104	66	168	96	71	8	19	14	-	**708**
	Total	**1,908**	**902**	**428**	**1,561**	**360**	**593**	**84**	**260**	**127**	**3**	**6,227**
Saturday	01:00 - 02:00	160	67	39	161	33	55	33	16	22	-	**587**
	02:00 - 03:00	228	95	26	134	27	50	18	14	14	-	**608**
	03:00 - 04:00	289	119	24	122	21	52	18	19	14	0	**676**
	04:00 - 05:00	250	113	28	127	18	59	16	24	15	1	**652**
	05:00 - 06:00	263	111	38	146	24	72	35	36	18	0	**743**
	11:00 - 12:00	176	127	62	152	17	86	11	38	25	0	**694**
	12:00 - 01:00	205	99	76	198	63	79	26	30	22	-	**798**
	01:00 - 02:00	230	138	76	211	63	80	15	16	14	-	**843**

Total	1,799	869	368	1,251	267	533	173	193	145	2	**5,601**
Total weekly Traffic	5,694	2,661	1,187	4,283	1,015	1,718	377	687	527	11	**18,160**
Weekly average Traffic-3days	1,897.89	887.1	395.67	1,427.67	338.22	572.78	125.67	229.00	175.78	3.56	**6,053.33**
Average Veh/h-8hrs	237.24	110.9	49.46	178.46	42.28	71.60	15.71	28.63	21.97	0.44	**756.67**
(Veh/h) corrected for errors-10%	260.96	121.9	54.40	196.30	46.51	78.76	17.28	31.49	24.17	0.49	**832.33**
Average Veh/h corrected											**833**

For aaSIDRA use		
	Normal Traffic	HV% Reduced to 4%
Total Veh/hr	833	707
No of HV	153	28
HV(%)	19.0	4

Average Counted Traffic with calculated Veh/h and HV%-MESSALEMIA leg

Days	Hours	Vehicle type										Total
		Cars/ Taxi	Pickups	Utilities (Jeeps, 4 WD's)	Small Bus (12 seats)	Large Bus (above 27seats)	light trucks	Medium Trucks (2 axles)	Heavy trucks (3 - 4 axles)	Trucks with trailers	Others (Tractors, graders)	
From Messalemia Side to 18 Mazoria-Intersection												
Monday	01:00 - 02:00	86	19	17	207	15	48	9	11	8	-	**420**
	02:00 - 03:00	33	11	12	137	11	28	5	7	5	-	**249**
	03:00 - 04:00	62	46	16	222	9	72	7	6	8	1	**449**
	04:00 - 05:00	55	31	13	186	12	55	9	9	6	-	**376**
	05:00 - 06:00	71	41	16	312	14	89	6	17	7	1	**574**
	11:00 - 12:00	137	42	21	217	36	56	15	9	11	-	**544**
	12:00 - 01:00	121	30	28	204	21	49	7	9	10	0	**479**
	01:00 - 02:00	184	30	34	239	22	49	8	11	4	-	**582**
	Total	**748**	**251**	**158**	**1,724**	**140**	**446**	**67**	**79**	**59**	**2**	**3,674**
Thursday	01:00 - 02:00	67	24	14	193	24	43	6	7	10	-	**388**
	02:00 - 03:00	83	24	26	184	21	45	5	12	10	-	**412**
	03:00 - 04:00	114	31	16	184	23	51	2	8	6	1	**435**
	04:00 - 05:00	133	46	31	214	19	57	5	7	5	-	**518**
	05:00 - 06:00	65	33	17	166	16	61	19	17	6	1	**400**
	11:00 - 12:00	122	40	14	215	16	50	3	6	6	-	**471**
	12:00 - 01:00	156	43	11	238	11	39	4	12	7	-	**521**
	01:00 - 02:00	135	35	12	211	17	36	5	4	4	-	**459**
	Total	**875**	**277**	**140**	**1,605**	**147**	**382**	**49**	**72**	**55**	**2**	**3,604**
Saturday	01:00 - 02:00	51	31	24	181	24	32	7	9	7	-	**364**
	02:00 - 03:00	67	15	28	212	24	42	3	13	8	-	**412**
	03:00 - 04:00	92	42	24	201	22	44	2	5	7	-	**438**
	04:00 - 05:00	122	30	22	195	17	56	6	7	5	1	**460**
	05:00 - 06:00	129	49	38	210	17	31	11	11	5	-	**500**
	11:00 - 12:00	81	43	10	205	10	41	2	6	5	1	**404**
	12:00 - 01:00	84	21	8	182	10	41	3	4	4	-	**358**
	01:00 - 02:00	123	38	5	211	13	44	7	3	7	-	**450**

Total	**748**	**269**	**159**	**1,597**	**136**	**330**	**41**	**58**	**48**	**1**	**3,386**
Total weekly Traffic	**2,372**	**797**	**456**	**4,925**	**422**	**1,158**	**157**	**209**	**161**	**5**	**10,663**
Weekly average Traffic-3days	**790.56**	**265.78**	**152.11**	**1,641.78**	**140.78**	**385.89**	**52.22**	**69.67**	**53.78**	**1.78**	**3,554.3**
Average Veh/h-8hrs	**98.82**	**33.22**	**19.01**	**205.22**	**17.60**	**48.24**	**6.53**	**8.71**	**6.72**	**0.22**	**444.29**
(Veh/h) corrected for errors-10%	**108.70**	**36.54**	**20.92**	**225.74**	**19.36**	**53.06**	**7.18**	**9.58**	**7.39**	**0.24**	**488.7**
Average Veh/h corrected											**489**

For aaSIDRA use		
	Normal Traffic	HV% Reduced to 4%
Total Veh/hr	489	429
No of HV	77	17
HV(%)	16.0	4

Average Counted Traffic with calculated Veh/h and HV%-WINGET leg

Days	Hours	Vehicle type										Total
		Cars/ Taxi	Pick ups	Utilities (Jeeps, 4 WD's)	Small Bus (12 seats)	Large Bus (above 27seats)	light trucks	Medium Trucks (2 axles	Heavy trucks (3 - 4 axles)	Trucks with trailers	Others (Tractors, graders)	
From Winget Side to 18 Mazoria-Intersection												
Monday	01:00 - 02:00	270	77	66	239	74	86	40	28	21	-	**900**
	02:00 - 03:00	222	82	64	172	23	73	20	43	35	0	**735**
	03:00 - 04:00	234	75	60	189	15	71	14	19	12	1	**689**
	04:00 - 05:00	271	108	55	175	14	93	15	35	16	-	**782**
	05:00 - 06:00	204	69	30	207	17	86	17	25	15	-	**670**
	11:00 - 12:00	165	70	15	142	26	42	10	15	9	1	**495**
	12:00 - 01:00	162	92	33	132	34	33	9	14	10	0	**519**
	01:00 - 02:00	156	82	29	144	20	33	7	8	8	-	**487**
	Total	**1,685**	**655**	**352**	**1,400**	**222**	**517**	**132**	**187**	**126**	**2**	**5,278**
Thursday	01:00 - 02:00	430	139	41	263	43	53	8	11	12	-	**1,001**
	02:00 - 03:00	307	84	34	272	31	42	8	10	15	0	**804**
	03:00 - 04:00	322	70	21	163	14	80	15	19	12	-	**716**
	04:00 - 05:00	240	73	17	153	14	64	17	24	15	-	**616**
	05:00 - 06:00	165	78	12	109	17	51	8	16	17	-	**473**
	11:00 - 12:00	168	69	19	129	23	32	10	23	11	1	**485**
	12:00 - 01:00	232	122	18	130	44	68	21	27	16	-	**677**
	01:00 - 02:00	174	105	24	140	52	30	13	12	7	-	**556**
	Total	**2,037**	**740**	**186**	**1,359**	**238**	**421**	**99**	**142**	**105**	**1**	**5,327**
Saturday	01:00 - 02:00	254	106	40	293	33	41	3	24	11	-	**805**
	02:00 - 03:00	289	107	30	210	16	34	4	30	10	0	**730**
	03:00 - 04:00	289	97	33	176	11	65	7	35	19	1	**733**
	04:00 - 05:00	227	83	27	133	15	163	10	13	10	-	**681**
	05:00 - 06:00	165	87	34	131	18	75	9	24	9	-	**552**
	11:00 - 12:00	215	95	18	170	35	42	3	26	19	1	**624**
	12:00 - 01:00	144	72	23	152	31	31	3	14	14	-	**485**

	01:00 - 02:00	198	42	28	181	22	33	2	14	9	-	**530**
	Total	**1,780**	**689**	**233**	**1,446**	**181**	**486**	**42**	**180**	**101**	**2**	**5,139**
Total weekly Traffic		**5,502**	**2,084**	**771**	**4,205**	**641**	**1,423**	**273**	**509**	**332**	**5**	**15,744**
Weekly average Traffic-3days		**1,833.89**	**694.56**	**256.89**	**1,401.67**	**213.56**	**474.33**	**91.00**	**169.67**	**110.67**	**1.67**	**5,247.9**
Average Veh/h-8hrs		**229.24**	**86.82**	**32.11**	**175.21**	**26.69**	**59.29**	**11.38**	**21.21**	**13.83**	**0.21**	**655.99**
(Veh/h) corrected for errors-5%		**252.16**	**95.50**	**35.32**	**192.73**	**29.36**	**65.22**	**12.51**	**23.33**	**15.22**	**0.23**	**721.58**
Average Veh/h corrected												**722**

For aaSIDRA use		
	Normal Traffic	HV% Reduced to 4%
Total Veh/hr	722	629
No of HV	117	25
HV(%)	16.0	4

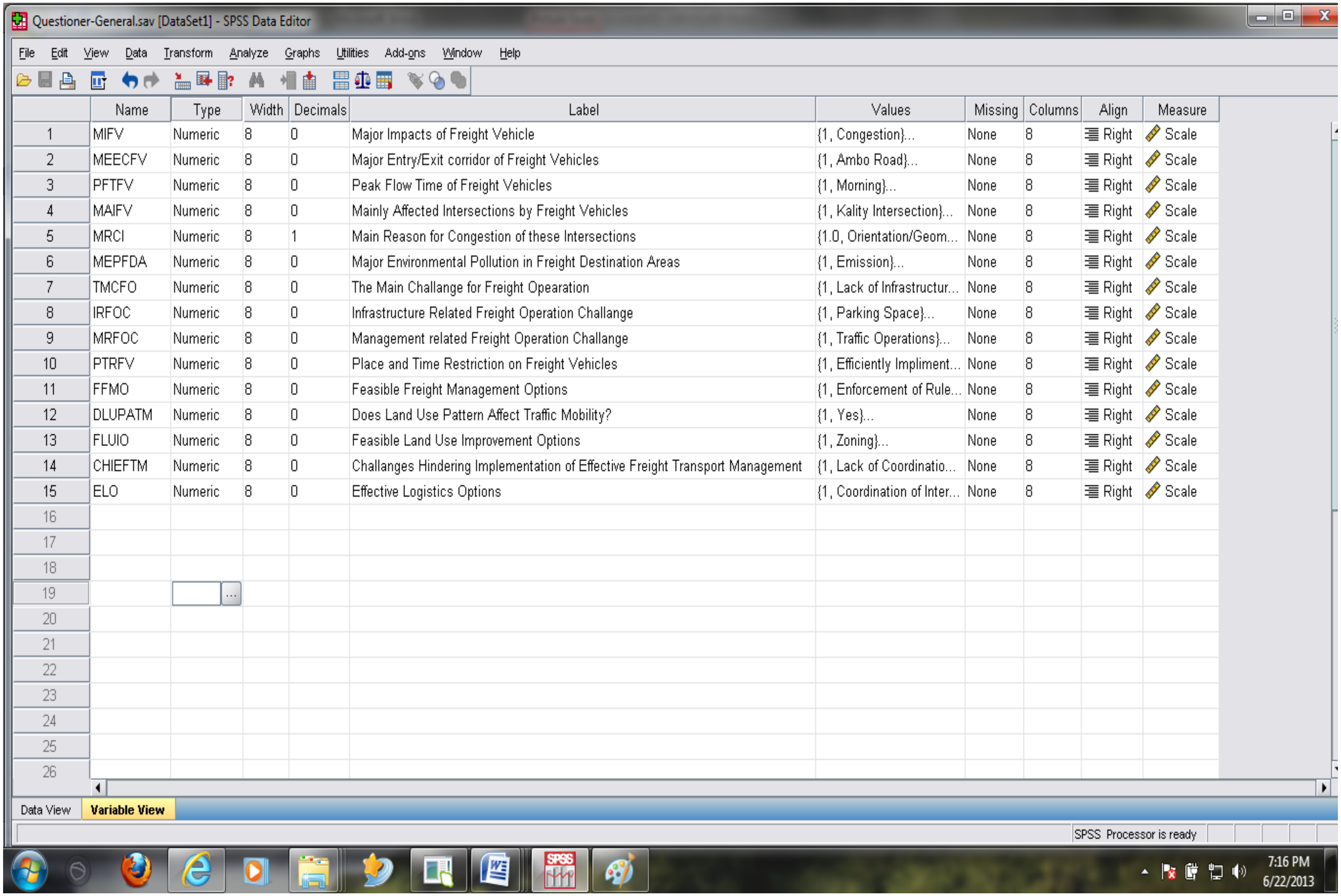
Appendix-A2 Accident record data and percentage freight share

Five years Accident Record caused by freight vehicles in the whole Addis Ababa city										
Vehicle Category (Loading Capacity)	Year									
	2011/2012		2010/2011		2009/2010		2008/2009		2007/2008	
	No of Accidents recorded	percentage	No of Accidents recorded	percentage	No of Accidents recorded	percentage	No of Accidents recorded	percentage	No of Accidents recorded	percentage
<10	1323	11.48	755	8.27	644	10.25	707	9.40	756	9.25
11-40	695	6.03	518	5.67	404	6.43	467	6.21	568	6.95
41-100	763	6.62	523	5.73	498	7.92	336	4.47	697	8.53
Truck	220	1.91	161	1.76	107	1.70	137	1.82	143	1.75
Liquid	35	0.30	30	0.33	36	0.57	46	0.61	43	0.53
Total number	**3036**	**26.33**	**1987**	**21.75**	**1689**	**26.87**	**1693**	**22.50**	**2207**	**27.02**
Total no of	**11529**		**9134**		**6285**		**7523**		**8169**	

Five Years Accident Record Caused by Freight vehicles in Akaki Kality Sub city										
Vehicle Category (Loading Capacity)	Year									
	2011/2012		2010/2011		2009/2010		2008/2009		2007/2008	
	No of Accidents recorded	percentage	No of Accidents recorded	percentage	No of Accidents recorded	percentage	No of Accidents recorded	percentage	No of Accidents recorded	percentage
<10	79	7.62	68	8.85	60	10.75	33	6.08	34	7.02
11-40	179	17.26	93	12.11	53	9.50	63	11.60	16	3.31
41-100	100	9.64	79	10.29	36	6.45	47	8.66	49	10.12
>100	121	11.67	81	10.55	87	15.59	72	13.26	79	16.32
Truck	116	11.19	74	9.64	38	6.81	42	7.73	35	7.23
Total number	**595**	**57.38**	**395**	**51.43**	**274**	**49.10**	**257**	**47.33**	**213**	**44.01**
Total no of	**1037**		**768**		**558**		**543**		**484**	

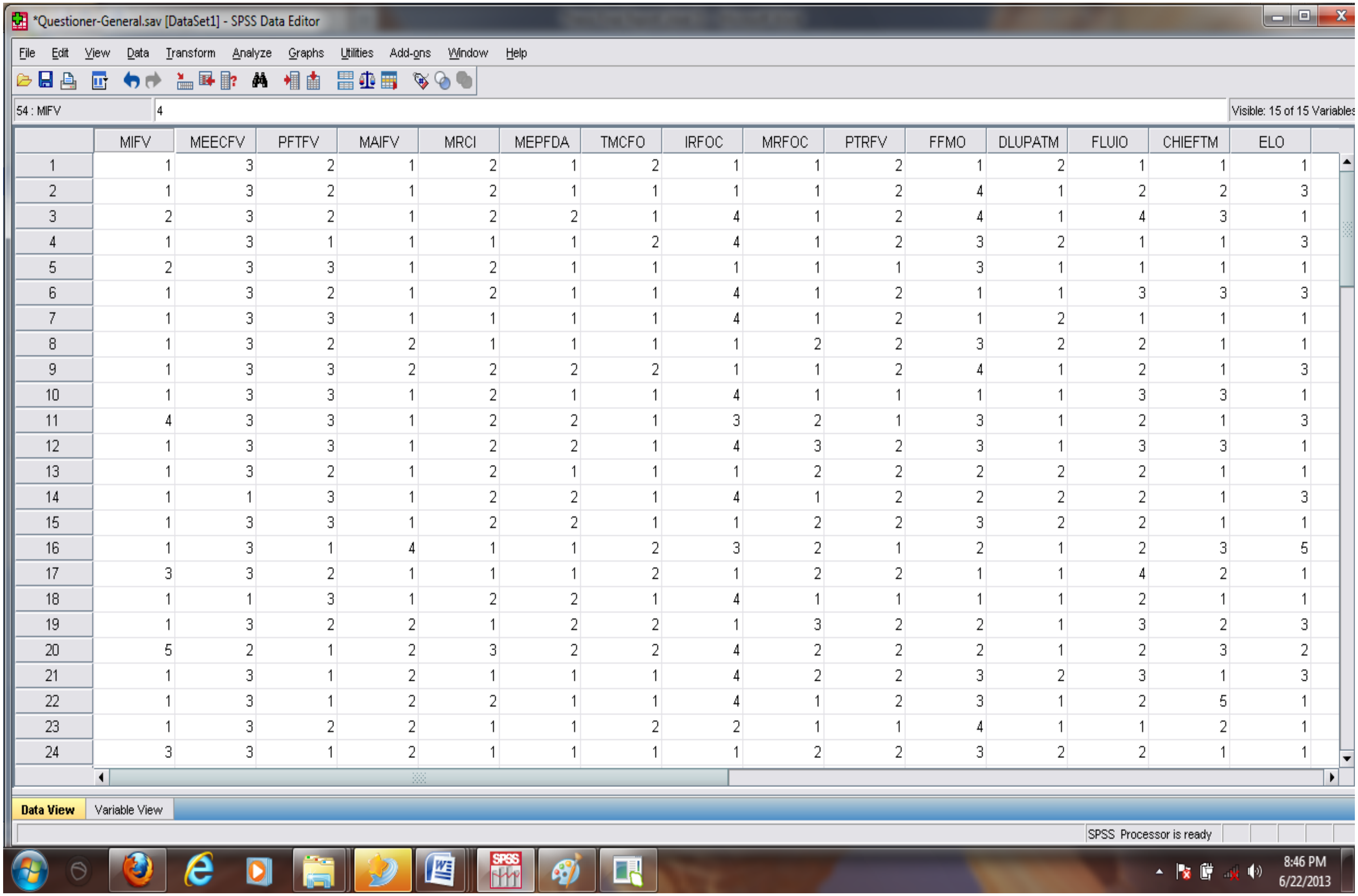
Appendix-B SPSS names, labels, values and measures used during analysis

Appendix-B1 Variable view



	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure
1	MIFV	Numeric	8	0	Major Impacts of Freight Vehicle	{1, Congestion}...	None	8	Right	Scale
2	MEECFV	Numeric	8	0	Major Entry/Exit corridor of Freight Vehicles	{1, Ambo Road}...	None	8	Right	Scale
3	PFTFV	Numeric	8	0	Peak Flow Time of Freight Vehicles	{1, Morning}...	None	8	Right	Scale
4	MAIFV	Numeric	8	0	Mainly Affected Intersections by Freight Vehicles	{1, Kality Intersection}...	None	8	Right	Scale
5	MRCI	Numeric	8	1	Main Reason for Congestion of these Intersections	{1.0, Orientation/Geom...	None	8	Right	Scale
6	MEPFDA	Numeric	8	0	Major Environmental Pollution in Freight Destination Areas	{1, Emission}...	None	8	Right	Scale
7	TMCFO	Numeric	8	0	The Main Challange for Freight Opearation	{1, Lack of Infrastructur...	None	8	Right	Scale
8	IRFOC	Numeric	8	0	Infrastructure Related Freight Operation Challange	{1, Parking Space}...	None	8	Right	Scale
9	MRFOC	Numeric	8	0	Management related Freight Operation Challange	{1, Traffic Operations}...	None	8	Right	Scale
10	PTRFV	Numeric	8	0	Place and Time Restriction on Freight Vehicles	{1, Efficiently Impliment...	None	8	Right	Scale
11	FFMO	Numeric	8	0	Feasible Freight Management Options	{1, Enforcement of Rule...	None	8	Right	Scale
12	DLUPATM	Numeric	8	0	Does Land Use Pattern Affect Traffic Mobility?	{1, Yes}...	None	8	Right	Scale
13	FLUIO	Numeric	8	0	Feasible Land Use Improvement Options	{1, Zoning}...	None	8	Right	Scale
14	CHIEFTM	Numeric	8	0	Challanges Hindering Implementation of Effective Freight Transport Management	{1, Lack of Coordinatio...	None	8	Right	Scale
15	ELO	Numeric	8	0	Effective Logistics Options	{1, Coordination of Inter...	None	8	Right	Scale

Appendix-B2 Data view



	MIFV	MEECFV	PFTFV	MAIFV	MRCI	MEPFDA	TMCFO	IRFOC	MRFOC	PTRFV	FFMO	DLUPATM	FLUIO	CHIEFTM	ELO
1	1	3	2	1	2	1	2	1	1	2	1	2	1	1	1
2	1	3	2	1	2	1	1	1	1	2	4	1	2	2	3
3	2	3	2	1	2	2	1	4	1	2	4	1	4	3	1
4	1	3	1	1	1	1	2	4	1	2	3	2	1	1	3
5	2	3	3	1	2	1	1	1	1	1	3	1	1	1	1
6	1	3	2	1	2	1	1	4	1	2	1	1	3	3	3
7	1	3	3	1	1	1	1	4	1	2	1	2	1	1	1
8	1	3	2	2	1	1	1	1	2	2	3	2	2	1	1
9	1	3	3	2	2	2	2	1	1	2	4	1	2	1	3
10	1	3	3	1	2	1	1	4	1	1	1	1	3	3	1
11	4	3	3	1	2	2	1	3	2	1	3	1	2	1	3
12	1	3	3	1	2	2	1	4	3	2	3	1	3	3	1
13	1	3	2	1	2	1	1	1	2	2	2	2	2	1	1
14	1	1	3	1	2	2	1	4	1	2	2	2	2	1	3
15	1	3	3	1	2	2	1	1	2	2	3	2	2	1	1
16	1	3	1	4	1	1	2	3	2	1	2	1	2	3	5
17	3	3	2	1	1	1	2	1	2	2	1	1	4	2	1
18	1	1	3	1	2	2	1	4	1	1	1	1	2	1	1
19	1	3	2	2	1	2	2	1	3	2	2	1	3	2	3
20	5	2	1	2	3	2	2	4	2	2	2	1	2	3	2
21	1	3	1	2	1	1	1	4	2	2	3	2	3	1	3
22	1	3	1	2	2	1	1	4	1	2	3	1	2	5	1
23	1	3	2	2	1	1	2	2	1	1	4	1	1	2	1
24	3	3	1	2	1	1	1	1	2	2	3	2	2	1	1

Appendix-C Capacity analysis outputs

Appendix-C1 Lane summary

Kality Intersection

LANE SUMMARY(By Actual Traffic)

Lane Use and Performance

	Demand Flows L	T	R	Total	HV	Cap.	Deg. Satn	Lane Util.	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Lane Length	SL Type	Cap. Adj.	Prob. Block.
	veh/h	veh/h	veh/h	veh/h	%	veh/h	v/c	%	sec		veh	m	m		%	%
South East: Akaki Side																
Lane 1	61	543	0	605	25.0	582	P	100	74.3	LOS F	19.9	182.9	500	–	0.0	0.0
Lane 2	0	190	428	618	25.0	595	P	100	73.6	LOS F	19.7	181.7	500	–	0.0	0.0
Approach	61	733	428	1222	25.0		1.038		73.9	LOS F	19.9	182.9				
North East: Megenagna Side																
Lane 1	522	0	0	522	29.0	343	P	100	277.1	LOS F	61.3	579.5	500	–	0.0	9.5
Lane 2	0	0	58	58	29.0	321	P	100	14.6	LOS B	0.4	3.5	500	–	0.0	0.0
Approach	522	0	58	580	29.0		1.520		250.8	LOS F	61.3	579.5				
North West: Saris Side																
Lane 1	40	297	0	337	16.0	618	P	100	15.3	LOS C	1.9	16.2	500	–	0.0	0.0
Lane 2	0	346	0	346	16.0	635	P	100	15.0	LOS B	1.8	15.4	500	–	0.0	0.0
Lane 3	0	0	121	121	16.0	618	P	36[5]	8.2	LOS A	0.5	3.9	500	–	0.0	0.0
Approach	40	643	121	803	16.0		0.545		14.1	LOS B	1.9	16.2				
South West: Lafto Side																
Lane 1	289	0	0	289	34.0	334	P	100	56.2	LOS F	3.8	36.7	500	–	0.0	0.0
Lane 2	0	0	433	433	34.0	355	P	100	153.8	LOS F	29.7	290.6	500	–	0.0	0.0
Approach	289	0	433	722	34.0		1.219		114.7	LOS F	29.7	290.6				
Intersection				3328	25.5		1.520		99.2	LOS F	61.3	579.5				

LANE SUMMARY (HV reduced to 6%)

Lane Use and Performance

	Demand Flows L	T	R	Total	HV	Cap.	Deg. Satn	Lane Util.	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Lane Length	SL Type	Cap. Adj.	Prob. Block.
	veh/h	veh/h	veh/h	veh/h	%	veh/h	v/c	%	sec		veh	m	m		%	%
South East: Akaki Side																
Lane 1	49	437	0	486	6.0	772	P	100	15.4	LOS C	2.6	20.9	500	–	0.0	0.0
Lane 2	0	150	343	492	6.0	782	P	100	15.2	LOS C	2.5	19.7	500	–	0.0	0.0
Approach	49	587	343	979	6.0		0.630		15.3	LOS C	2.6	20.9				
North East: Megenagna Side																
Lane 1	394	0	0	394	6.0	573	P	100	22.4	LOS C	3.2	25.2	500	–	0.0	0.0
Lane 2	0	0	44	44	6.0	548	P	100	7.5	LOS A	0.2	1.6	500	–	0.0	0.0
Approach	394	0	44	438	6.0		0.688		20.9	LOS C	3.2	25.2				
North West: Saris Side																
Lane 1	36	266	0	301	6.0	696	P	100	11.2	LOS B	1.4	11.4	500	–	0.0	0.0
Lane 2	0	309	0	309	6.0	713	P	100	11.0	LOS B	1.4	10.8	500	–	0.0	0.0
Lane 3	0	0	108	108	6.0	696	P	36[5]	6.9	LOS A	0.4	3.1	500	–	0.0	0.0
Approach	36	574	108	718	6.0		0.433		10.5	LOS B	1.4	11.4				
South West: Lafto Side																
Lane 1	201	0	0	201	6.0	480	P	100	14.9	LOS B	1.4	10.9	500	–	0.0	0.0
Lane 2	0	0	301	301	6.0	506	P	100	20.0	LOS C	2.3	18.2	500	–	0.0	0.0
Approach	201	0	301	502	6.0		0.595		18.0	LOS C	2.3	18.2				
Intersection				2637	6.0		0.688		15.4	LOS C	3.2	25.2				

18-Mazoria Intersection

LANE SUMMARY (By Actual Traffic)

Lane Use and Performance

	Demand Flows L	Demand Flows T	Demand Flows R	Demand Flows Total	HV	Cap.	Deg. Satn	Lane Util.	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Lane Length	SL Type	Cap. Adj.	Prob. Block.
	veh/h	veh/h	veh/h	veh/h	%	veh/h	v/c	%	sec		veh	m	m		%	%
South: Tor Hailoch Side																
Lane 1	185	111	0	296	19.0	465	P	98[5]	23.6	LOS C	2.2	19.6	500	–	0.0	0.0
Lane 2	0	296	0	296	19.0	465	P	98[5]	23.6	LOS C	2.2	19.6	500	–	0.0	0.0
Lane 3	0	0	317	317	19.0	485	P	100	23.6	LOS C	2.2	19.7	500	–	0.0	0.0
Approach	185	407	317	909	19.0		0.653		23.6	LOS C	2.2	19.7				
East: Mesalemiya Side																
Lane 1	106	399	27	532	16.0	561	P	100	53.1	LOS F	8.6	74.3	500	–	0.0	0.0
Approach	106	399	27	532	16.0		0.948		53.1	LOS F	8.6	74.3				
North: Winget side																
Lane 1	353	0	0	353	16.0	536	P	100	22.1	LOS C	2.5	21.5	500	–	0.0	0.0
Lane 2	0	216	0	216	16.0	515	P	64[5]	14.0	LOS B	1.2	10.6	500	–	0.0	0.0
Lane 3	0	177	39	216	16.0	515	P	64[5]	14.0	LOS B	1.2	10.6	500	–	0.0	0.0
Approach	353	392	39	785	16.0		0.659		17.7	LOS C	2.5	21.5				
West: Likuwanda Side																
Lane 1	58	349	0	407	14.0	496	P	100	36.7	LOS E	4.3	36.2	500	–	0.0	0.0
Lane 2	0	0	174	174	14.0	472	P	45[5]	13.9	LOS B	1.1	9.0	500	–	0.0	0.0
Approach	58	349	174	582	14.0		0.821		29.9	LOS D	4.3	36.2				
Intersection				2807	16.6		0.948		28.8	LOS D	8.6	74.3				

LANE SUMMARY (HV Reduced to 4%)

Lane Use and Performance

	Demand Flows L	Demand Flows T	Demand Flows R	Demand Flows Total	HV	Cap.	Deg. Satn	Lane Util.	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Lane Length	SL Type	Cap. Adj.	Prob. Block.
	veh/h	veh/h	veh/h	veh/h	%	veh/h	v/c	%	sec		veh	m	m		%	%
South: Tor Hailoch Side																
Lane 1	157	94	0	251	4.0	591	P	97[5]	12.7	LOS B	1.4	10.8	500	–	0.0	0.0
Lane 2	0	251	0	251	4.0	591	P	97[5]	12.7	LOS B	1.4	10.8	500	–	0.0	0.0
Lane 3	0	0	269	269	4.0	612	P	100	12.6	LOS B	1.4	10.8	500	–	0.0	0.0
Approach	157	346	269	772	4.0		0.440		12.7	LOS B	1.4	10.8				
East: Mesalemiya Side																
Lane 1	93	350	23	466	4.0	711	P	100	17.5	LOS C	3.2	25.4	500	–	0.0	0.0
Approach	93	350	23	466	4.0		0.656		17.5	LOS C	3.2	25.4				
North: Winget side																
Lane 1	308	0	0	308	4.0	660	P	100	12.4	LOS B	1.6	12.4	500	–	0.0	0.0
Lane 2	0	188	0	188	4.0	640	P	63[5]	9.4	LOS A	0.8	6.5	500	–	0.0	0.0
Lane 3	0	154	34	188	4.0	640	P	63[5]	9.4	LOS A	0.8	6.5	500	–	0.0	0.0
Approach	308	342	34	684	4.0		0.466		10.8	LOS B	1.6	12.4				
West: Likuwanda Side																
Lane 1	52	312	0	364	4.0	609	P	100	17.3	LOS C	2.4	19.2	500	–	0.0	0.0
Lane 2	0	0	156	156	4.0	585	P	45[5]	9.7	LOS A	0.7	5.8	500	–	0.0	0.0
Approach	52	312	156	521	4.0		0.599		15.1	LOS C	2.4	19.2				
Intersection				2443	4.0		0.656		13.6	LOS B	3.2	25.4				

Appendix-C2 Movement summary

Kality Intersection

MOVEMENT SUMMARY (By Actual Traffic)

Movement Performance - Vehicles												
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South East: Akaki Side											
3X	L	61	25.0	1.038	74.3	LOS F	19.9	182.9	1.00	1.89	21.8
8X	T	733	25.0	1.038	74.1	LOS F	19.9	182.9	1.00	1.89	20.5
18X	R	428	25.0	1.038	73.6	LOS F	19.7	181.7	1.00	1.88	20.3
Approach		1222	25.0	1.038	73.9	LOS F	19.9	182.9	1.00	1.88	20.5
North East: Megenagna Side											
1X	L	522	29.0	1.520	277.1	LOS F	61.3	579.5	1.00	5.00	8.3
16X	R	58	29.0	0.181	14.6	LOS B	0.4	3.5	0.67	0.77	42.9
Approach		580	29.0	1.520	250.8	LOS F	61.3	579.5	0.97	4.58	8.9
North West: Saris Side											
7X	L	40	16.0	0.545	15.3	LOS C	1.9	16.2	0.53	1.00	40.1
4X	T	643	16.0	0.545	15.1	LOS C	1.9	16.2	0.52	0.71	42.5
14X	R	121	16.0	0.195	8.2	LOS A	0.5	3.9	0.42	0.60	48.6
Approach		803	16.0	0.545	14.1	LOS B	1.9	16.2	0.50	0.71	43.2
South West: Lafto Side											
5X	L	289	34.0	0.864	56.2	LOS F	3.8	36.7	0.81	1.23	24.9
12X	R	433	34.0	1.219	153.8	LOS F	29.7	290.6	1.00	3.37	11.8
Approach		722	34.0	1.219	114.7	LOS F	29.7	290.6	0.92	2.51	15.4
All Vehicles		3328	25.5	1.520	99.2	LOS F	61.3	579.5	0.86	2.21	17.1

MOVEMENT SUMMARY (HV Reduced to 6%)

Movement Performance - Vehicles												
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South East: Akaki Side											
3X	L	49	6.0	0.630	15.4	LOS C	2.6	20.9	0.44	0.92	39.9
8X	T	587	6.0	0.630	15.4	LOS C	2.6	20.9	0.43	0.58	42.4
18X	R	343	6.0	0.630	15.2	LOS C	2.5	19.7	0.42	0.56	42.4
Approach		979	6.0	0.630	15.3	LOS C	2.6	20.9	0.43	0.59	42.2
North East: Megenagna Side											
1X	L	394	6.0	0.688	22.4	LOS C	3.2	25.2	0.71	1.00	35.8
16X	R	44	6.0	0.080	7.5	LOS A	0.2	1.6	0.50	0.66	49.4
Approach		438	6.0	0.688	20.9	LOS C	3.2	25.2	0.69	0.96	36.6
North West: Saris Side											
7X	L	36	6.0	0.433	11.2	LOS B	1.4	11.4	0.48	0.98	42.5
4X	T	574	6.0	0.433	11.1	LOS B	1.4	11.4	0.47	0.66	45.9
14X	R	108	6.0	0.155	6.9	LOS A	0.4	3.1	0.39	0.56	50.0
Approach		718	6.0	0.433	10.5	LOS B	1.4	11.4	0.46	0.66	46.2
South West: Lafto Side											
5X	L	201	6.0	0.419	14.9	LOS B	1.4	10.9	0.67	0.93	39.7
12X	R	301	6.0	0.595	20.0	LOS C	2.3	18.2	0.72	0.88	38.9
Approach		502	6.0	0.595	18.0	LOS C	2.3	18.2	0.70	0.90	39.2
All Vehicles		2637	6.0	0.688	15.4	LOS C	3.2	25.2	0.53	0.73	41.4

18-Mazoria Intersection

MOVEMENT SUMMARY (By Actual Traffic)

Movement Performance - Vehicles

Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Tor Hailoch Side											
3	L	185	19.0	0.638	23.6	LOS C	2.2	19.6	0.65	1.02	33.0
8	T	407	19.0	0.638	23.6	LOS C	2.2	19.6	0.65	0.92	34.8
18	R	317	19.0	0.653	23.6	LOS C	2.2	19.7	0.64	0.94	34.1
Approach		909	19.0	0.653	23.6	LOS C	2.2	19.7	0.65	0.95	34.2
East: Mesalemiya Side											
1	L	106	16.0	0.948	53.1	LOS F	8.6	74.3	0.81	1.41	23.6
6	T	399	16.0	0.948	53.1	LOS F	8.6	74.3	0.81	1.33	23.9
16	R	27	16.0	0.948	53.1	LOS F	8.6	74.3	0.81	1.35	23.8
Approach		532	16.0	0.948	53.1	LOS F	8.6	74.3	0.81	1.35	23.8
North: Winget side											
7	L	353	16.0	0.659	22.1	LOS C	2.5	21.5	0.63	0.99	33.5
4	T	392	16.0	0.419	14.0	LOS B	1.2	10.6	0.57	0.82	40.9
14	R	39	16.0	0.419	14.0	LOS B	1.2	10.6	0.57	0.89	40.3
Approach		785	16.0	0.659	17.7	LOS C	2.5	21.5	0.60	0.90	37.1
West: Likuwanda Side											
5	L	58	14.0	0.821	36.7	LOS E	4.3	36.2	0.78	1.17	28.2
2	T	349	14.0	0.821	36.7	LOS E	4.3	36.2	0.78	1.08	29.0
12	R	174	14.0	0.370	13.9	LOS B	1.1	9.0	0.62	0.87	40.3
Approach		582	14.0	0.821	29.9	LOS D	4.3	36.2	0.73	1.03	31.5
All Vehicles		2807	16.6	0.948	28.8	LOS D	8.6	74.3	0.68	1.03	31.7

MOVEMENT SUMMARY (HV Reduced to 4%)

Movement Performance - Vehicles

Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Tor Hailoch Side											
3	L	157	4.0	0.426	12.7	LOS B	1.4	10.8	0.55	0.94	38.9
8	T	346	4.0	0.426	12.7	LOS B	1.4	10.8	0.55	0.81	41.9
18	R	269	4.0	0.440	12.6	LOS B	1.4	10.8	0.53	0.84	41.0
Approach		772	4.0	0.440	12.7	LOS B	1.4	10.8	0.55	0.85	40.9
East: Mesalemiya Side											
1	L	93	4.0	0.656	17.5	LOS C	3.2	25.4	0.63	1.03	36.3
6	T	350	4.0	0.656	17.5	LOS C	3.2	25.4	0.63	0.88	38.4
16	R	23	4.0	0.656	17.5	LOS C	3.2	25.4	0.63	0.91	38.2
Approach		466	4.0	0.656	17.5	LOS C	3.2	25.4	0.63	0.91	38.0
North: Winget side											
7	L	308	4.0	0.466	12.4	LOS B	1.6	12.4	0.53	0.90	38.8
4	T	342	4.0	0.294	9.4	LOS A	0.8	6.5	0.49	0.75	44.7
14	R	34	4.0	0.294	9.4	LOS A	0.8	6.5	0.49	0.82	44.0
Approach		684	4.0	0.466	10.8	LOS B	1.6	12.4	0.51	0.82	41.7
West: Likuwanda Side											
5	L	52	4.0	0.599	17.3	LOS C	2.4	19.2	0.63	1.03	36.5
2	T	312	4.0	0.599	17.3	LOS C	2.4	19.2	0.63	0.88	38.6
12	R	156	4.0	0.267	9.7	LOS A	0.7	5.8	0.52	0.80	43.6
Approach		521	4.0	0.599	15.1	LOS C	2.4	19.2	0.60	0.87	39.7
All Vehicles		2443	4.0	0.656	13.6	LOS B	3.2	25.4	0.56	0.86	40.3

Appendix-C3 Intersection summary

Kality Intersection

INTERSECTION SUMMARY (By Actual Traffic)

Intersection Performance - Hourly Values				
Performance Measure	**Vehicles**		**Persons**	
Demand Flows (Total)	3328	veh/h	4438	pers/h
Percent Heavy Vehicles	25.5	%		
Degree of Saturation	1.520			
Practical Spare Capacity	-44.1	%		
Effective Intersection Capacity	2189	veh/h		
Control Delay (Total)	91.66	veh-h/h	110.00	pers-h/h
Control Delay (Average)	99.2	sec	89.2	sec
Control Delay (Worst Lane)	277.1	sec		
Control Delay (Worst Movement)	277.1	sec	277.1	sec
Geometric Delay (Average)	P	sec		
Stop-Line Delay (Average)	P	sec		
Intersection Level of Service (LOS)	LOS F			
95% Back of Queue - Vehicles (Worst Lane)	61.3	veh		
95% Back of Queue - Distance (Worst Lane)	579.5	m		
Total Effective Stops	7339	veh/h	8806	pers/h
Effective Stop Rate	2.21	per veh	1.98	per pers
Proportion Queued	0.86		0.77	
Performance Index	222.9		222.9	
Travel Distance (Total)	2246.8	veh-km/h	2696.2	pers-km/h
Travel Distance (Average)	675	m	607	m
Travel Time (Total)	131.8	veh-h/h	158.1	pers-h/h
Travel Time (Average)	142.5	sec	128.3	sec
Travel Speed	17.1	km/h	17.1	km/h
Cost (Total)	2667.57	$/h	2667.57	$/h
Fuel Consumption (Total)	678.7	L/h		
Carbon Dioxide (Total)	1715.3	kg/h		
Hydrocarbons (Total)	2.466	kg/h		
Carbon Monoxide (Total)	131.50	kg/h		
NOx (Total)	4.301	kg/h		

P: You need to Process this Site (F9) for this variable to be computed.

Level of Service (LOS) Method: Delay & v/c (HCM 2010).
Roundabout LOS Method: Same as Sign Control.
Intersection LOS value for Vehicles is based on average delay for all vehicle movements.
Roundabout Capacity Model: US HCM 2010.
HCM Delay Model used. Geometric Delay not included.

INTERSECTION SUMMARY (HV Reduced to 6%)

Intersection Performance - Hourly Values				
Performance Measure	Vehicles		Persons	
Demand Flows (Total)	2637	veh/h	3609	pers/h
Percent Heavy Vehicles	6.0	%		
Degree of Saturation	0.688			
Practical Spare Capacity	23.6	%		
Effective Intersection Capacity	3833	veh/h		
Control Delay (Total)	11.31	veh-h/h	13.57	pers-h/h
Control Delay (Average)	15.4	sec	13.5	sec
Control Delay (Worst Lane)	22.4	sec		
Control Delay (Worst Movement)	22.4	sec	22.4	sec
Geometric Delay (Average)	P	sec		
Stop-Line Delay (Average)	P	sec		
Intersection Level of Service (LOS)	LOS C			
95% Back of Queue - Vehicles (Worst Lane)	3.2	veh		
95% Back of Queue - Distance (Worst Lane)	25.2	m		
Total Effective Stops	1924	veh/h	2309	pers/h
Effective Stop Rate	0.73	per veh	0.64	per pers
Proportion Queued	0.53		0.47	
Performance Index	55.5		55.5	
Travel Distance (Total)	1775.6	veh-km/h	2130.8	pers-km/h
Travel Distance (Average)	673	m	590	m
Travel Time (Total)	42.9	veh-h/h	51.5	pers-h/h
Travel Time (Average)	58.6	sec	51.4	sec
Travel Speed	41.4	km/h	41.4	km/h
Cost (Total)	890.21	$/h	890.21	$/h
Fuel Consumption (Total)	245.0	L/h		
Carbon Dioxide (Total)	614.0	kg/h		
Hydrocarbons (Total)	0.893	kg/h		
Carbon Monoxide (Total)	44.01	kg/h		
NOx (Total)	1.532	kg/h		

P: You need to Process this Site (F9) for this variable to be computed.

Level of Service (LOS) Method: Delay & v/c (HCM 2010).
Roundabout LOS Method: Same as Sign Control.
Intersection LOS value for Vehicles is based on average delay for all vehicle movements.
Roundabout Capacity Model: US HCM 2010.
HCM Delay Model used. Geometric Delay not included.

18-Mazoria Intersection

INTERSECTION SUMMARY(By Normal traffic)

Intersection Performance - Hourly Values				
Performance Measure	Vehicles		Persons	
Demand Flows (Total)	2807	veh/h	3990	pers/h
Percent Heavy Vehicles	16.6	%		
Degree of Saturation	0.948			
Practical Spare Capacity	-10.3	%		
Effective Intersection Capacity	2961	veh/h		
Control Delay (Total)	22.47	veh-h/h	26.96	pers-h/h
Control Delay (Average)	28.8	sec	24.3	sec
Control Delay (Worst Lane)	53.1	sec		
Control Delay (Worst Movement)	53.1	sec	53.1	sec
Geometric Delay (Average)	P	sec		
Stop-Line Delay (Average)	P	sec		
Intersection Level of Service (LOS)	LOS D			
95% Back of Queue - Vehicles (Worst Lane)	8.6	veh		
95% Back of Queue - Distance (Worst Lane)	74.3	m		
Total Effective Stops	2880	veh/h	3456	pers/h
Effective Stop Rate	1.03	per veh	0.87	per pers
Proportion Queued	0.68		0.57	
Performance Index	76.1		76.1	
Travel Distance (Total)	1780.0	veh-km/h	2136.0	pers-km/h
Travel Distance (Average)	634	m	535	m
Travel Time (Total)	56.1	veh-h/h	67.3	pers-h/h
Travel Time (Average)	71.9	sec	60.7	sec
Travel Speed	31.7	km/h	31.7	km/h
Cost (Total)	1218.64	$/h	1218.64	$/h
Fuel Consumption (Total)	345.3	L/h		
Carbon Dioxide (Total)	869.0	kg/h		
Hydrocarbons (Total)	1.318	kg/h		
Carbon Monoxide (Total)	71.11	kg/h		
NOx (Total)	2.185	kg/h		

P: You need to Process this Site (F9) for this variable to be computed.

Level of Service (LOS) Method: Delay & v/c (HCM 2010).
Roundabout LOS Method: Same as Sign Control.
Intersection LOS value for Vehicles is based on average delay for all vehicle movements.
Roundabout Capacity Model: US HCM 2010.
HCM Delay Model used. Geometric Delay not included.

INTERSECTION SUMMARY (HV Reduced to 4%)

Intersection Performance - Hourly Values				
Performance Measure	Vehicles		Persons	
Demand Flows (Total)	2443	veh/h	3552	pers/h
Percent Heavy Vehicles	4.0	%		
Degree of Saturation	0.656			
Practical Spare Capacity	29.6	%		
Effective Intersection Capacity	3723	veh/h		
Control Delay (Total)	9.20	veh-h/h	11.04	pers-h/h
Control Delay (Average)	13.6	sec	11.2	sec
Control Delay (Worst Lane)	17.5	sec		
Control Delay (Worst Movement)	17.5	sec	17.5	sec
Geometric Delay (Average)	P	sec		
Stop-Line Delay (Average)	P	sec		
Intersection Level of Service (LOS)	LOS B			
95% Back of Queue - Vehicles (Worst Lane)	3.2	veh		
95% Back of Queue - Distance (Worst Lane)	25.4	m		
Total Effective Stops	2093	veh/h	2511	pers/h
Effective Stop Rate	0.86	per veh	0.71	per pers
Proportion Queued	0.56		0.46	
Performance Index	50.2		50.2	
Travel Distance (Total)	1548.7	veh-km/h	1858.4	pers-km/h
Travel Distance (Average)	634	m	523	m
Travel Time (Total)	38.5	veh-h/h	46.1	pers-h/h
Travel Time (Average)	56.7	sec	46.8	sec
Travel Speed	40.3	km/h	40.3	km/h
Cost (Total)	780.57	$/h	780.57	$/h
Fuel Consumption (Total)	209.7	L/h		
Carbon Dioxide (Total)	525.2	kg/h		
Hydrocarbons (Total)	0.872	kg/h		
Carbon Monoxide (Total)	42.52	kg/h		
NOx (Total)	1.299	kg/h		

P: You need to Process this Site (F9) for this variable to be computed.

Level of Service (LOS) Method: Delay & v/c (HCM 2010).
Roundabout LOS Method: Same as Sign Control.
Intersection LOS value for Vehicles is based on average delay for all vehicle movements.
Roundabout Capacity Model: US HCM 2010.
HCM Delay Model used. Geometric Delay not included.

Appendix-D Interview Questioner

<u>Analyzing Impacts of Freight Transport and Land use Structures on urban traffic functions and travel behavior</u>
<u>(The Case of Addis Ababa)</u>

By: - Abel Desalegn
(Addis Ababa University, Addis Ababa Institute of Technology, School of Civil and Environmental Engineering)

List of Questions

Part I (General)

1. What are the impacts of freight vehicle movements in Addis Ababa road networks?
    i. Congestion
    ii. Pollution
    iii. Road Deterioration
    iv. Accidents
    v. City aesthetics
    vi. No Impact
    vii. All(If your answer is more than one choice or all please rank them)
    viii. Others(Specify)--
2. Which entry corridor of Addis Ababa is under major mobility problems related to freight vehicles? Rank them
    i. Ambo road
    ii. Jimma road
    iii. Bishoftu road
    iv. Dessie road
    v. Gojjam road
3. What is the peak flow time of a day along the major entry corridor you chosen above?
    i. Morning
    ii. Noon
    iii. Evening
    iv. Other(Specify)--
4. Which intersection in Addis Ababa is highly congested by freight vehicles? Mention as much as you know.
5. What do you think is the main reason for those intersections to be congested?
    i. Orientation/Geometry of the intersections
    ii. Excessive freight traffic
    iii. Lack of traffic signs and signals
    iv. All (If your answer is more than one choice or all please rank them)
    v. Others (Specify)--
6. Around freight destination areas of the city which environmental pollution problem do you think is dominant?
    i. Emission
    ii. Noise
    iii. Both (If your answer is both rank them)
    iv. Other(Specify)--

7. What do you think is the major challenge in freight operation in Addis Ababa City?
    i. Freight related infrastructure
    ii. Freight Management
    iii. Both(If your answer is both rank them)
    iv. Others(specify)---
8. If your answer in question number 7 is “i” or “iii” what are the main infrastructure related challenges of freight operations in Addis Ababa?
    i. Parking space
    ii. Loading unloading facilities
    iii. Storage facilities
    iv. Road network
    v. Land use pattern
    vi. All of the above (If your answer is more than one choice or “all” please rank them.
    vii. Others(specify) --
9. If your answer in question number 7 is “ii” or “iii” what are the main management related challenges of freight operations in Addis Ababa?
    i. Traffic operations
    ii. Rules and regulations
    iii. Others(specify) --
10. Do you think the place and time restriction of freight movements in Addis Ababa is implemented efficiently?
    i. Effective
    ii. Not effective

    If your answer is “ii”, what do you think are the reasons for failure in efficient implementation of these rules? --
11. What do you think are feasible freight management options that may address the current traffic mobility problems in Addis Ababa?
    i. Enforcement of existing freight traffic rules and regulations
    ii. Coordination of inter and intra city freight movements
    iii. Freight transshipment at suburb areas
    iv. Application of intelligent transport systems
    v. All (If your answer is more than one choice or all please rank them)
    vi. Others (Specify)--
12. Do you think the land use pattern of Addis Ababa city has an impact on travel behavior and traffic functions of the city?
    i. Yes
    ii. No

    If your answer is “Yes” how? Discuss your answer in depth ------------------------------------
13. What do you think are the feasible land use improvement options that may facilitate efficient freight transport system in Addis Ababa?
    i. General zoning of the city
    ii. Decentralization of freight depots or warehouses
    iii. Providing the suburb with infrastructures
    iv. Looking for underground freight options?
    v. All (If your answer is more than one choice or all please rank them)

vi. Others (Specify)--

14. What do you think are the main challenges that may hinder proper implementation of effective freight transport management systems in Addis Ababa?
    i. Lack of coordination between stakeholders
    ii. Poor land use pattern of the city
    iii. Poor infrastructure
    iv. Shortage of Transport professionals
    v. Corruption in the system at different levels
    vi. All (If your answer is more than one choice or all please rank them)
    vii. Others (Specify)--
15. How do you think that effective logistics options have been attained in relation to land use and congestion in Addis Ababa city?
    i. By coordinating inter and intra city freight movements
    ii. By increasing the load rate
    iii. By developing freight facilities
    iv. Reducing Just-In-Time delivery habits for non perishable goods
    v. Implementing technology
    vi. All (If your answer is more than one choice or all please rank them)

<u>Part II (Transporters Specific)</u>:- Questions #16 to #30 are only to be replied by sample transporters.

16. Do you have a central station (Terminal) where your vehicles have been managed?
    i. Yes
    ii. No
    iii. Other(Specify) --
17. If your answer in question number 16 is "Yes" where in the city is your terminal found? Specify particular locations --
18. If your answer for question number 16 is "Yes" do you have sufficient parking lot for your vehicles?
    i. Yes
    ii. No
    iii. Other(Specify) --
19. If your answer for question number 18 is "No" where do you park your vehicles when they are off duty because of different reasons?
    i. On street
    ii. Other(specify) --
20. Do you have a fleet management structure under you company?
    i. Yes
    ii. No
    iii. Other(specify) --
21. How many are your fleet size? ---------------Tonnage/---------------number
22. What is the average Capacity of your fleet?-------------------quintal/Tone
23. What is the average fleet utilization (%/year)? --
24. What is the average vehicle utilization (Km/day)? --
25. What is the usual load rate/ load factor of your fleets? --
26. How do you manage the back haul? Do you work in coordination with other transporters?
    i. Yes

ii. No

If your answer is "yes" discuss how---

27. What is the average age of you vehicle that are currently in operation?
28. Do you have vehicle replacement policy?
    i. Yes
    ii. No

    If your answer is "yes", in how many years? --------------------------------------
29. Are you well aware and interested for the use of technology like GPS tracker and others for your vehicle while they are on duty?
    i. Yes
    ii. No
    iii. Other(specify) ---
30. Where are your main ORIGINS and DESTINATIONS? Discuss them-------------------------

<u>Part III (Traffic Police Specific)</u>:- Questions #31 to #33 are only to be replied by sample Traffic Polices.

31. How do you evaluate the implementation efficiency of freight related rules and regulations in Addis Ababa?
    i. Highly efficient
    ii. Efficient
    iii. Less efficient
32. If your answer to question number 31 "3" who do you think is responsible
    i. Drivers
    ii. Transport offices
    iii. Traffic police
    iv. All of the above listed(If your answer is "All" rank them)
33. What do you think are the main problems related to freight vehicle drivers that may result in poor traffic mobility in Addis Ababa city?
    i. Lack of driving skill
    ii. Behavioral problems
    iii. Lack of awareness on urban traffic regulations
    iv. All of the above listed(If your answer is all rank them)
    v. Other (specify)

<u>Part IV (Drivers Specific)</u>:- Questions #34 to #36 are only to be replied by sample Drivers.

34. Is your Origin or Destination Addis Ababa?
    i. Yes
    ii. No
    iii. If your answer is "No" where is your Origin and Destination

    Specify O --------------------------- D -----------------------------------
35. Where do you mostly park before loading or after loading your cargo?
    i. On street
    ii. Other (specify) --
36. Are you comfortable or interested in the application of technology like GPS trackers or others if it is implemented on your vehicle?
    i. Yes
    ii. No
    iii. Indifferent

Appendix-E Some demonstrative pictures

Fig. The busiest Kality intersection

Fig. Common collision accident at Kality intersection

Fig. High Emission around Kality Intersection

Fig. Busy street of Akaki kality

Fig. Mostly congested 18-Mazoria intersection

Fig. Narrow and Congested 18-Mazoria intersection