4 Estimation of Direct Economic Costs of Traffic Congestion in Cairo

4.1 Introduction

This section provides the calculation of estimated direct economic costs of traffic congestion in the Greater Cairo Metropolitan Area (GCMA). In order to estimate costs of congestion, first a definition of congestion is presented. Then, based on a literature review a selection of suitable methods of measurement of congestion levels is described.

The next step is to identify the adverse components of traffic congestion. For each element a calculation method is explained and proposed, based on literature review. This resulted into two main approaches to calculate in particular the delay costs for the GCMA (one of the components). The approaches are divided into two parts: first a calculation on direct congestion costs on the 11 Principal Corridors (sections 4.3-4.7) and secondly an extension of the calculation to cover the complete GCMA (section 4.8)

Moreover, a zonal based distribution of congestion cost is conducted by applying an engineering judgment based on available information. Finally, this chapter presents a reflection of the calculation method in view of the data used.

4.2 Methods to Measure Direct Economic Costs of Congestion

4.2.1 Definition of congestion

To the traveler, congestion comprises motionless or slowly moving lines of vehicles on a freeway or urban street, a lane closure because of road construction or an accident, or some sort of traffic backup. The transportation professional, on the other hand, thinks of congestion in terms of flow rates, capacities, volumes, speeds, and delay.

Congestion occurs when the road capacity does not meet traffic demand at an adequate speed, traffic controls are improperly used, or there is an incident on the road such as an accident or disabled vehicle. Congestion can occur during any time of the day and along any type of roadway.

Congestion can take various forms, such as *recurring* or *nonrecurring*, and can be located across a network or at isolated points. Recurring congestion exists when the traffic volume on roadway exceeds its capacity at a particular location during a predictable and repeated time of day. Nonrecurring congestion is caused by random or unpredictable events that temporarily increase, demand, or reduce capacity on a roadway. Such events include accidents, disabled vehicles, road construction, and inclement weather.

4.2.2 How to measure congestion?

Measuring congestion is a necessary step in order to deliver better congestion outcomes. However, congestion should not be described using a *single* metric for policy purposes. Such an approach is sure to obscure either the quantitative aspects of congestion or its relative and qualitative aspects. These two aspects can not be disassociated and progress in managing congestion should be based on sets of indicators that capture both of these aspects.

Good indicators can be based on a wide network of roadway sensors but simple indicators based on less elaborate monitoring can sometimes adequately guide policy. What is important is to select metrics that are relevant to both road managers (e.g. speed and flow, queue length and duration, etc.) and road users (e.g. predictability of travel times, system reliability, etc).

Congestion has an impact on both the speed of travel and on the *reliability* of travel conditions. It is the latter that may be of greatest concern to individuals and businesses. Thus congestion management policies should keep track of travel reliability indicators. These may capture the variance in travel times or, alternatively, communicate the amount of time buffers road users have to include in their travel plans to make their trips “on time”. Insofar as these reliability indicators give an understanding of the quality of travel conditions, they are important to policymakers seeking to address the qualitative aspects of congestion.

The manner in which *congestion is measured* has a fundamental impact on the manner in which *congestion is defined and managed*. Measures of congestion based alternately on speed, access, user costs, delay, reliability, etc. will give rise to different problem statements regarding congestion and will motivate sometimes radically different policy interventions.

There is no “simple” measure of congestion that is good for all purposes and all situations. The rating of a specific roadway segment’s performance as translated by hourly vehicle counts against rated capacity will mean little to a user even if they travel over that link every day. Conversely, knowing the amount of time one must plan for to get from one suburb to another at peak hours in order to arrive before 09:30 will not necessarily help an engineer better time traffic signals in the central business district. There are not necessarily “better” indicators of congestion than others, but there may exist a *better fit* between those indicators selected and specific outcomes desired. In this respect, it is important not to simply use a specific congestion indicator because it is available (others might be as well), but because it allows one to measure progress towards a specific goal (e.g. link performance, system operation, user experience, etc…).

Based on an analysis of the commonly used performance measure(s) that reflects congestion levels on roads (see literature review Annex 9) it is concluded that both travel speed characteristics (differences between peak and off-peak) as well as the number of vehicles divided by the capacity (V/C[11]) are suitable for this study to calculate direct economic costs of congestion.

4.2.3 Economic Costs Elements and Calculation Method

Based on the literature review (see Annex 9) the following direct cost elements are commonly used to calculate the direct costs of traffic congestion:

- Costs of travel time delay imposes to users (passengers as well as freight)
- Costs of travel time unreliability in passenger transportation
- Cost of excess fuel consumption in vehicular transportation (Diesel and Gasoline)
- The associated cost of CO_2 emissions due to excess fuel consumption

The method used to estimate cost of time delay and the cost of excess fuel consumption is primarily based on the methodology developed by the Texas Transportation Institute[12].This methodology focuses on the calculation of delay costs and the costs of excess fuel consumption. The remaining cost items, namely the costs of travel time unreliability and associated costs of CO_2 emissions due to excess fuel consumption are estimated using other sources. These sources represent research on monetizing travel time uncertainty and the valuation of external costs of transport and are listed in the sections 4.4 and 4.6 in which the calculation of these costs is described.

It is noted that the detailed methodology used for the calculation of each direct cost item, including formulas used, is presented in Annex 10. The main report presents the main steps in the calculation, and focuses on the results.

4.3 Costs of Travel Time Delay

The methodology is outlined as follows and is performed on individual roadway segments. The three aforementioned peak period times (morning, afternoon, and evening) were used as the time for the beginning of congestion.

Most of the basic performance measures are developed as part of calculating travel delay (the amount of extra time spent traveling due to congestion).

An overview of the process is followed by more detailed descriptions of the individual steps. Travel delay calculations are performed in two steps: recurring (or usual) delay and secondly nonrecurring delay (due to crashes, vehicle breakdowns, etc.).

Recurring delay estimates are developed using a process designed to identify peak period congestion due to 1) differences in peak and off-peak speeds and 2) traffic volume and useable capacity.

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[11] Congestion occurs if the number of vehicles is close to the capacity, the ratio of 0.77 V/C as provided in the Highway Capacity Manual is often used as a threshold.

[12] (http://mobility.tamu.edu/ums/report/Annex_a.pdf

Delay caused by stochastic events is included in the non recurring delay estimate. Generally, these events can be categorized as one of the eleven sources of unreliability:

- Traffic Incidents
- Work Zones
- Weather
- Fluctuation in Demand
- Special Events
- Traffic Control Devices
- Inadequate Base Capacity
- Vehicle breakdown
- Random Pedestrian Crossing
- Random Minibus Stops
- Security Checks

Given the available information from the Floating Car Survey (see Chapter 2) only estimates of nonrecurring travel delay from incidents, security checks, vehicle breakdowns, random minibus stops, and finally random pedestrian crossings have been taking into account in this assignment.

4.3.1 Estimation of Delay from Recurrent Traffic Congestion

In order to estimate delay from recurrent traffic congestion, determining the congestion threshold is essential. In order to determine the congestion threshold two different approaches have been applied as follows:

- Approach 1: Applying Principal Corridors Collective Assessment for corridors' speed plot
- Approach 2: Applying V/C based on traffic counts and useable road capacity

Approach 1: Applying Principal Corridors Collective Assessment for corridors' speed plot

The consultant uses the speed indices plots (see Chapter 2 and Annex 4) to determine the corridors' level of service and thus the congestion level. The hours that the speed indices show the average speed below 0.6 is considered as congested hours.

Travel delay from recurrent traffic congestion is estimated by equations relating vehicle traffic volume per lane and traffic speed. The calculation proceeds through the following simplified steps based on the method proposed by Texas Transportation Institute (TTI Method):

1. Estimate the daily volume of vehicles per lane corresponding to the congested peak hours
2. Calculate daily vehicle kilometers traveled (DVKT) for each roadway section as the average daily traffic (ADT) of a section of roadway multiplied by the length of that section of roadway
3. Calculate peak period volume
4. Determine average freeway speeds during the peak period based on data collected from travel time and speed surveys in corridors

5. Estimate travel delay. The difference between the amount of time it takes to travel the peak-period vehicle-Kilometers at the average speed and at free-flow speeds is termed delay.
6. Calculate daily recurring vehicle-hour delay

The amount of delay incurred in the peak period is the difference between the time to travel at the average speed and the travel time at the free-flow speed, multiplied by the distance traveled in the peak period.

The daily vehicle-kilometers of travel (DVKT) is the average daily traffic (ADT) of a section of roadway multiplied by the length (in kilometers) of that section of roadway. This allows the daily volume of all urban facilities to be presented in terms that can be utilized in cost calculations. The DVKT was estimated for the freeways and principal arterial streets located in each urbanized study area.

Approach 2: Applying V/C based on traffic counts and useable road capacity

By this approach the consultant applied the following multistep method to identify congested peak hours and segments for the corridors:

1. Divide each corridor into segments based on the useable segment's capacity
2. Calculate V/C for each segment during peak hours
3. Identify congested segments when V/C >0.77.

The FHWA model used 0.77 V/C ratio as threshold markers for traffic congestion. In fact, in 1991, the FHWA completed additional research in the area of quantifying congestion. The focus of this work was on recurring congestion on urban area freeways and the development of a congestion indicator combining both the duration and extent of congestion in a single measure (Cottrell, 1991), (Texas Transportation Institute, 1992), and (Epps et al. 1993). The only impact of congestion considered in this work was recurring congestion-induced delay expressed in terms of both its duration and physical extent by a newly developed indicator called the lane-mile duration index.

Given description above, the consultant applied the following steps to estimate the delay from recurrent congestion:

1. Calculate capacity based on number of lanes, an adjustment factor for lane width, lateral clearance, the presence of trucks, and type of terrain, and a value of 2,200 vehicles per lane per hour for the basic lane capacity assuming a roadway design speed of at least 60 Km per hour (kph)
2. Calculate volume-to-capacity ratio (V/C) for each hour of a typical day based on new counts
3. Determine which hours of the day are to be classified as congested. A V/C ratio of 0.77 was used to indicate the onset of congested travel conditions (boundary between LOS C and LOS D).
4. Calculate total annual congested vehicle Kms of travel (DVKT) based on AADT, roadway section length, and percentage of daily traffic experiencing congested conditions, which is the sum of the percentages of traffic occurring during those hours of the day with a V/C ratio greater than or equal to 0.77.

5. Estimate Travel Delay*:* The difference between the amount of time it takes to travel the peak-period vehicle-Kilometers at the average speed and at free-flow speeds is termed delay.
6. Calculate daily recurring vehicle-hour delay by the following formula:

4.3.2 Estimation of Delay from Nonrecurring Traffic Congestion

Another type of delay encountered by travelers is the delay that results from incidents, Security Checks, Vehicle Breakdowns, Random Minibus Stops, and finally Random Pedestrian Crossings. Incident delay is related to the frequency of crashes or vehicle breakdowns, how easily those incidents are removed from the traffic lanes and shoulders and the “normal” amount of recurring congestion. The basic procedure used to estimate incident delay in this study is to multiply the recurring delay by a ratio.

The process used to develop the delay factor ratio is a detailed examination of the freeway characteristics and volumes. In addition, a methodology developed by the Texas Transportation Institute is used to model the effect of incidents based on the design characteristics and estimated volume patterns.

The road incident delay factor is calculated based on TTI method. The process used to develop the delay factor ratio is a detailed examination of the road characteristics and volumes. The consultant uses daily traffic influencing events in the car floating survey to estimate the incident delay factor.
Incident delay occurs in different ways on streets than freeways. While there are driveways that can be used to remove incidents, the crash rate is higher and the recurring delay is lower on streets. Arterial street designs are more consistent from city to city than freeway designs. For the purpose of this study, the road incident delay factor for arterial streets is estimated between 110 to 160 percent of arterial street recurring delay depending on:

- No. of accidents
- Security checks
- Vehicle breakdowns
- Random Microbus stops
- Random pedestrian crossings

Based on engineering judgment most of the corridors are allocated the value of 1.1 as the incident delay ratio.

For corridor 1 with the following nonrecurring events, the value of 1.3 is considered as the incident delay ratio.

Average Daily Frequency	Accidents	0.2
	Security Checks	4.5
	Vehicle Breakdowns	7.4
Qualitative Observation	Random Microbus Stops	High
	Random Pedestrian Crossings	Medium

For corridor 3 with the following nonrecurring events, the value of 1.6 is considered as the incident delay ratio

Average Daily Frequency	Accidents	2
	Security Checks	5
	Vehicle Breakdowns	17
Qualitative Observation	Random Microbus Stops	High
	Random Pedestrian Crossings	Medium

For corridor 4 with the following nonrecurring events, the value of 1.2 is considered as the incident delay ratio

Average Daily Frequency	Accidents	0.3
	Security Checks	1.4
	Vehicle Breakdowns	1.4
Qualitative observation	Random Microbus Stops	High
	Random Pedestrian Crossings	High

Inputs and assumptions

It should be noted that estimating recurrent as well as nonrecurring delay costs needs update data for the value of time, and vehicle occupancy factor. The vehicle occupancy factor for diverse vehicular modes is assumed as follows:

Passenger Transportation:

Table 4.1: Vehicle occupancy factor for diverse vehicular modes (passenger)

Passenger car	Pickup	Motorcycle	Taxi	Microbus	Minibus	Bus
1.5	1.3	1.0	2.5	13	21	49

Freight Transportation:

Table 4.2: Truck Load capacity (Ton)

Light Truck	Medium Truck	Large Truck
5	9	15

Source:
The strategic Development Master Plan Study for Sustainable Development of the Greater Cairo region in the Arab Republic of Egypt March 2008

In order to monetize the delays to costs, the following value of time classified for passenger car users, taxi users, and transit riders have been applied. The value of time for motorcyclists is assumed to be equal to that for transit riders.

Table 4.3: Value of time for diverse transport user classes (adjusted for 2010)

Passenger car users (LE/hr)	Taxi users (LE/hr)	Transit riders (LE/hr)	Freight transporters (LE/ton)
13,8	5,4	3.5	4.2

Sources:
For passenger transport: *Transportation Master Plan and Feasibility Study of Urban Transport Projects in Greater Cairo Region in the Arab Republic of Egypt, November 2002*

For freight transport: Developing Harmonized European Approaches for Transport Costing and Project Assessment (HEATCO), May 2006

Working Days
Cost calculations were based on 250 working days per year.

4.3.3 Total Delay Cost for 11 Corridors

The annual recurring and nonrecurring cost for the 11 corridors amount to **2.6 billion LE** using approach 1 (speed plots) and **2.4 billion LE** using approach 2(V/C ratios).

The share of recurrent delay costs is estimated to be approximately 40% leaving 60% for the non-recurrent delay (valid for both approaches). The estimation is based on the TTI methodology in which ratios have been determined on recurrent and non-recurrent delays. The information in the Floating Car Survey on the level of incidents in the corridors is used in this estimation; it is noted that the duration of the incidents is not known. Nevertheless, the non-recurrent delays are a substantial part of the delay costs, indicating that avoiding vehicle breakdowns and incidents provides substantial benefits.

Further information and a series of detailed analyses on delay costs for individual corridors can be found in Annex 11.

4.4 Costs of Travel Time Unreliability

Basically, average travel time between two destinations includes both expected and unexpected delays. It is assumed that network users accommodate expected delays into their travel time through, say, the inclusion of buffer time. However, it is more difficult and costly to incorporate the unpredictable the unexpected delays that lead to variation from planned or anticipated travel time.

The terms unreliability and congestion are often used synonymously. However, a congested network does not necessarily have to be unreliable. Unreliability refers to unanticipated delays, and therefore a congested network is not necessarily unreliable because journey time along a congested road can be fairly predictable. However, congestion increases the likelihood of unreliability: as traffic levels increase the time delays due to slight perturbations tend to increase more than proportionality.

4.4.1 Observed Travel Time Unreliability

A wide variety of temporal indicators (e.g. STD, COV, 95th Percentile, Buffer time index) can be used to provide a range of perspectives of the reliability issue. The consultant applied the *Coefficient of Variation of Travel time (COV)* in observed travel speeds from multiple floating car runs in the corridors as the travel time reliability measure. This approach is chosen since it directly uses the outcomes of the Floating Car Survey. On average 16 runs were recorded for each direction of each route for each peak period through the FC survey. Variations in trips' length caused some alterations. As such, the undertaken reliability analysis is based on the estimated coefficients of variation of the corridors average speeds (Figures 3.12)
The shown variability in traffic speeds is likely to encapsulate both day to day variability in traffic volumes as well as within-day variability due to situational differences (such as the random stop of a microbus) and personal differences (such as drivers' experiences and responsiveness).

The coefficient of variation of travel times is defined as standard deviation divided by mean travel time:

$$COV_i = \frac{STD_i}{\bar{T}_i}$$

Where:
i: corridor number
STD: The standard deviation of travel time
$\bar{T}$: The mean travel time

$$STD_v = standard\ deviation\ of\ speeds$$

$$STD_T = standard\ deviation\ of\ travel\ times = \frac{L}{STD_v}$$

$$T = \frac{L}{V_i}$$

4.4.2 Cost of Unreliability for 11 Corridors

In general, reliability is highly valued by travelers and commercial vehicle operators reflecting the fact that a reliable transport network is a net benefit for society and that an unreliable network represents a net cost to society. A lot of work has been carried out in among others the Netherlands to monetize unreliability of travel time. Based on the research's outcomes (OECD 2010) and the local conditions, the consultant assumed the following rates for monetizing travel time unreliability:

Passenger cars and motorcycle:	1.0 minute travel time variation is equivalent to 0.9 minute travel time
Public Transport including taxi:	1.0 minute travel time variation is equivalent to 1.1 minute in vehicle travel time

It should be noted that reliability perception is a controversial issue and may range from 0.9 to 2.5 in different countries *(Senna 1991; Copley et al 2002)*. Also, due to lack of reliable source for economic valuation of buffer time index, the consultant uses the standard deviation of travel time derived from COV in economic analyses.

In order to estimate the accurate value of reliability, a SP survey seems to be essential. Given the aforementioned values, the consultant estimates monetary value of travel time unreliability for the 11 corridors as well as for all road users. The freight users have been excluded since no rates for monetizing travel time unreliability are available.

The total unreliability associated cost for the 11 corridors is estimated approximately **1.7 billion LE**. The level of unreliability costs is close to the delay costs, which is mainly caused by the assumed ratio of minutes travel time variation equivalent to minutes travel time.

Further information and a series of detailed analyses on unreliability associated costs for individual corridors can be found in Annex 11.

4.4.3 Unreliability in freight transport

Given the lack of sufficient information on annual cargo shipment volume and type in the Cairo region, the consultant is incapable to estimate the cost of unreliability in freight transportation. However, a rough estimation based on the annual tonnage of cargo transported in the region could be made to give a clue on impacts of unreliability on freight transport cost. The consultant applies the criterion of Willingness To Pay (WTP) which is derived from cargo transport companies in Nigeria. The case study has been done by Ogwude in (1990-1993) and reported in National Cooperative Highway Research Program (NCHRP 431). The Nigerian firms were willing to pay for 1.6 and 0.6 Naira per ton of consumer and capital goods respectively to reduce the standard deviation of travel time by an hour. Given the aforementioned value and inflation rate in the country, the consultant estimate the Willingness to Pay for Egypt approximately 0.70 LE and 0.26 LE per ton of consumer and capital goods respectively to reduce the standard deviation of travel time by an hour.

Thus, the total unreliability cost for freight transportation is estimated around **13.5 Million LE per year.**

4.5 Cost of Excess Fuel Consumption

The average fuel economy calculation is used to estimate the fuel consumption of the vehicles running in the congested condition. The formula used is derived from the TTI methodology, a metric conversion has been applied to the equation since it is originally formulated based on non metric units (Miles per Gallon).

In order to estimate excess fuel consumption due to traffic congestion the following steps are applied:

- Calculate average speed
- Calculate average fuel efficiency

- Calculate total excess fuel (liters) used as a result of recurring and nonrecurring delay, based on the mix of traffic and fuel used (diesel and gasoline)

The total annual gasoline consumption for the 11 corridors due to congestion is estimated around **608 million liters** (2.4 million liters per morning and evening peak hours – approach 1) and **552 million liters** (2.2 million liters per morning and evening peak hours – approach 2).

Similarly, the total annual diesel consumption for the 11 corridors due to congestion is estimated around **102 million liters** (410 thousands liter per morning and evening peak hours) by using approach 1 and **81 million liters** (326 thousand liters per morning and evening peak hours) by using approach 2.

Based on an interview with a petroleum company in Cairo, the following tariffs have been applied to estimate the total excess Gasoline and Diesel costs in Cairo:

- Gasoline (grade 80): 0.90 LE
- Gasoline (grade 90): 1.75 LE
- Gasoline (grade 92): 1.85 LE
- Gasoline (grade 95): 2.75 LE
- Diesel: 1.10 LE

Furthermore, it should be noted that a fuel subsidy has been assumed being 2.2 LE/Ltr for gasoline, and 1.1 LE/Ltr for Diesel according to GTZ Transport Policy Advisory reported in International Fuel Prices (2009). Both the costs for the users of excess fuel and the costs for the Government (subsidy provided) have been calculated:

Table 4.4: Excess fuel cost in the Greater Cairo because of traffic congestion

Approach 1			Approach 2		
Excess fuel cost imposed to transport users	Excess Fuel Subsidy	Excess total Fuel Cost	Excess fuel cost imposed to transport users	Excess Fuel Subsidy	Excess total Fuel Cost
1.20	1.46	2.85	1.08	1.30	2.38

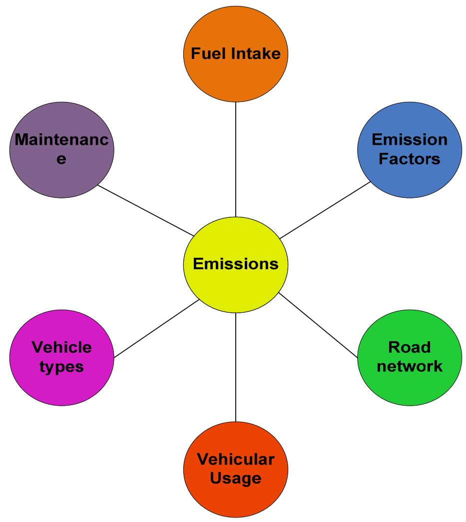
The total excess fuel costs for the 11 corridors are estimated to be **2.85 billion LE** using approach 1 (speed plots) and **2.38 billion LE** using approach 2(V/C ratios). The share of the costs to the user is 45% and the costs for the Government represent 55% of the total amount.

Further information and a series of detailed analyses on excess fuel consumption and costs for individual corridors can be found in Annex 11.

4.6 Associated Cost of CO_2 Emissions due to Excess Fuel Consumption

This section outlines the method of estimating emissions from vehicular activity using available data from car floating survey.

A number of studies, in developed and developing countries, apportioning the sources of air pollution put the transport sector atop – both from direct exhaust and indirect road dust. Increasing fuel consumption on the road mean emissions increase, air quality will only get worse. The following figure provides the framework for the emissions from road traffic. The fuel intake is one of the elements determining the level of emissions.



Given the following standard emission rates for diverse vehicular modes, the CO_2 emission caused by excess fuel consumption due to congestion is estimated per year.

Table 4.5: The emission rate for diverse vehicular modes

Emission rate	CO2
Vehicular Mode	**kg/L**
Cars (diesel and gasoline)	2,40
Motorcycle	2,42
Taxi	2,40
Bus	2,41
BRT	2,24

Source: *Guttikunda, S., 2008, Simple Interactive Models for Better Air Quality, Vehicular Air Pollution Information System VAPIS. www.sim-air.org*

Likewise other cost components, the consultant applied both approaches to estimate emission weight and consequent cost for the region.

The total CO2 emission weight is estimated 1.7 million ton per annum for the 11 corridors using approach 1 (speed plots).The emission cost for each corridor is estimated by converting emission weights to costs. The consultant applied the conversion factor 57 (LE/Ton) based on the World Bank estimation. The total emission costs due to traffic congestion for the 11 corridors is estimated approximately **97 million LE** per annum.

When applying approach 2 (V/C ratios), the total CO2 emission weight is estimated 1.5 million ton per annum for 11 corridors and the emission cost due to traffic congestion is estimated approximately **86 million LE** per annum.

Further information and a series of detailed analyses on emission costs for 11 corridors can be found in Annex 11.

4.7 Total Direct Costs of Traffic Congestion for 11 Corridors

Summarizing the aforementioned traffic congestion cost components, the total direct traffic congestion cost for the 11 corridors is estimated as follows by:

Table 4.6: Direct cost components of traffic congestion (approach 1)

Delay cost	Unreliability cost	Excess fuel cost	Excess fuel subsidy	Emission Cost	Total cost
2.625.668.148	1.712.392.281	1.207.697.012	1.451.004.736	97.299.441	**7.094.061.618**

Table 4.7: Direct cost components of traffic congestion (approach 2)

Delay cost	Unreliability cost	Excess fuel cost	Excess fuel subsidy	Emission Cost	Total cost
2.375.181.344	1.712.392.281	1.084.507.106	1.305.544.977	86.813.921	**6.564.439.628**

The data that has been used for all calculations is presented in Annex 12.

Figure 4.1 and 4.2 illustrates the total direct economic cost of traffic congestion for 11 corridors given the approach 1 and 2. The main cause of difference between results of these two approaches is the applied method to determine the congested part of the corridors. Due to lack of sufficient information on legal and illegal onsite parking status on the corridors, police checks, random pedestrian crossings and microbus stops, the actual corridor's capacity in approach 2 might be overestimated and thus results in lower traffic congestion cost compared to approach 1. This is especially the case for corridors 2, and 10 which is the estimated length of congested segments in approach 2 is shorter than that in approach 1.

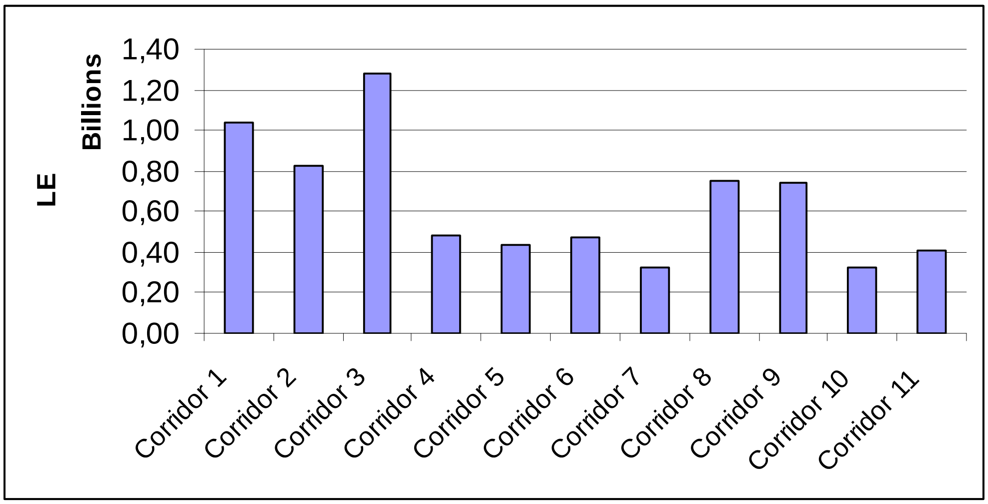


Figure 4.1 Total annual direct cost due to traffic congestion in 11 corridors (approach 1)

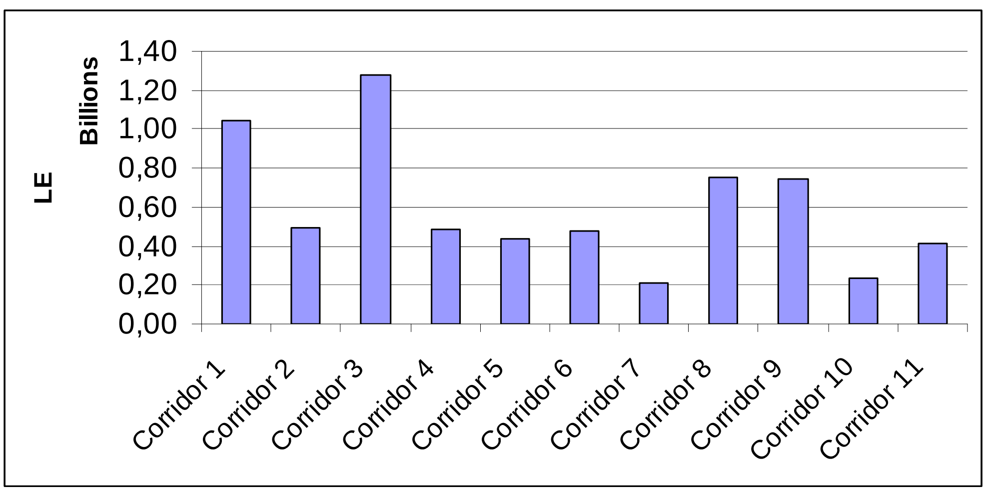


Figure 4.2 Total annual direct cost due to traffic congestion in 11 corridors (approach 2)

The figure shows that transportation in corridor 1 (26th of July/15th of May Travel Corridor) and corridor 3 (Ring Road Southern segment) faces the highest excess cost due to traffic congestion in Cairo compared to other corridors. For corridor 3, total excess cost exceeds 1.28 billion LE annually. This amount decreases for corridor 1 and approximately reaches to 1.1 billion LE per annum.

4.8 Sensitivity analysis

As indicated before, in the 2nd approach the congestion threshold is determined by using the V/C index. The road capacity in the GCMA is affected by onsite parking. In the lack of a comprehensive parking inventory analysis the consultant assumed that one lane of the corridors is occupied during peak hours by legally and/or illegally parked vehicles. By restricting onsite parking to 50% of corridors' length (instead of no restriction), the congestion level in the corridors decreases accordingly. In this case the total traffic congestion cost can be reduced down to 20%. In other words, an onsite parking inventory analysis on the GCMA network seems to be essential and would lead to more precise estimation of congestion cost in the region.

The second sensitivity analysis was performed based on the value of time for all road users (passenger car users, taxi users, transit users, and freight transporters). The analysis demonstrates that ± 1 LB change in the VoT results in approximately ± 8% alteration in the total congestion cost.

The third sensitivity analysis focused on fuel economy formulation. The consultant used the original fuel efficiency formula calibrated in 80th decade base on the US car fleet composition. In other words, the average fuel consumption is estimated around 10 litres/100 km (24 MPG) in the city based on speed of 60 Km/hr. The actual fuel consumption in Cairo depends on the fleet composition and the age of the fleet. This information is not yet available. In absence of fleet data, a sensitivity analysis has been conducted. The analysis results show that 20% reduction in fuel efficiency (12 liters/ 100 km), increases the excess fuel cost, the excess emission cost, and the total congestion cost around 25 %, 25% , and 10% respectively.

4.9 Total Direct Cost of Traffic Congestion for GCMA

The 11 corridors have been selected to represent the vast majority of traffic congestion locations in GCMA and have been done together with traffic police representatives. Clearly, the direct congestion costs of the entire GCMA will be higher compared to the amount calculated for the 11 corridors.

In order to estimate congestion cost for the entire GCMA, crucial information is needed to be able to calculate vehicle capacity ratios. The calculation of V/C ratios can only be done through assigning the total traffic to the total network. The following information is needed:

- Transit route(s) between OD pairs
- Taxi and shared taxi (microbus) route(s) between OD pairs
- Freight transportation routes between OD pairs
- Actual peak hour capacity of the routes
- Free flow speed, peak hour speed, and average speed of in the entire network

- The standard deviation of travel time in the route(s)

This listed information is not available, and therefore it is not possible to assign traffic to the network using transport modeling software.

The consultant used an alternative method to extend the direct economic cost of traffic congestion from 11 corridors to the GCMA and provide a framework for further research on the issue. The applied methodology can be outlined as a two step procedure as follows:

The consultant developed a Traffic Model in Emme3 based on the trip generation and distribution tables and the 11 major corridors attributes and alignments. By running this model we came out with traffic volumes in Greater Cairo distributed only on the 11 major corridors. Therefore, to calculate the percentage of the traffic in Greater Cairo carried by the 11 major corridors, we compared the actual traffic counts results to the Emme Traffic volumes on these corridors.

The method used is as follows:

- Summing up the traffic counts results on the 11 corridors in each direction and the total Emme traffic volume in one direction;
- Dividing the total traffic count in each direction by the total Emme traffic volume in one direction;
- Taking the average of the ratios in both directions.

This procedure was applied on the PM and AM traffic counts and the ratios turned out to be: 50.4% (AM) and 50.9% (PM). The average of these ratios has been used to extrapolate the congestion cost of the 11 corridors to the entire GCMA. The results are shown in the following tables:

Table 4.8: Direct cost components of traffic congestion for the entire GCMA (approach 1)

Delay cost	Unreliability cost	Excess fuel cost	Excess fuel subsidy	Emission Cost	Total cost
5.251.336.295	3.424.784.562	2.415.394.024	2.902.009.472	194.598.882	**14.188.123.236**

Table 4.9: Direct cost components of traffic congestion for the entire GCMA (approach 2)

Delay cost	Unreliability cost	Excess fuel cost	Excess fuel subsidy	Emission Cost	Total cost
4.750.362.688	3.424.784.562	2.169.014.212	2.611.089.953	173.627.841	**13.128.879.256**

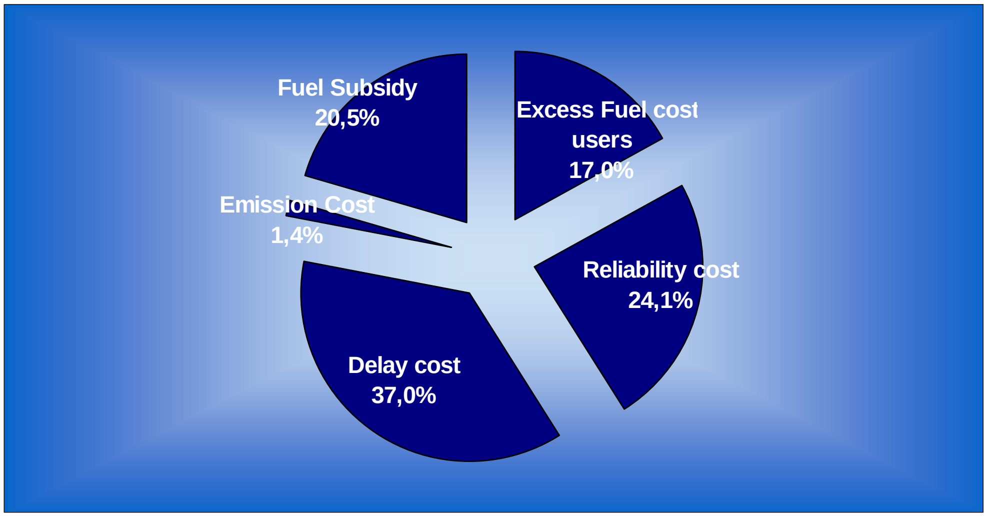


Figure 4.3 Distribution of total annual direct cost due to traffic congestion in GCMA (approach 1)

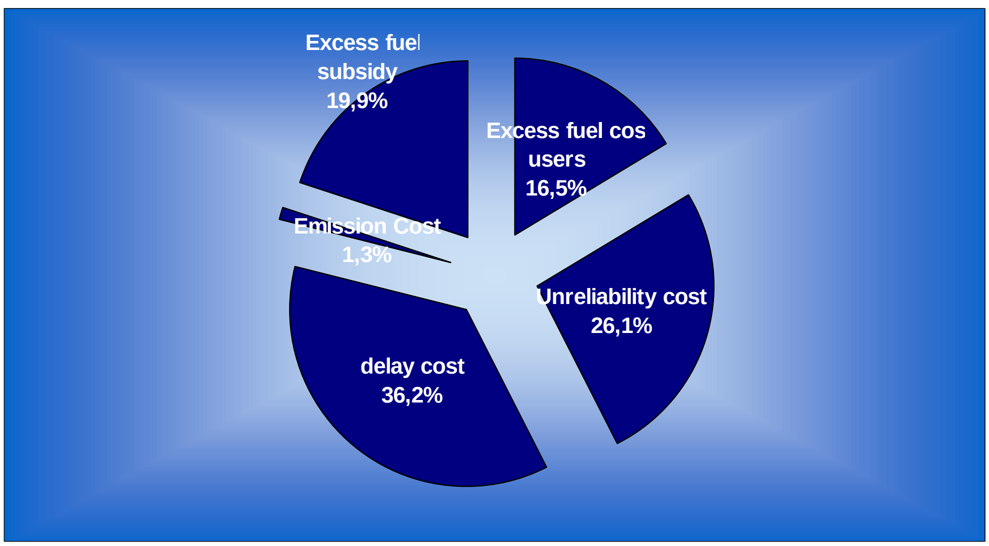


Figure 4.4 Distribution of total annual direct cost due to traffic congestion in GCMA (approach 2)

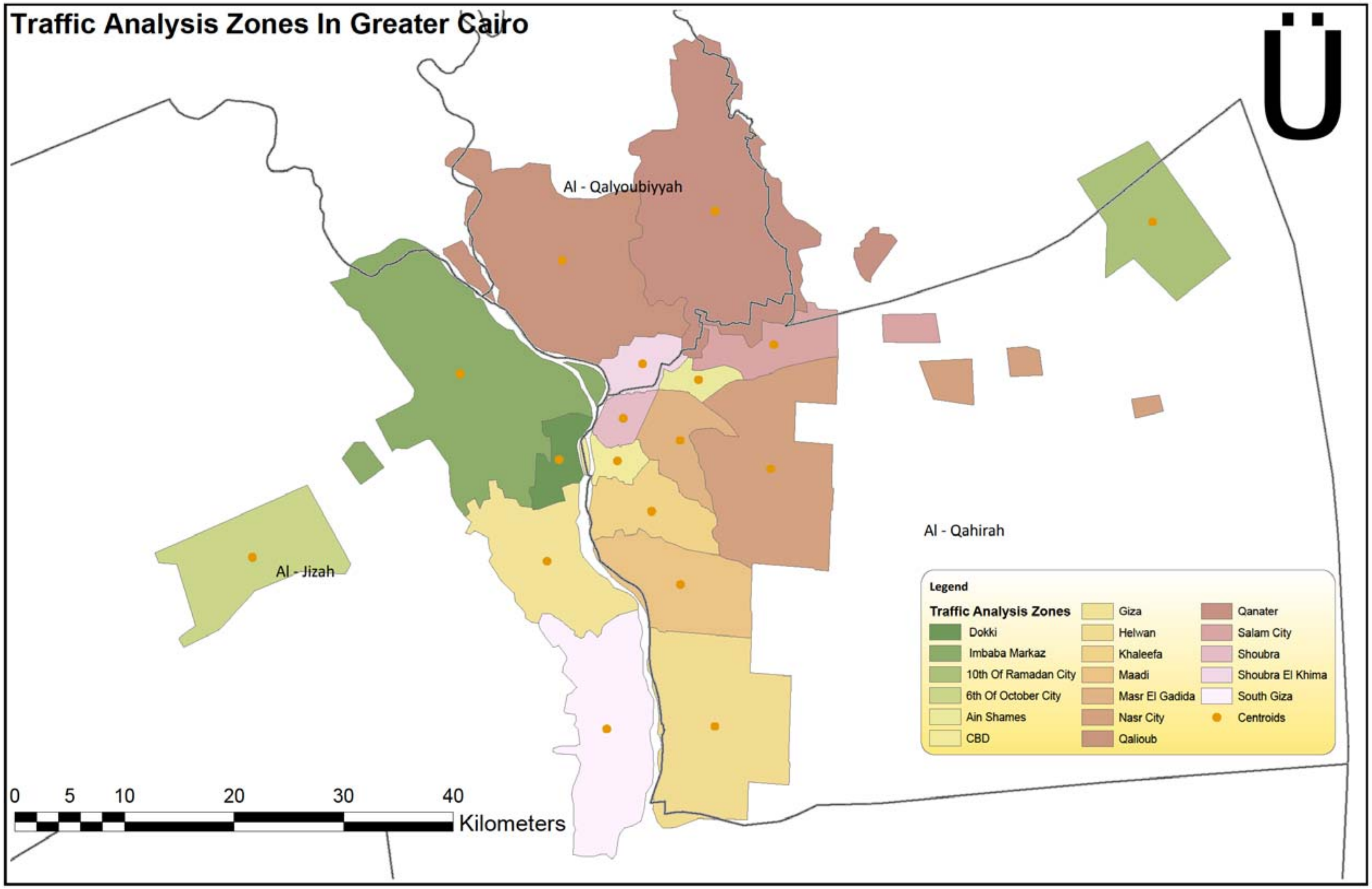
Based on the estimated figures the following conclusions are drawn:

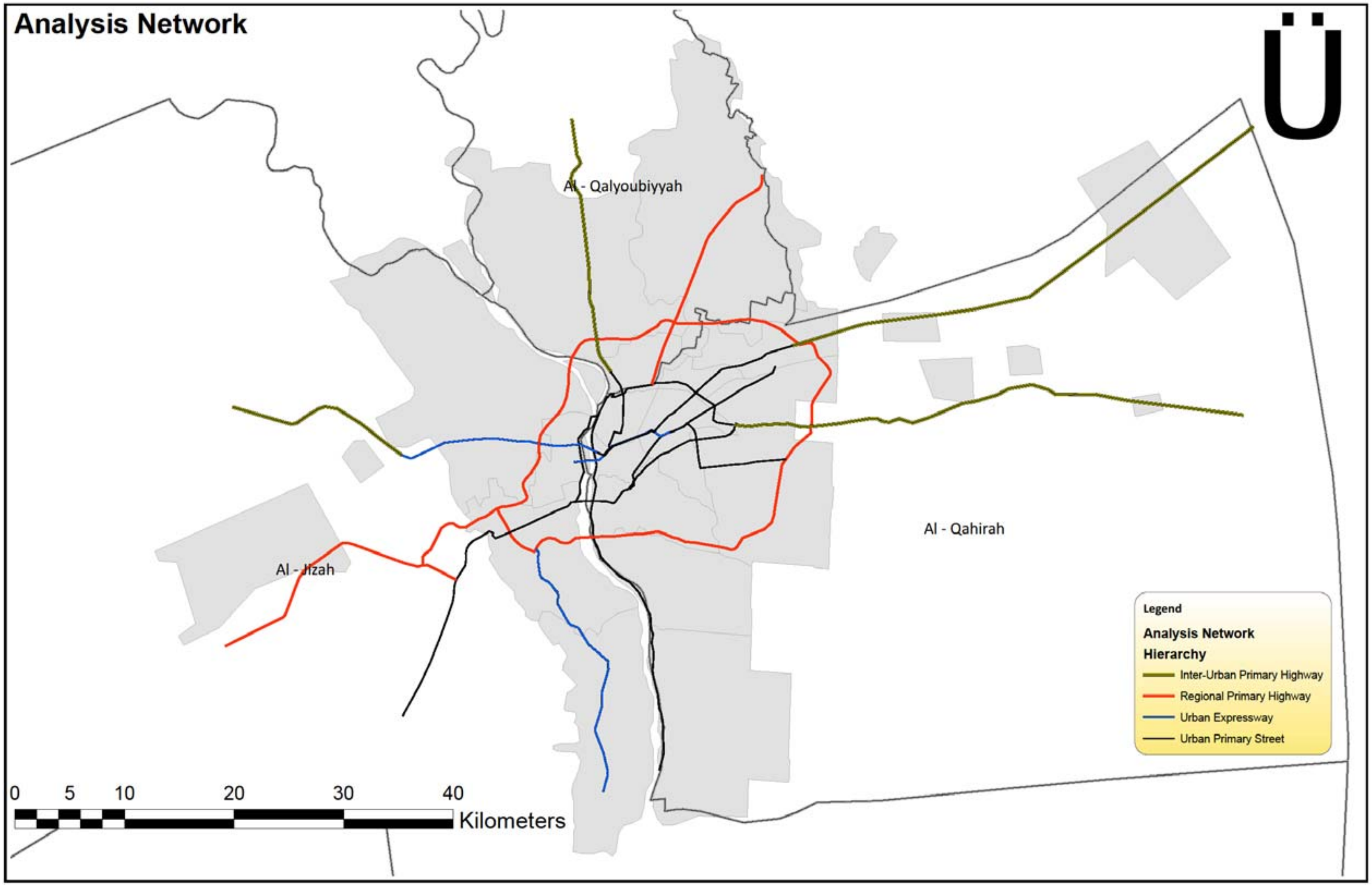
- The total annual direct congestion costs for GCMA is in the range from **13 to 14 billion LE.** This range is based on two approaches used: actual speed flow characteristics and calculated vehicle capacity ratios. The latter approach show higher values.
- The main contributor to the total direct cost is the delay costs (36%), which consist of recurrent and non-recurrent congestion costs. The non-recurrent delay costs represent approximately more than half of the total delay costs.
- The unreliability costs also represent a major part of total congestion costs (25%); though these costs are not as high as the total delay costs.
- The total share of the costs for excess fuel is 37% of total costs, of which half is paid by users (retail price of fuel) and the other half is additional costs to the Government (fuel subsidies).

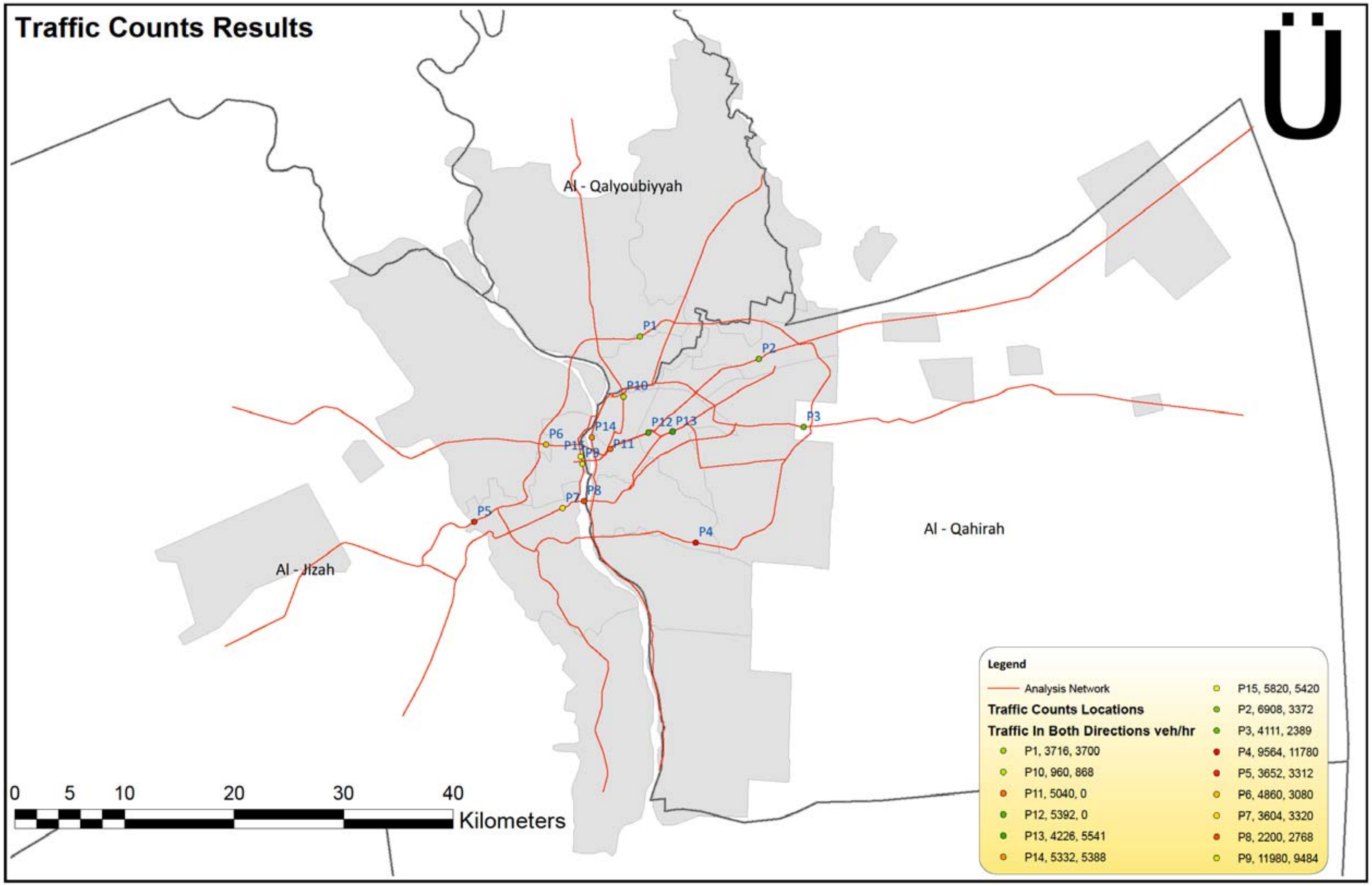
- The emission cost, which only consists of CO_2 emissions, is modest with a share of less than 1% of total costs.

An additional analysis has been carried comparing the traffic counts (2010 figures) and the Emme assigned traffic in

Tables 4.10, 4.11 4.12, and 4.13 summarize a comparison between traffic counts and EMME assignment results.


Traffic Analysis Zones In Greater Cairo
Al - Qalyoubiyyah
Al - Qahirah
Al - Jizah
Legend
Traffic Analysis Zones
Dokki
Imbaba Markaz
10th Of Ramadan City
6th Of October City
Ain Shames
CBD
Giza
Helwan
Khaleefa
Maadi
Masr El Gadida
Nasr City
Qalioub
Qanater
Salam City
Shoubra
Shoubra El Khima
South Giza
Centroids
0 5 10 20 30 40
Kilometers


Analysis Network
Ü
Al - Qalyoubiyyah
Al - Qahirah
Al - Jizah
Legend
Analysis Network Hierarchy
Inter-Urban Primary Highway
Regional Primary Highway
Urban Expressway
Urban Primary Street
0 5 10 20 30 40
Kilometers


Traffic Counts Results
Al - Qalyoubiyyah
Al - Qahirah
Al - Jizah
P1
P2
P3
P4
P5
P6
P7
P8
P9
P10
P11
P12
P13
P14
P15
0 5 10 20 30 40
Kilometers
Legend
Analysis Network
Traffic Counts Locations
Traffic In Both Directions veh/hr
P1, 3716, 3700
P10, 960, 868
P11, 5040, 0
P12, 5392, 0
P13, 4226, 5541
P14, 5332, 5388
P15, 5820, 5420
P2, 6908, 3372
P3, 4111, 2389
P4, 9564, 11780
P5, 3652, 3312
P6, 4860, 3080
P7, 3604, 3320
P8, 2200, 2768
P9, 11980, 9484

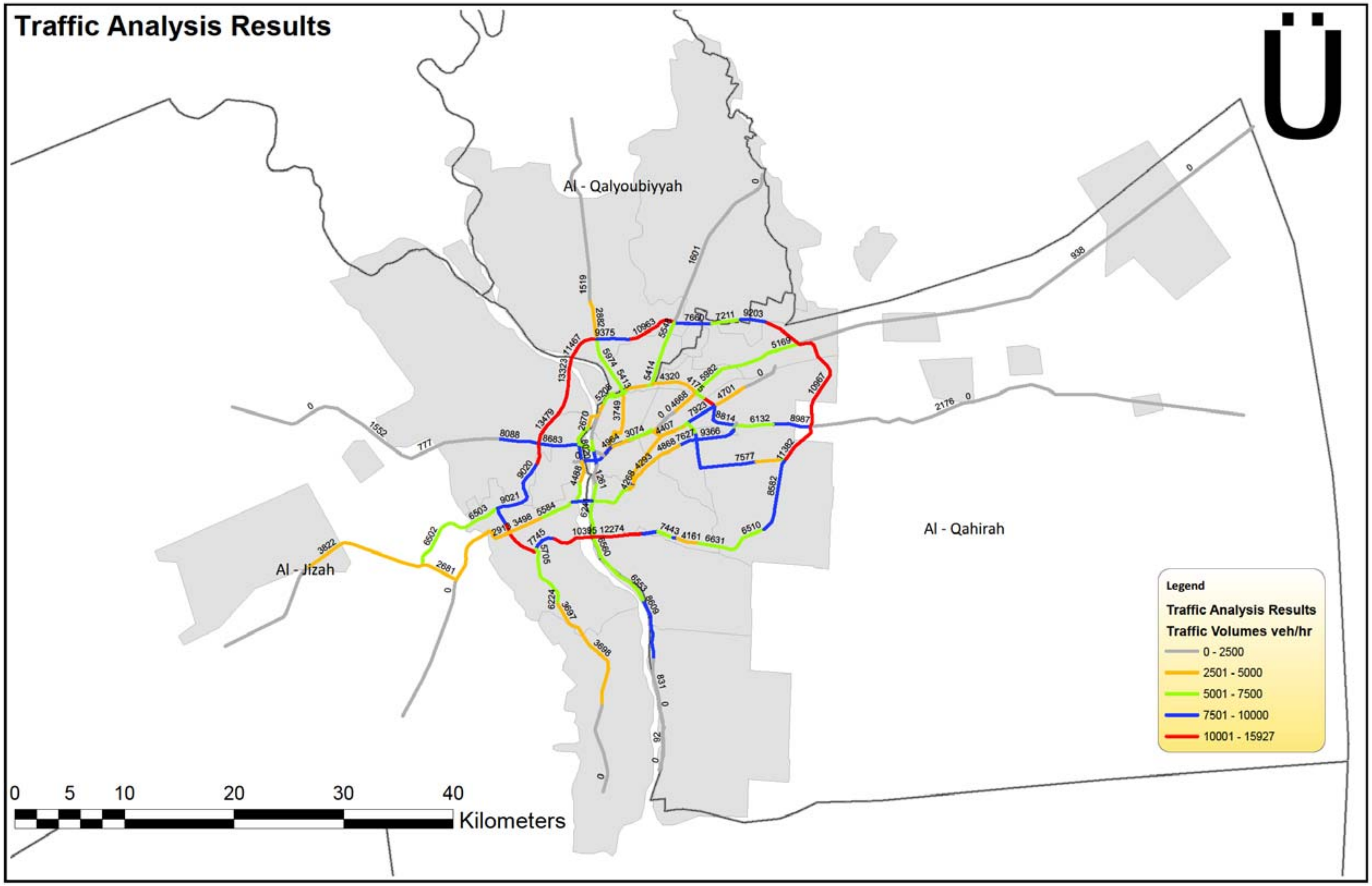

Traffic Analysis Results
Al - Qalyoubiyyah
Al - Qahirah
Al - Jizah
Legend
Traffic Analysis Results
Traffic Volumes veh/hr
0 - 2500
2501 - 5000
5001 - 7500
7501 - 10000
10001 - 15927
0 5 10 20 30 40
Kilometers

Table 4.10: Comparison Traffic Counts and Emme Assigned Traffic (vehicles/hour) (AM)

No	Road name	Traffic Count Direction 1 (v/h)	Traffic Count Direction 2 (v/h)	EMME Each direction
P1	Ring Road / Between El Khosoos & Cairo-Alex Agr.Rd	3299	3212	8879
P2	Gesr El-Suez/between Ring Road and Ainshams Str.	5708	2766	5169
P3	Suez Desert Road / Between KM 4.5 and Ring Road	3051	1890	8988
P4	Ring Road / Carfour Al Maadi	6969	6716	7543
P5	Ring Road / Above Cairo-Alex Desert Road	3418	2981	6502
P6	26th July / Between Railway and Ring Road	4389	2398	7587
P7	Al-Ahram Street / Electricity Station	2242	2813	5584
P8	Middle of Abbas Bridge	1512	2022	7800
P9	6 October Bridge between Zamalk and Agozah	7400	7154	9685
P10	Ahmed Helmy Str./ Before Abo Wafya Bridge	651	497	3749
P11	Ramses St. between Ghmara and Ahmed Said St. (One Way to Abasia)	4244		4964
P12	Lotifi Al Said St. between Abasia and Ghamrah (One Way to Ramses Square)	4093		4648
P13	Salah Salem Str./Between Elfangary and Abbasey	3873	3600	4575
P14	Cornish El-Nil /Between 15th May & El-Sahel Bridge	2535	4016	5982
P15	Gamal Abd El-Naser (El-Nile St.)/Kornish al Agouza	4058	3000	8020
		57.4	43.1	99.7

Table 4.11: Comparison Traffic Counts and Emme Assigned Traffic (ratio count/model) (AM)

No	Road name	Direction 1	Direction 2
P1	Ring Road / Between El Khosoos & Cairo-Alex Agr.Rd	0,37	0,36
P2	Gesr El-Suez/between Ring Road and Ainshams Str.	1,10	0,54
P3	Suez Desert Road / Between KM 4.5 and Ring Road	0,34	0,21
P4	Ring Road / Carfour Al Maadi	0,92	0,89
P5	Ring Road / Above Cairo-Alex Desert Road	0,53	0,46
P6	26th July / Between Railway and Ring Road	0,58	0,32
P7	Al-Ahram Street / Electricity Station	0,40	0,50
P8	Middle of Abbas Bridge	0,19	0,26
P9	6 October Bridge between Zamalk and Agozah	0,76	0,74
P10	Ahmed Helmy Str./ Before Abo Wafya Bridge	0,17	0,13
P11	Ramses St. between Ghmara and Ahmed Said St. (One Way to Abasia)	0,85	
P12	Lotifi Al Said St. between Abasia and Ghamrah (One Way to Ramses Square)	0,88	
P13	Salah Salem Str./Between Elfangary and Abbasey	0,85	0,79
P14	Cornish El-Nil /Between 15th May & El-Sahel Bridge	0,42	0,67
P15	Gamal Abd El-Naser (El-Nile St.)/Kornish al Agouza	0,51	0,37

Table 4.12: Comparison Traffic Counts and Emme Assigned Traffic (vehicles/hour) (PM)

No	Road name	Traffic Count Direction 1 (v/h)	Traffic Count Direction 2 (v/h)	EMME Each direction
P1	Ring Road / Between El Khosoos & Cairo-Alex Agr.Rd	2968	2985	8879
P2	Gesr El-Suez/between Ring Road and Ainshams Str.	5532	2821	5169
P3	Suez Desert Road / Between KM 4.5 and Ring Road	3996	2009	8988
P4	Ring Road / Carfour Al Maadi	7821	9605	7543
P5	Ring Road / Above Cairo-Alex Desert Road	2765	2958	6502
P6	26th July / Between Railway and Ring Road	3323	2499	7587
P7	Al-Ahram Street / Electricity Station	3267	2318	5584
P8	Middle of Abbas Bridge	1765	2464	7800
P9	6 October Bridge between Zamalk and Agozah	5695	3197	9685
P10	Ahmed Helmy Str./ Before Abo Wafya Bridge	606	726	3749
P11	Ramses St. between Ghmara and Ahmed Said St. (One Way to Abasia)	4448		4964
P12	Lotifi Al Said St. between Abasia and Ghamrah (One Way to Ramses Square)	4111		4648
P13	Salah Salem Str./Between Elfangary and Abbasey	3773	5454	4575
P14	Cornish El-Nil /Between 15th May & El-Sahel Bridge	3460	3249	5982
P15	Gamal Abd El-Naser (El-Nile St.)/Kornish al Agouza	3513	4192	8020
		57.043	44.447	99.675

Based on the traffic counts, the total number of vehicles in peak hours in the eleven corridors is estimated around 605.000 PCU per morning and evening peak hours. Similarly, the total number of vehicles in peak hours in the entire GCMA is approximated to 1.210.000 PCU per morning and evening peak hours.

Given the figures above, the total direct cost of traffic congestion for the entire GCMA is estimated as follows:

Table 4.13: Comparison Traffic Counts and Emme Assigned Traffic (ratio count/model) (PM)

No	Road name	Direction 1	Direction 2
P1	Ring Road / Between El Khosoos & Cairo-Alex Agr.Rd	0,33	0,34
P2	Gesr El-Suez/between Ring Road and Ainshams Str.	1,07	0,55
P3	Suez Desert Road / Between KM 4.5 and Ring Road	0,44	0,22
P4	Ring Road / Carfour Al Maadi	1,04	1,27
P5	Ring Road / Above Cairo-Alex Desert Road	0,43	0,45
P6	26th July / Between Railway and Ring Road	0,44	0,33
P7	Al-Ahram Street / Electricity Station	0,59	0,42
P8	Middle of Abbas Bridge	0,23	0,32
P9	6 October Bridge between Zamalk and Agozah	0,59	0,33
P10	Ahmed Helmy Str./ Before Abo Wafya Bridge	0,16	0,19
P11	Ramses St. between Ghmara and Ahmed Said St. (One Way to Abasia)	0,90	
P12	Lotifi Al Said St. between Abasia and Ghamrah (One Way to Ramses Square)	0,88	
P13	Salah Salem Str./Between Elfangary and Abbasey	0,82	1,19
P14	Cornish El-Nil /Between 15th May & El-Sahel Bridge	0,58	0,54
P15	Gamal Abd El-Naser (El-Nile St.)/Kornish al Agouza	0,44	0,52

As the results show, there is a major difference between traffic counts and the Emme model in most of the count stations. It is recommended to further analyse these differences before using the present model for transport planning purposes.

4.10 Breakdown of Traffic Congestion costs

Tables 4.14 and 4.15 outline congestion costs breakdown for the entire GCMA for the flowing vehicular modes:

- Passenger cars
- Transit (incl. Taxi, Microbus, Minibus, Bus)
- Freight transport

As the results show, the share of passenger cars in traffic congestion costs is the highest (56%). Public transport also contributes significantly in traffic congestion costs (41%). The share of freight transportation is the lowest (7 %).

Table 4.8:Breakdown of traffic congestion costs for the entire GCMA (Approach 1)

GCMA		Excess Fuel cost users	Reliability cost	Delay cost	Emission Cost	Fuel Subsidy	Total cost
Vehicular mode	Passenger Car	1.554.736.357	1.532.168.985	2.827.446.364	124.543.284	1.900.233.325	7.939.128.316
	Transit	711.745.492	1.857.479.502	2.251.811.697	56.433.676	852.863.972	5.730.334.339
	Freight	148.912.175	27.061.318	156.030.239	13.621.922	148.912.175	494.537.828

Table 4.9:Breakdown of traffic congestion costs for the entire GCMA (Approach 2):

GCMA		Excess Fuel cost users	Reliability cost	Delay cost	Emission Cost	Fuel Subsidy	Total cost
Vehicular mode	Passenger Car	1.412.431.994	1.532.168.985	2.559.609.174	111.121.818	1.726.305.771	7.341.637.743
	Transit	637.997.790	1.857.479.502	2.043.672.258	50.352.074	766.199.755	5.355.701.378
	Freight	118.584.427	27.061.318	131.491.781	12.153.949	118.584.427	407.875.903

4.11 Zonal Based Direct Economic Cost of Traffic Congestion

In this section the distribution of congestion cost to traffic zones is dealt with. In order to determine direct economic cost in a disaggregate level for each zone of GCMA; the consultant considers the following factors for each zone:

- Geographic size
- Local road types
- Traffic network types
- Number of available lanes in the traffic network
- Land use

Figure 4.5 illustrates local road types in GCMA. Local road types are divided into 3 classes:

- Dual Carriage Road
- Main Paved Road
- Secondary Paved Road

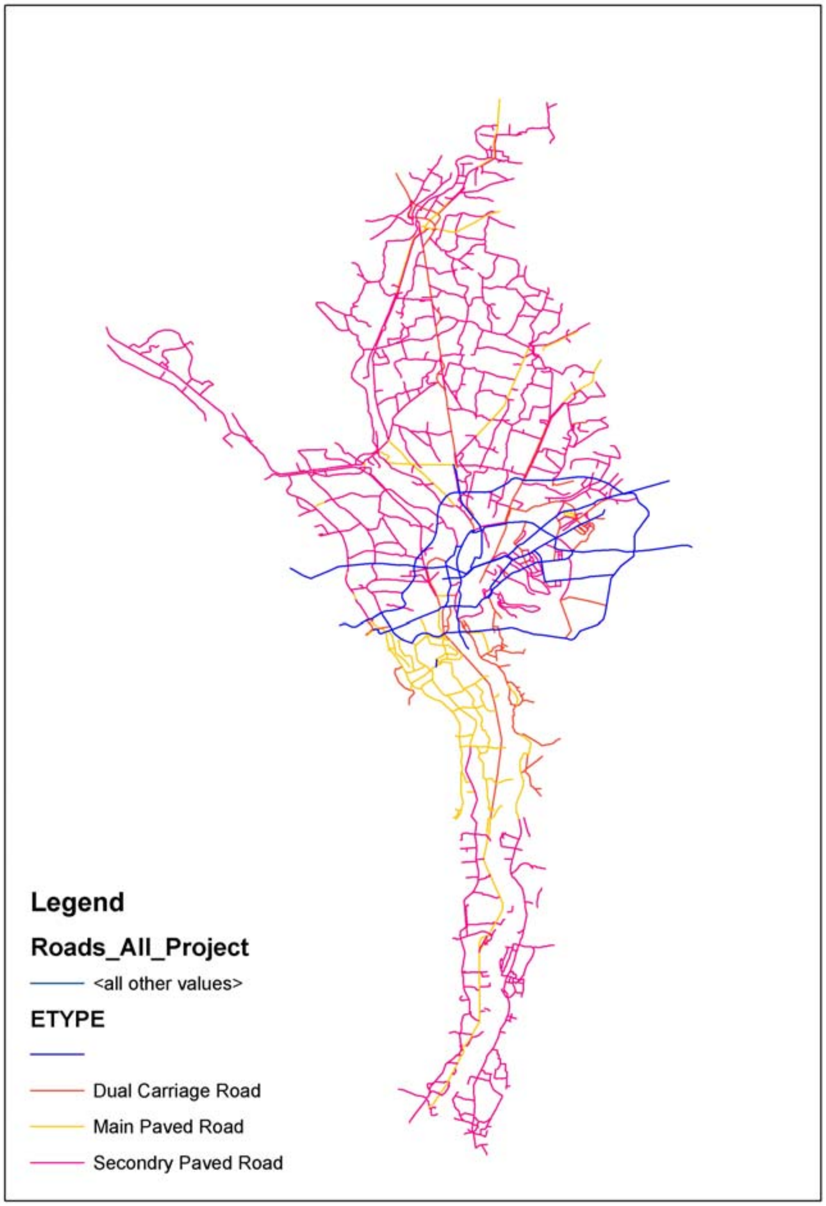


Figure 4.5 Local road types in GCMA

As is shown, most of the local roads in the suburban area belong to dual carriage road class with one lane available capacity in each direction. Excluding interzonal trips that are normally made via local network, it is not expected that main traffic between zones use such local roads.

Figure 4.6 illustrates traffic network types in the entire GCMA. The network consists of 5 road types as follows:

- Inter- Urban Primary Highway
- Regional Primary Highway

- Urban Expressway
- Urban Primary Street
- Other

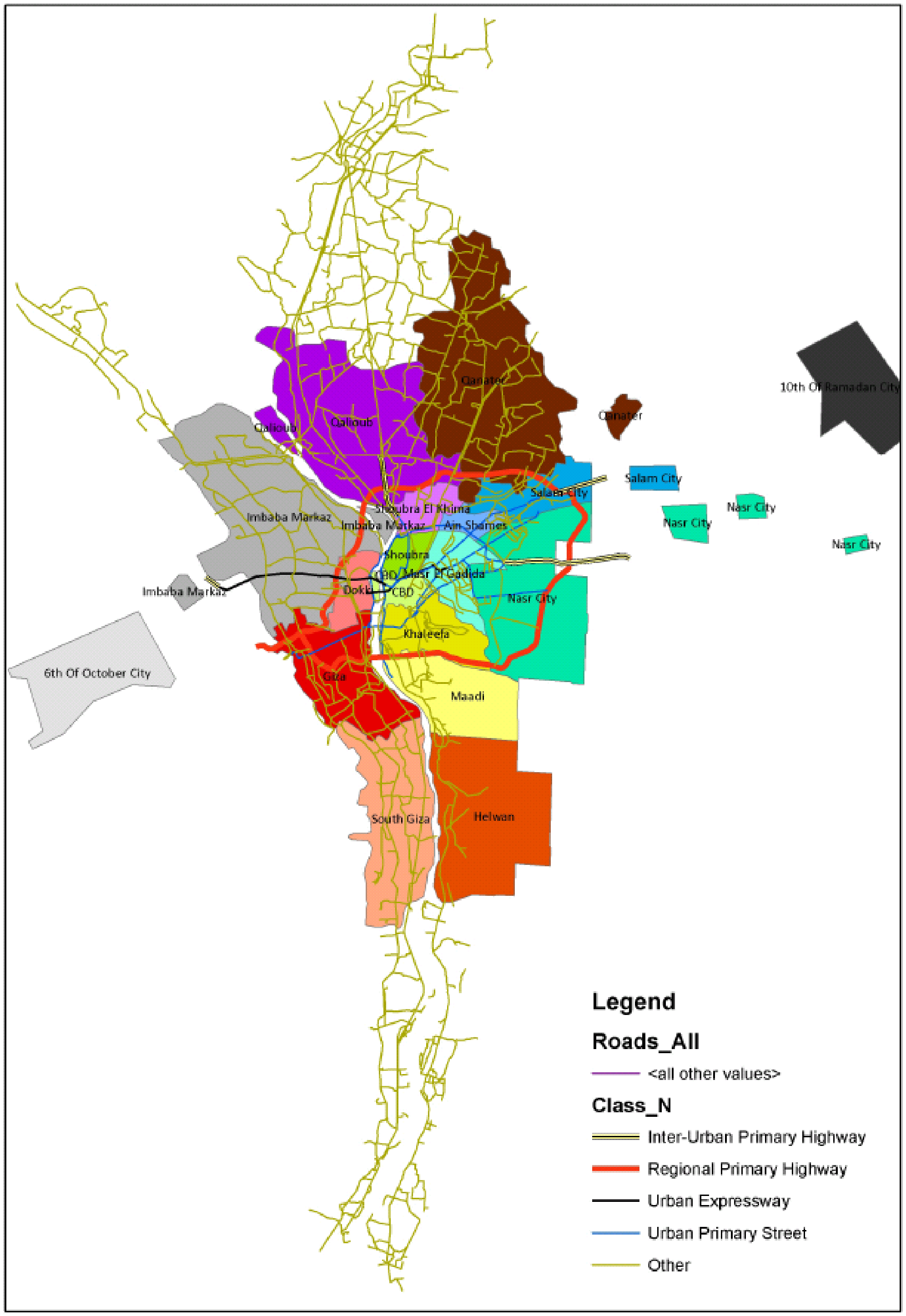


Figure 4.6 **Traffic Network types in GCMA**

Table 4.16 outlines GCMA zones existing network types:

Table 4.10: GCMA zones network types

Zone	InterUrban Primary Highway	Regional Primary Highway	Urban Expressway	Urban Primary Street	Local
South Giza					
Helwan					
10th of Ramadan					
6th of October					
Giza					
Imbaba Markaz					
Maadi					
Khaleefa					
Dokki					
CBD					
Shoubra					
Nasr City					
Ain Shams					
Masr Al Gadida					
Salam City					
Shoubra El Khima					
Qanater					
Qalioub					

Figure 4.7 illustrates the number of lanes in the main corridors of the region.

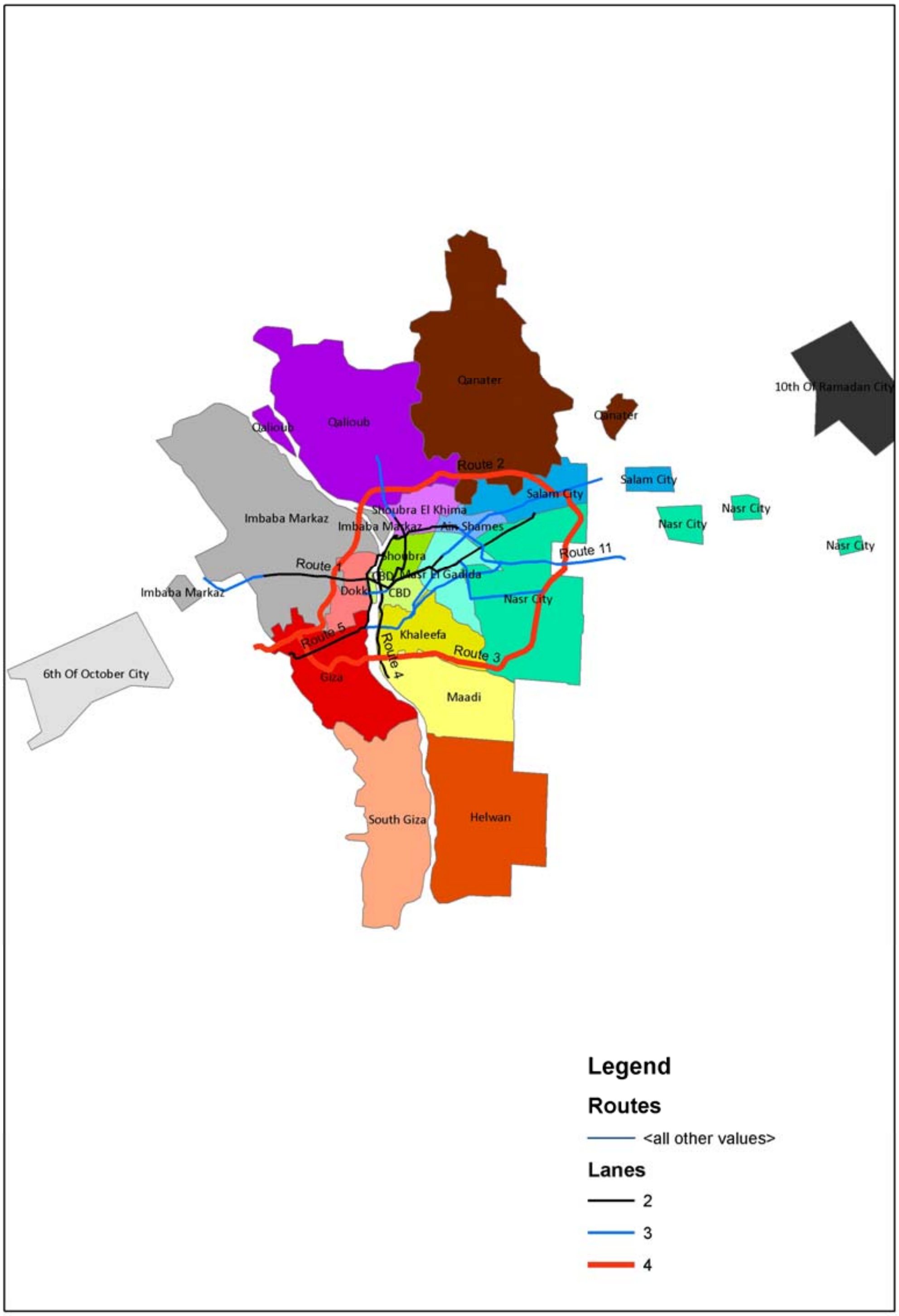


Figure 4.7 Number of Lanes in Main corridors of GCMA

As it is shown in the most of regions, especially suburbs, local roads having one lane in each direction are predominant. Although the ring road contains 4 lanes, the number of lanes in other main corridors is commonly limited to 3, or even 2.

Figure 4.8 illustrates the land use as well as network classes in the entire GCMA. Agriculture is the predominant land use in the most of the region especially in the suburbs.

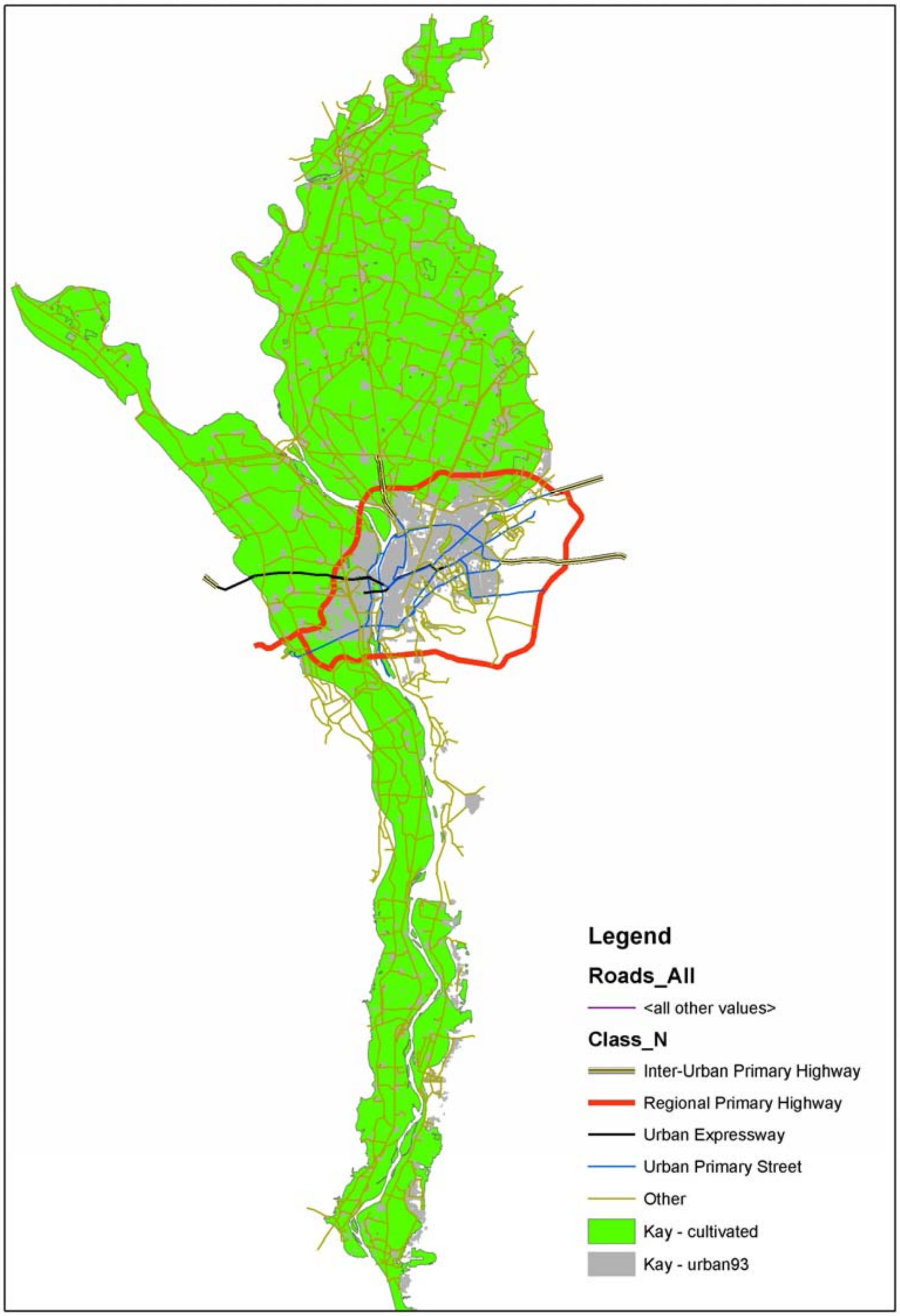


Figure 4.8 Land use and Network classes in the GCMA

Table 4.17 outlines the land use of GCMA zones.

Table 4.11: Predominant Land Use of GCMA

Zone	Agriculture	Urbanized
South Giza		
Helwan		
Giza		
Imbaba Markaz		
Maadi		
Khaleefa		
Dokki		
CBD		
Shoubra		
Nasr City		
Ain Shams		
Masr Al Gadida		
Salam City		
Shoubra El Khima		
Qanater		
Qalioub		

In order to calculate the share of each traffic zone of total direct economic of traffic congestion the aforementioned information are used by the consultant. The following factors are used to determine the share of each traffic zone from congestion:

- Number of originated and attracted trips from the adjusted OD matrix from JICA for 2010 *as proxy for traffic flow*
- Network type(s) *as proxy for design road capacity and free flow speed*
- Number of trips per lane-kilometer *as proxy for actual road capacity and average speed*
- Land Use *as proxy for level of congestion*
- The Network length

The congestion costs in the eleven corridors cover the following zones: Salam City, Nasr City, Khaleefa, Giza, Dokki, CBD, Masr El Gadida, Shoubra, Shoubra El Khima, Part of Imbaba Markaz and Ain Shams.

The share of each aforementioned zone based on the trip production/attraction, the network type and the network capacity are approximated (table 4.18).

Table 4.12: Traffic congestion cost in traffic zones in the GCMA

District	Share of Congestion (%)	Congestion cost Million LE(approach 1)	Congestion cost Million LE (approach 2)
Ain Shams	3.4	237.9	220.1
CBD	5.8	410.5	379.8
Dokki	8.3	592.0	547.8
Giza	14.7	1,043.4	965.5
Khaleefa	7.5	530.1	490.5
Masr El Gadid	19.0	1,345.3	1,244.8

Nasr City	23.6	1,675.8	1,550.7
East side Imbaba Markaz	6.2	443.1	410.0
Salam City	3.8	270.3	250.1
Shoubra	5.5	389.5	360.5
Shoubra El Khima	2.2	156.0	144.3
Total	100.0	7,094.1	6,564.4

Similarly, the method is applied for suburban areas. Table 4.19 summarizes the congestion costs for traffic zones located in the suburbs.

Table 4.13: Traffic congestion cost in suburban traffic zones in the GCMA

District	Share of Congestion (%)	Congestion cost Million LE(approach 1)	Congestion cost Million LE (approach 2)
10th of Ramadan	6.3	445.6	412.3
6th of October	8.5	600.0	555.2
Helwan	3.0	213.0	197.1
Imbaba Markaz	13.2	934.1	864.4
Maadi	13.5	957.7	886.2
Qalioub	22.8	1617.1	1496.4
Qanater	24.5	1737.8	1608.0
South Giza	8.3	588.7	544.8
Total	100.0	7,094.1	6,564.4

4.12 Reflection of the Applied Methodology

The calculation method applied, which to a large degree is based on the TTI method, has provided a sound basis for the direct congestion costs for GCMA within the available data and information. The method has been extended using two different approaches, which provide comparable results for the overall direct costs. The method is replicable and justifiable, though the calculation method can be enhanced in future to yield more accurate results. The following issues could be elaborated:

Fuel efficiency calculation

The fuel efficiency calculation based on a linear regression model which has been developed for the US in line with American car standards and existing fuel octane in US. Thus, the formulation needs to be adjusted for the Cairo region based on fleet ages, composition, vehicle motor standards and efficiency, and widely used fuel octane.

Reliability indicator

The consultant uses the standard deviation and thus coefficient of variation (COV) as the measure for travel time reliability. For a more accurate measure, the buffer index could be chosen as well, because it relates to the reliability of an individual vehicle trip. The travel rates used in this calculation can be derived from average speed readings and the length of a route. This measure will help determining the impact of congestion on one vehicle traveling on a segment of roadway during a specific time period.

The buffer index represents the reliability of travel rates associated with single vehicles. This measure may be beneficial to the public because it tells them how congestion will affect them as individuals. For example a buffer index of 40% means that a traveler should budget an additional 8 minute buffer for a 20 minute average peak travel time to ensure on time arrival “most” of the time (where “most” is defined as 95% of the time).

However, it should be noted that in practice the buffer time varies across the users because of each user’s individual experiences with variability and because of each user’s individual requirement for arriving at the destination on time.

To summarize, the consultant believes buffer time related indicators such as the Buffer Time Index and Planning Time Index are appropriate monitors to describe and communicate travel time reliability to planners as well as users. Other more simple measures such as travel time percentiles, median travel times and the standard deviation of travel time may also serve as appropriate indicators, but they should be used with caution, as relevant characteristics of the travel time distributions could be easily overlooked. For instance, using the standard deviation of travel time as a utility component in route choice may results in biased outcomes.

To estimate the unreliability associated cost for the entire network, using the standard deviation of travel time seems to be accurate enough since the indicator does not need to express traveler’s behavior facing travel time unreliability.

In other words, applying a buffer time indicator (e.g. the buffer time index) is essential when transport planners particularly deal with the way in which travelers make their decision (mode choice, route choice, and departure time choice).

Monetizing unreliability

When unreliability is measured as the standard deviation of travel time, data for the valuation of the standard deviation should be obtained through a stated preference survey by including a representation of the variance and the mean travel time as attributes. Thus, a utility function is specified that includes the mean journey duration as well as the standard deviation of the journey duration. Parameters for both variables are estimated usually on the stated preference data.

The ratio of coefficient for the standard deviation to the coefficient for the mean travel time can be calculated. This gives the disutility of a minute standard deviation of travel time in terms of minutes of mean travel time. A monetary value for unreliability can be derived by combining this with a value of time.

Given the lack of stated preference survey, the consultant used quantitative results on value of reliability in passenger transport from European studies carried out in recent years. Regarding the potential differences in trip patterns, peak hours, commuting trips between EU countries and Egypt, estimation of unreliability associated costs would be more precise if a SP survey performed in the region to derive a monetary value of 1 minute standard deviation of travel time in the Cairo Region.

Coverage of the entire GCMA

The methodology that was applied to estimate the direct economic cost of traffic congestion is based on several assumptions that impact accuracy. Therefore, the consultant believes in order to gain an accurate estimation of traffic congestion cost in the GCMA, a complete and detailed transport network is needed, socio economic information is needed, an effective transport model in a commonly used transport software should be developed, and finally Stated Preference survey to derive reliability perception need to be carried out.

The systematic procedure that the consultant recommends to obtain more accurate results consists of the following steps:

- Trip generation is estimated based on existing land use. Thus, a comprehensive socio-economic data are required.
- The detailed transport, as well as transit networks should be designed in ARC GIS based software (e.g. Map Info) and then linked to commercial softwares such as Emme, TransCad, or Visum.
- Design as well as actual transport and transit network specifications including, speed, length, number of lanes, types of right of way, on site parking places, bus and micro bus stops, signal setting at intersection, etc are determined and implemented into the model.
- Travel time functions (e.g. adapted BPR function) should be allocated to the network depending on road type. For the links suffering from incidental delays, BPR functions should be adjusted accordingly.
- TTI or FHWA recurrent as well as nonrecurring delay functions, reliability indicators, the fuel efficiency function, and the air emission function are applied to the model to estimate delay costs, unreliability costs, excess fuel cost, excess fuel subsidy, and emission cost.
- The four steps of the classical urban transportation planning system model consisting: Trip generation, Trip Distribution, Mode Choice, Route Assignment are done by running commercial packages such as Emme, TransCad, or Visum.
- Given outputs, several sensitivity analyses are carried out in order to test the accuracy of the model.
- The most accurate outputs are chosen as the reliable result.