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Cairo Traffic Congestion Study

Final Report

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Acknowledgments

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1.0Introduction

The total population of Egypt increased from 63 million in 1996 to 85 million, in 2011. The Greater Cairo Metropolitan Area (GCMA) plays host to a large share of Egypt's population, economy, industry, and human resources. With a population of 17 million in 2006 (expected to reach 24 million in 2027), and a fast rate of urbanization, the GCMA is one of the largest mega cities in the World and is Egypt's largest agglomeration (22 percent of Egypt's population).

Traffic congestion is a serious problem in the Cairo metropolitan area with large adverse effects on both the quality of life and the economy of the GCMA. The causes of traffic congestion are complex, as are the range of possible policies and investments that could be arrayed to address the problem. In the GCMA, roughly two thirds of all motorized trips are made by public transport (mostly taxis and minibuses), and there are therefore significant opportunities for reducing congestion by promoting, for example, mass transit systems.

The government's vision for transforming the urban transport sector in GCMA is reflected in the Greater Cairo Urban Transport Master Plan. The implementation of plans for reducing traffic congestion in the GCMA has been slower than expected and traffic has increased faster than projected, primarily due to increased motorization rates that seem to go hand in hand with rising incomes and urbanization.

There is increasing concern that if left unaddressed, the already large and negative impacts of traffic congestion on both the quality of life and the economy in the GCMA, will increase further. Thus, there is a pressing need to find effective and feasible solutions for the traffic congestion problems in the GCMA. This study focuses on finding such effective and feasible solutions.

PURPOSE OF THIS STUDY

The Cairo Cost of Congestion Study Phase 2 is the second part of a two-phase study to evaluate the costs and causes of congestion in the Greater Cairo Metropolitan Area (GCMA). Phase 1 estimated the direct costs of congestion for major corridors in the GCMA (see Figure 1.1) and identified the causes, types, and locations of congestion. The direct costs were defined to include the costs from traffic delays, the lack of reliability of travel times, excess fuel use, and CO2 emissions from vehicles.

The objectives in Phase 2 were to:

1. Refine the direct costs of congestion that were estimated in Phase 1;
2. Estimate the indirect costs of congestion; and

3. Develop a set of policy recommendations for addressing the problem of congestion in the GCMA.

The Phase 1 estimates were based on data gathered for the major corridors. This data was extrapolated to the complete network. However, one concern about the extrapolation and resulting estimates was that they underestimated congestion on roads other than "major" corridors. In Phase 1, the average speeds for the 11 major corridors, all of which are within the area contained by the Ring Road, were estimated to be between 20 to 45 kph. On the Ring Road itself, the speeds were higher, between 50 to 60 kph. Average speeds on other routes of lower functional classification tend to be lower, however, resulting in a likely underestimate of the magnitude of congestion in the GCMA.

Thus, Phase 2 refines the estimates from by:

1. Collecting additional count data for an expanded network that includes local roads, roads that are not part of the "major" corridors, and
2. Doing a floating car survey to collect additional data on speeds on local roads
3. Using GIS data indicating the type of road and the number of available lanes.

In Phase 2 as in Phase 1, the refined direct costs were defined as the costs from traffic delays, the lack of reliability of travel times, excess fuel use, and CO2 emissions from vehicles. The indirect costs of congestion are defined to include safety, vehicle operating costs, emissions other than CO2, effect on the demand and supply of housing, and agglomeration effects. CO2[1] is often grouped with indirect costs and vehicle operating costs are often grouped with direct costs, but this approach was maintained for comparability with the Phase 1 study[2]. These indirect costs were quantified to the extent possible. In addition to estimating the indirect costs, we also compared the magnitude of these indirect costs to our estimates from other regions.

Finally, a large number of potential policy measures are explored for their suitability and effectiveness in addressing the traffic congestion problems in the GCMA. The initial list of policy measures was developed based on what has been done elsewhere in the world and by interviewing relevant stakeholders familiar with the traffic conditions and problems in the GCMA. The list of policy

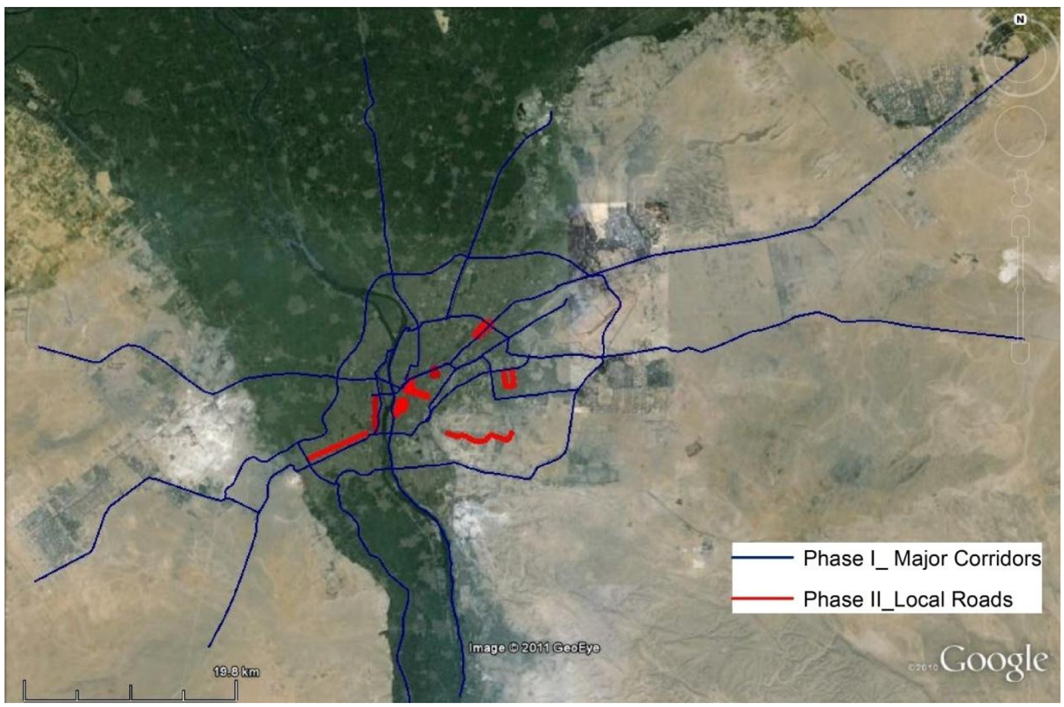
[1] CO2 usually are referred to in economic literature as indirect costs. However given the particular interest for climate change, it had to be done as early as phase 1, hence it appears in the table and analysis of direct costs.

[2] Vehicle Operating Costs are usually part of Direct Costs. However for practical reasons of data collection, it was estimated in Phase 2 with indirect costs, hence it appears in the tables and analysis of indirect costs.

options includes both "soft" measures (for example, enforcement) and "hard" measures (new transport infrastructure). The suitability and effectiveness of the policy measures is evaluated using the model developed for this purpose in Phase 2, by soliciting the opinion of local experts, and considering the experience with using these policy measures in other parts of the world. The performance of the policy measures is evaluated on a number of criteria, and one of these criteria is the feasibility of implementation of the measure in the GCMA.

Based on the evaluation of measures, this study develops policy packages, combinations of policy measures, and recommendations for implementing these measures.

Figure 1.1 Phase 1 Major Corridors and Phase 2 Expanded Network Data Collection



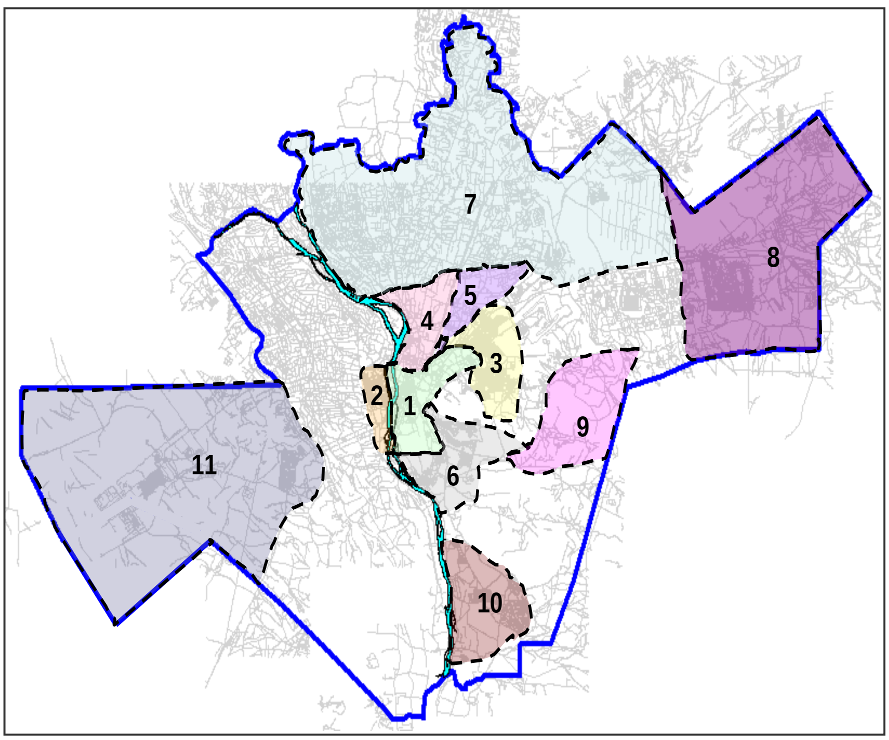
STUDY AREA

The study area in Phase 2 is unchanged from the study area in Phase 1. The GCMA includes the governorates of Cairo, Giza and Qalyobiyain, in addition to the new cities of New Cairo City, 6th of October City, 15th May City, 10th of Ramadan City, El-Obour City and Badr City. It is consistent with the study area defined by the Greater Cairo Urban Transport Master Plan (CREATS) funded by JICA. (This study is referred to as the "JICA Study" in the remainder of this report.)

In administrative terms, the Study Area covers 11 districts identified by the JICA Study, namely (see Figure 1.2):

1. Central Cairo;
2. Central Giza;
3. Heliopolis/Nasr City;
4. Shoubra/Shoubra El Kheima;
5. Mataryia;
6. Maadi/Qatamiya Road;
7. Shibin El Qanater/El Obour;
8. 10th of Ramadan/Badr/El Shorook;
9. New Cairo;
10. Helwan/15th of May; and
11. 6th of October/El Sheikh Zayed.

Figure 1.2 GCMA Major Districts



Source: JICA, CREATS, 2003.

SUMMARY OF PHASE 1 RESULTS

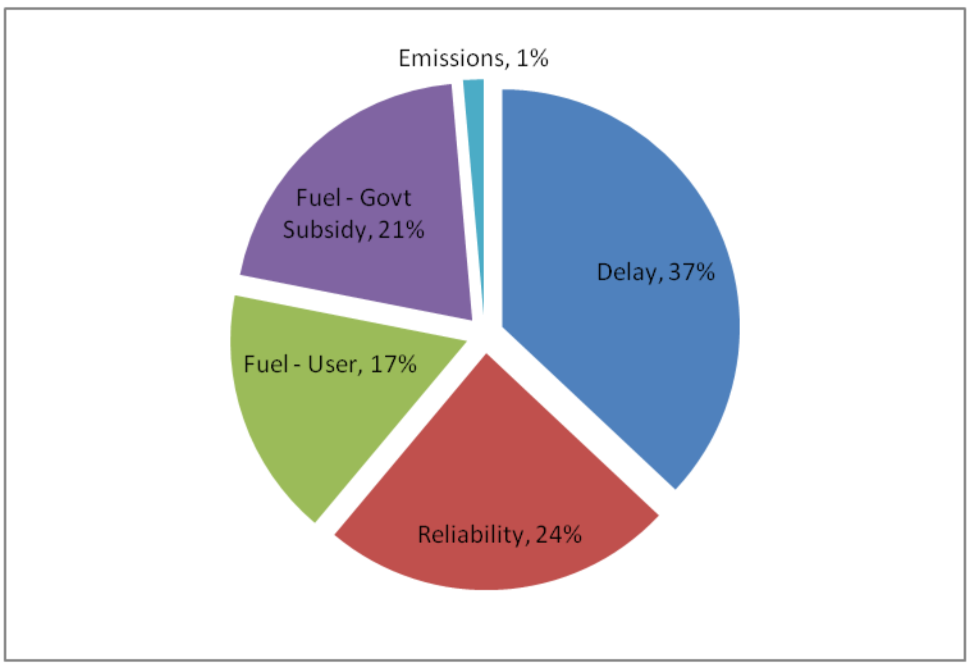
Phase 1 estimated only the direct costs of congestion. These direct costs, based only on data for the major routes, were estimated at 14 billion Egyptian pounds (LE), equivalent to about U.S.$2.5 billion, or 1.4 percent of Egypt's gross domestic product (GDP). The breakdown of direct costs among four components is shown in Figure 1.3 and includes the costs of:

1. Delays for both passengers and freight;
2. Travel time unreliability in passenger transportation;
3. Excess fuel consumption in vehicular transportation (diesel and gasoline);
4. Carbon dioxide (CO_2) emissions due to excess fuel consumption; and
5. The costs of the fuel subsidy.

Phase 1 also identified the major causes of congestion in the GCMA, these included:

- Lack of traffic management and control;
- Poor design features of the road network;
- Lack of observing the law (e.g., illegal parking), aggressive driving behavior and lack of enforcement;
- Numerous and unpredictable traffic influencing events (e.g., security checks and vehicle breakdowns);
- Numerous construction work zones;
- Few alternatives to the private car; and
- Lack of coordination between land use and transportation planning.

Figure 1.3 Distribution of Phase 1 Direct Costs



Structure of the Report

Section 2.0 describes traffic patterns in the GCMA by interpreting the data collected as part of Phase 2 as well as Phase 1. Section 3.0 describes the development and use of the travel demand model for this study. Sections 4.0 and 5.0 use the model and the data from Section 2.0 to estimate the current and future direct and indirect costs of congestion in the GCMA. Section 6.0 summarizes these costs and compares them to other regions. Section 7.0 summarizes the stakeholder outreach conducted as part of this study. Section 8.0 identifies the policy strategies and evaluation methodology, which are summarized in an implementation strategy in Section 9.0.

2.0Traffic Patterns in GCMA

INTRODUCTION

In this section, we present a picture of traffic patterns in the GCMA. This picture is based on the collected in Phase 1 of this study, and the data collection effort in Phase 2. The data collection effort in Phase 2 essentially expands the network for which data is collected beyond the 11 major corridors to surface streets, supplements the speed data with data collected from a floating car survey, and adds details about capacity of the road network. The data collected includes data on travel times, traffic volumes, roadway characteristics, and potential causes of congestion

By improving and adding to the data that was collected in Phase 1 of this study, we are able to provide more reliable and accurate estimates of congestion and its costs in the GCMA. The improved data also helps to support a better analysis of the performance of policy measures designed to mitigate congestion

APPROACH

Sample Selection

The 11 corridors surveyed during Phase 1 of the study represented four functional classifications of roads, namely:

- Interurban primary arterial highway;
- Regional primary arterial highway;
- Urban expressway; and
- Urban primary arterial street.

In Phase 2 we expanded the data collection to cover surface city streets, called "other" routes. These other routes were classified into three categories, namely:

- Urban Secondary Arterial;
- Collector/Distributor Street; and
- Local Street.

Furthermore, in Phase 1, the focus of the data collection was on the area within the ring road, and the main corridors linking the peripheral cities to the area within the ring road (see Appendix A for the corridors included in the study).

In Phase 2, we chose sample segments from other routes to cover the three classifications of "other" routes so as to provide a more representative sample of the city street network. The sample of other routes was chosen to:

- Be geographically representative of Central, East and West Cairo;
- Cover congested areas within GCMA characterized by different land uses, such as high-density residential areas, mixed-use areas with residential, offices, industrial, commercial, and retail facilities;
- Include areas where academic and government offices buildings are located;
- Include major attractions, such as universities, sports clubs, malls, and mosques;
- Include areas experiencing severe congestion during peak periods (such as universities and schools) and off-peak periods (such as clubs and malls);
- Include areas along public transport routes; and
- Cover a varied topographical landscape.

The sample of other roads in Phase 2 does not include any routes in new urban communities since these areas are less densely populated than older communities in the GCMA and as a rule have better designed road networks. However, the roads leading to these new urban communities are often congested, for example, the Ismailia Desert Road in the East Region and 26th of July Corridor in the West Region (these corridors were covered in Phase 1).

Figure 2.1 depicts the sample of other roads in the GCMA that were covered by the data collection in Phase 2. Figure 2.2 shows the major corridors from Phase 1 together with the other roads covered in Phase 2.

Among the eight other routes that were selected in Phase 2, three are located in East Cairo, two in West Cairo, and three in Central Cairo. Appendix B lists the sample of other routes; their locations, lengths, and relevant characteristics. Figures B.1 through B.8 illustrate the selected routes and the traffic count locations.

Figure 2.1 Location of Sample for Other Routes

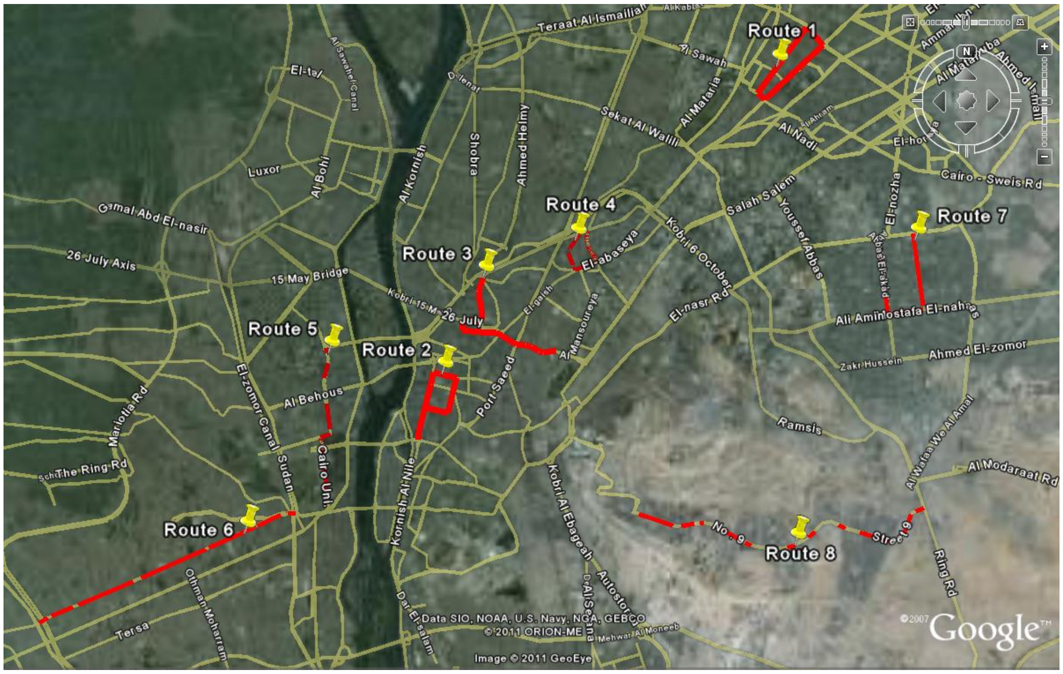
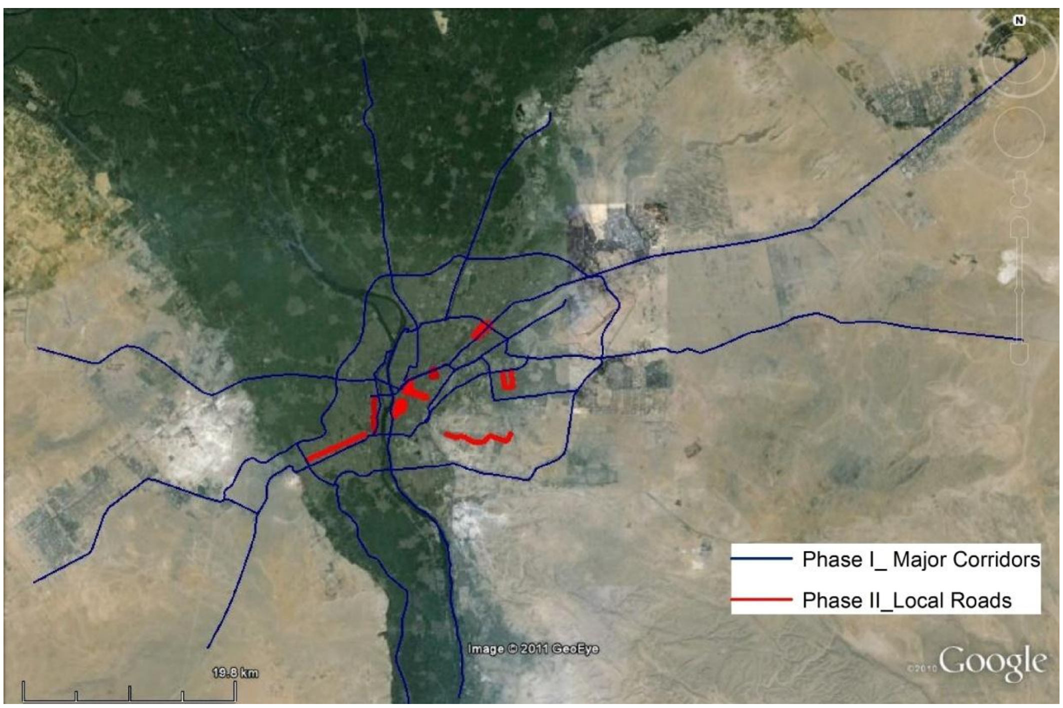


Figure 2.2 Phase 1 Major Corridors and Phase 2 Expanded Network Data Collection



Traffic data on the other routes was collected using two different techniques. First, a floating car survey was conducted along the selected routes with a record being kept at five-minute intervals of:

- Travel distance;
- Actual number of lanes;
- Judgment-based estimate of the congestion level; and
- Traffic- and congestion-influencing features and incidents:
  - Intersections;
  - Random stopping of shared taxis;
  - Microbus drop-offs/pick-ups;
  - Random pedestrian crossings (jaywalking);
  - Security checks; and
  - Accidents.

Second, manual traffic counts also were made at 24 locations; 10 of these were classified traffic counts. Traffic count locations were selected along the floating car survey routes to allow for the validation of the volume and speed data collected from the floating car survey. In selecting the traffic count locations for:

- C**losed loop routes** (e.g., Route 1), the count locations were selected to represent the centroid of the zone bounded by the route, resulting in almost two equal segments between the two count locations.
- L**inear routes** (e.g., Route 6), locations were selected near the peripheries to represent major egress/ingress points to the route.

Both, the floating car survey and the traffic counts were carried out during peak periods between 7:00 a.m. to 11:00 a.m. and 3:00 p.m. to 7:00 p.m. The floating car survey also was conducted during the off-peak period from 5:00 a.m. to 6:00 a.m. This was necessary in order to obtain traffic speeds during "congestion free times," in order to be able to estimate "free-flow" speeds.

Results and Analysis

Traffic Volumes

Table 2.1 provides the locations for the classified and nonclassified traffic counts. (See Appendix B for additional details on the traffic counts.)

Table 2.1 Traffic Count Locations

Route	Count	Road Name	Direction
Classified			
3	L3-1	El Gomhoreya Street	To Opera Square
3	L3-2	26 of July Street	To Ramses Street
6	L6-1 (in)	Faisal Street	Giza to Haram

6	L6-1 (out)	Faisal Street	Haram to Giza
6	L6-2 (in)	Faisal Street	Haram to Giza
6	L6-2 (out)	Faisal Street	Giza to Haram
7	L7-1 (in)	Abbas El Akkad Street	From El Nasr Road to Mostafa El Nahas
7	L7-1 (out)	Abbas El Akkad Street	From Mostafa El Nahas to El Nasr Road
7	L7-2 (in)	Makram Obaid Street	From El Nasr road to Mostafa El Nahas
7	L7-2 (out)	Makram Obaid Street	From Mostafa El Nahas to El Nasr Road
Nonclassified			
1	L1-1	Tomanbey Street	West to East
1	L1-2	Gisr El Suez Street	East to West
2	L2-1	El Kasr Al Aini Street	To Tahrir Square
2	L2-2	Nubar Street	Rihan Street to Maglis El Shaab Street
4	L4-1	Ramses Street	To Abasiyah
4	L4-2	El Gaish Street	To Atabah
5	L5-1 (in)	Gameat El Qahera Street	From Giza to Doqqi
5	L5-1 (out)	Gameat El Qahera Street	From Doqqi to Giza
5	L5-2 (in)	El Doqqi Street	From Doqqi to Giza
5	L5-2 (out)	El Doqqi Street	From Giza to Doqqi
8	L8-1 (in)	Street No. 9 (Central Cairo)	From Ring Road to Cairo
8	L8-1 (out)	Street No. 9 (Central Cairo)	From Cairo to Ring Road
8	L8-2 (in)	Street No. 9 (Ring Road)	From Ring Road to Cairo
8	L8-2 (out)	Street No. 9 (Ring Road)	From Cairo to Ring Road

Tables 2.2 and 2.3 give the average and maximum hourly traffic volumes recorded at each location during the morning (7:00-11:00 a.m.) and evening (3:00-7:00 p.m.) peak periods, respectively. Table 2.4 gives the average and maximum hourly traffic volumes during the off-peak period (5:00 and 6:00 a.m.). The number of lanes shown in these tables represents the lanes that can be used by through traffic as observed during the survey and exclude, for example, lanes functioning as on-street parking.

The morning peak has higher traffic volumes than the afternoon peak (10 percent higher on average). Directional split is relatively uniform across locations with an average 49/51 percent (direction 1/direction 2) split during the morning peak and 52/48 percent (direction 1/direction 2) split during the afternoon peak. Compared to the morning peak, the afternoon peak has a more balanced directional split across count locations when compared, and exhibits a greater diversity of trip types, i.e., for recreational, shopping and other discretionary purposes.

The highest average traffic volume during the morning peak (4,343) was recorded on Route 5 (El Doqqi Street), followed by 3,482 on Route 1 (Gasr El Suiz Street) and (2,804) on Route 2 (El Kasr Al Aini). Also for the local roads, during the afternoon peak, the highest average volume 3,081 was on Route 1, followed by (3,038) on Route 5 and (2,149) on Route 2. However, looking at the maximum hourly volumes, it is Route 5 which has the highest average traffic volumes during the morning and afternoon peaks, with 4,905 and 4,012, respectively. (See Appendix B for the results of the traffic counts.)

During the morning peak hours, the average traffic volumes *per lane* was between 138 and 1,741 vehicles, per hour, per lane on Route 2 (Nubar Street) and Route 1 (Gasr El Suiz Street), respectively. During the evening peak, the average traffic volume per lane was between 128 and 1,541 vehicles per hour, per lane, on the same two routes.

Table 2.2 Traffic Count Results: Morning Peak Period (7:00 a.m. to 11:00 a.m.)

		Vehicles/Hour			
Traffic Count	**Road Name**	**Avg Traffic Volume Direction 1**	**Avg Traffic Volume Direction 2**	**Maximum Hourly Volume Direction 1**	**Maximum Hourly Volume Direction 2**
L1-1	Tomanbey Street	593		721	
L1-2	Gasr El Suiz Street	3,482		3,774	
L2-1	El Kasr Al Aini Street	2,804		3,105	
L2-2	Nubar Street	415		474	
L3-1	El Gomhoreya Street	1,400		1,537	
L3-2	26 of July Street	1,761		2,097	
L4-1	Ramses Street	789		878	
L4-2	El Giash Street	1,281		1,626	
L5-1	Gameat El Qahera Street	2,189	1,610	2,434	1,907
L5-2	El Doqqi Street	4,343	4,147	4,905	4,663
L6-1	Faisal Street	973	1,348	1,151	1,657
L6-2	Faisal Street	753	1,355	1,016	1,489
L7-1	Abbas El Akkad Street	1,986	1,771	2,112	2,071
L7-2	Makram Obaid Street	1,311	1,524	1,486	1,704
L8-1	Street No. 9 (Central Cairo)	713	746	824	840
L8-2	Street No. 9 (Ring Road)	1,498	1,057	1,727	1,196

Table 2.3 Traffic Count Results: Evening Peak Period (3:00 p.m. to 7:00 p.m.)

		Vehicles/Hour			
Traffic Count	Road Name	Avg Traffic Volume Direction 1	Avg Traffic Volume Direction 2	Maximum Hourly Volume Direction 1	Maximum Hourly Volume Direction 2
L1-1	Tomanbey Street	753		814	
L1-2	Gasr El Suiz Street	3,081		3,297	
L2-1	El Kasr Al Aini Street	2,149		2,543	
L2-2	Nubar Street	384		408	
L3-1	El Gomhoreya Street	953		1,133	
L3-2	26th of July Street	1,209		1,420	
L4-1	Ramses Street	735		768	
L4-2	El Giash Street	1,807		1,865	
L5-1	Gameat El Qahera Street	1,592	983	1,688	1,185
L5-2	El Doqqi Street	3,038	3,141	3,669	4,012
L6-1	Faisal Street	1,176	1,501	1,254	1,557
L6-2	Faisal Street	936	859	1,067	918
L7-1	Abbas El Akkad Street	1,827	1,890	1,919	2,006
L7-2	Makram Obaid Street	1,668	1,399	1,769	1,523
L8-1	Street No. 9 (Central Cairo)	825	862	869	924
L8-2	Street No. 9 (Ring Road)	1,473	1,353	1,544	1,406

Table 2.4 Traffic Count Results: Off-Peak Period (5:00 a.m. to 6:00 a.m.)

		Vehicles/Hour	
Traffic Count	Road Name	Hourly Traffic Volume Direction 1	Hourly Traffic Volume Direction 2
L1-1	Tomanbey Street	50	
L1-2	Gasr El Suiz Street	408	
L2-1	El Kasr Al Aini Street	354	
L2-2	Nubar Street	28	
L3-1	El Gomhoreya Street	136	
L3-2	26 of July Street	212	
L4-1	Ramses Street	66	
L4-2	El Giash Street	68	
L5-1	Gameat El Qahera Street	168	138
L5-2	El Doqqi Street	379	291
L6-1	Faisal Street	133	140
L6-2	Faisal Street	85	173
L7-1	Abbas El Akkad Street	192	140
L7-2	Makram Obaid Street	111	133
L8-1	Street No. 9 (Central Cairo)	56	50
L8-2	Street No. 9 (Ring Road)	107	66

At most of the count locations, the highest morning peaks occur between 8:00 and 11:00. During the afternoon hours, while the volumes are comparable to the morning period, there does not seem to be any discernible peaking pattern. During the off-peak period, the traffic volumes are significantly lower, on average, 10 percent of the hourly traffic volume during peak hours. These data show a pattern that is consistent with what was seen in Phase 1 of this study, namely; the highest peaks occurred between 8:00 and 9:00 a.m. and there was no discernible peaking pattern during the afternoon hours.

Modal Split

Classified vehicle counts were performed along Routes 3 (two locations), 6 (four locations), and 7 (four locations) during the morning peak, afternoon peak, and off-peak periods to identify the mix of vehicle types and modal split.

For the surveyed routes, private car use is highest on Route 7 (East Cairo). Use of public transport, including taxis and buses, is highest on Routes 3 (Central Cairo) and 6 (West in Cairo). Route 3, El Gomhoreya Street, is the location for many business compounds and government buildings resulting in a greater use of private cars and taxis, with the two having a combined share of 83 percent (see

Figure 2.3). Al Gomhoreya Street connects many central axes in Cairo such as Ramsis Street, 6th of October Bridge, and Al Azhar Bridge and making it a popular route for taxis and private vehicles.

Route 6, El Malek Faisal Street, is the home of dense residential neighborhoods and small- to medium-sized businesses ranging from convenience and furniture stores to big malls. The mixed, and diverse, land use and activities along El Malek Faisal Street make it attractive for low-middle economic class visitors and shoppers. These visitors and shoppers make use of public transport, resulting in a share of 25.5 percent for Microbuses and Minibuses (see Figure 2.4). Also, El Malek Faisal Street being parallel to Al Haram Street and connecting Al Giza Square with Al Mariotia Road contributes to the high share of micro and minibuses on this street.

Route 7, Abbas El Akkad and Makram Obaid Streets, like El Gomhoreya St, is the site for many businesses, including medium-high class shopping malls, but is relatively affluent with high levels of private car ownership compared to other surveyed routes. This route also is a major feeder to Al Nasr Road and aligned with Al Nozha Street. The relative affluence of the area and its connection with Al Nasr and Al Nozha streets contribute to the high share of private cars and taxis (see Figure 2.5).

Figure 2.3 Modal Split, Route 3 – El Gomhoreya/26th of July

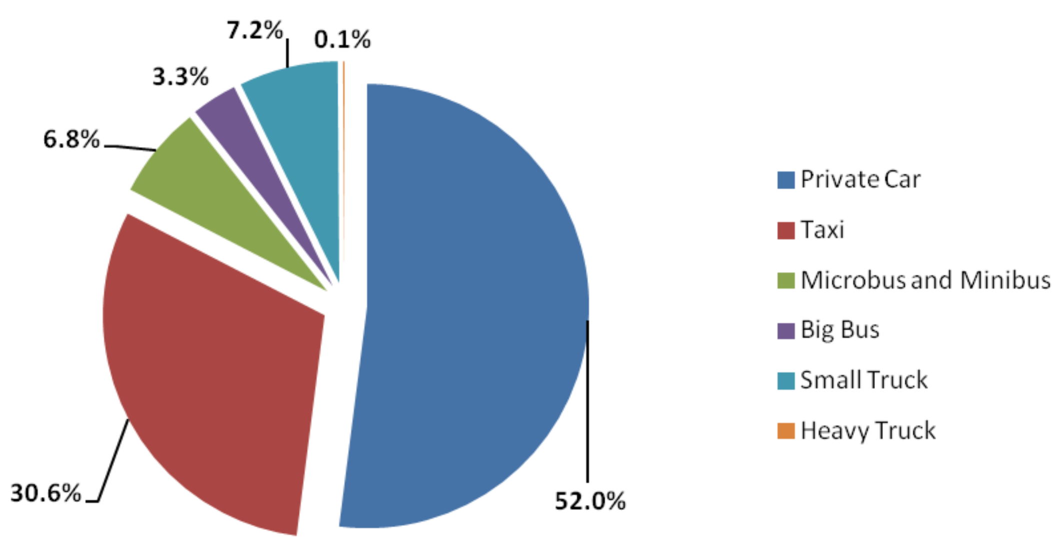


Figure 2.4 Average Modal Split, Route 6 – El Malek Faisal

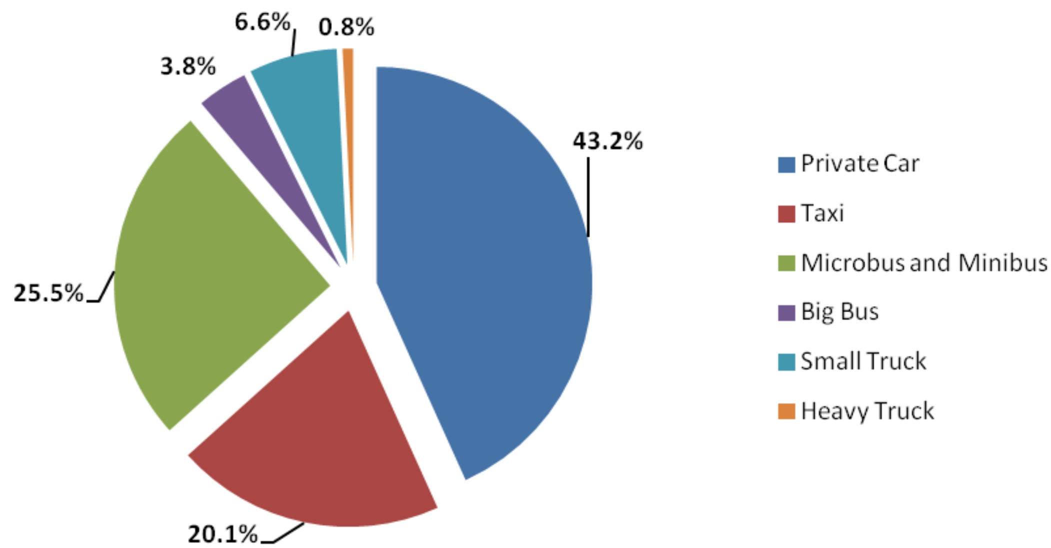


Figure 2.5 Modal Split, Route 7 – Abbas El Akkad/Makram Abiad

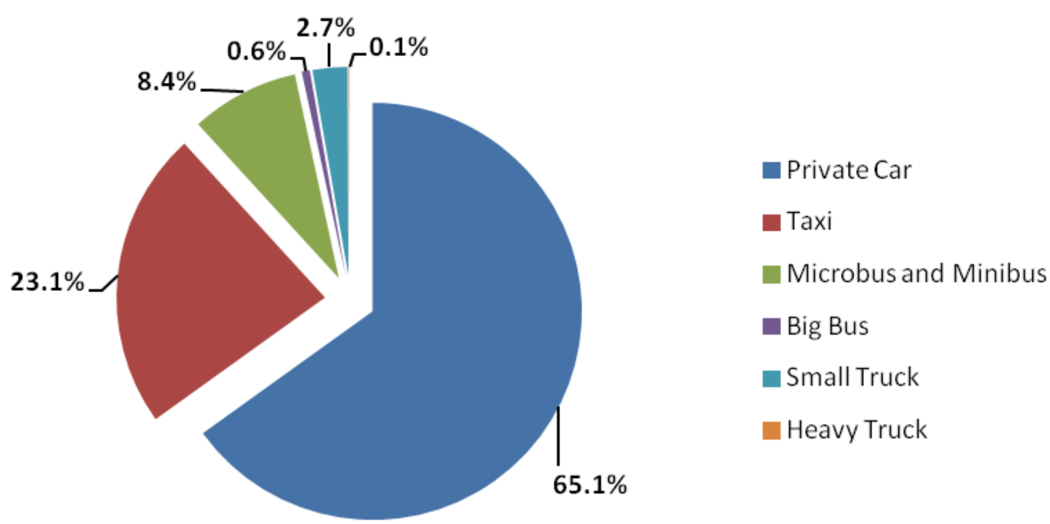


Figure 2.6 summarizes the modal split on the three other routes where we conducted a classified traffic count: private cars have a share of 56 percent, taxis have a share of 24 percent, microbuses and minibuses have a share of 14 percent, and big buses have a share of 2 percent. Small trucks and heavy trucks constitute 5 percent and 0.3 percent of road traffic, respectively.

The Phase 2 results are significantly different from the Phase 1 (Figure 2.7) results. Most striking is the share of private cars which is only 55 percent in Phase 1 compared to 70 percent in Phase 2. In Phase 2, private cars were estimated to have a share of 70 percent, taxis 15 percent, and microbuses and minibuses 7 percent. The share of taxis and micro/minibuses increased from 15 and 7 percent in Phase 1 to 23.6 and 13.6 percent, respectively, in Phase 2.

Figure 2.6 Modal Split on Other Routes (Phase 2)

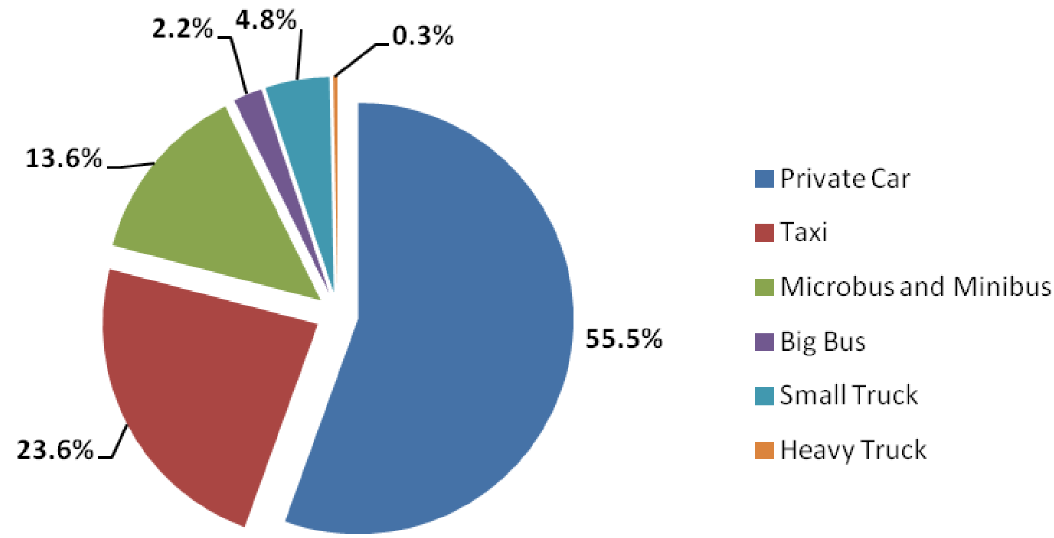
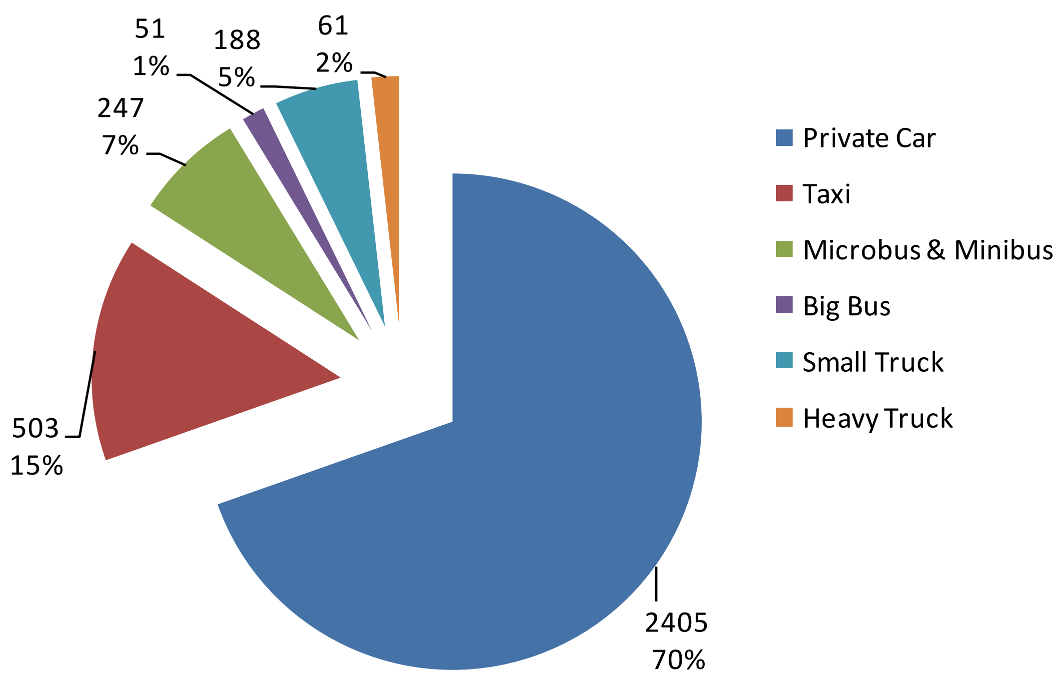


Figure 2.7 Modal Split on Major Corridors (Phase 1)



Source: Cairo Cost of Congestion Phase 1 Study.

Current Performance of the System

This section presents the results from comparing the results for the eight other routes included in Phase 2.to the 11 major corridors from Phase 1. The speed and reliability data from the floating car survey, together with the traffic volume data are used to analyze the other routes and calculate the costs of congestion (Section 4.0).

Speed Analysis

Average Speeds

Average travel speeds as well as speed indices (ratios of average speeds to free-flow speeds) are estimated and used to analyze and compare the other routes. (See Appendix B for details.) Results are shown in Figures 2.8 and 2.9.

Figure 2.8 Average Speeds on 8 Sample Other Routes, AM Peak Period

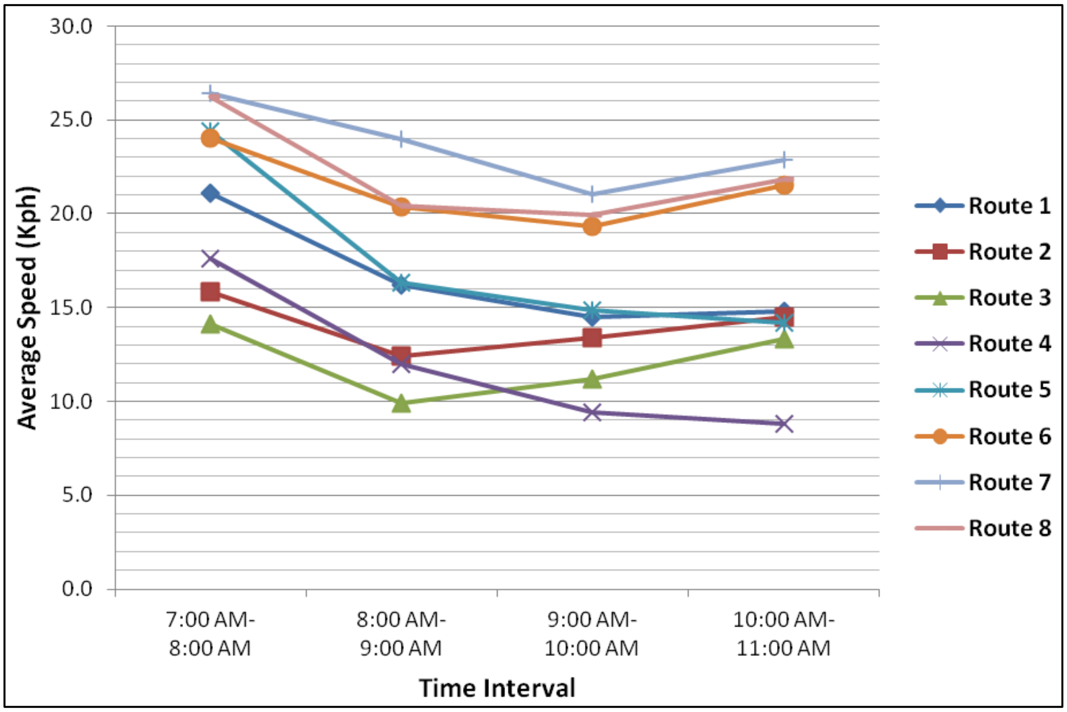
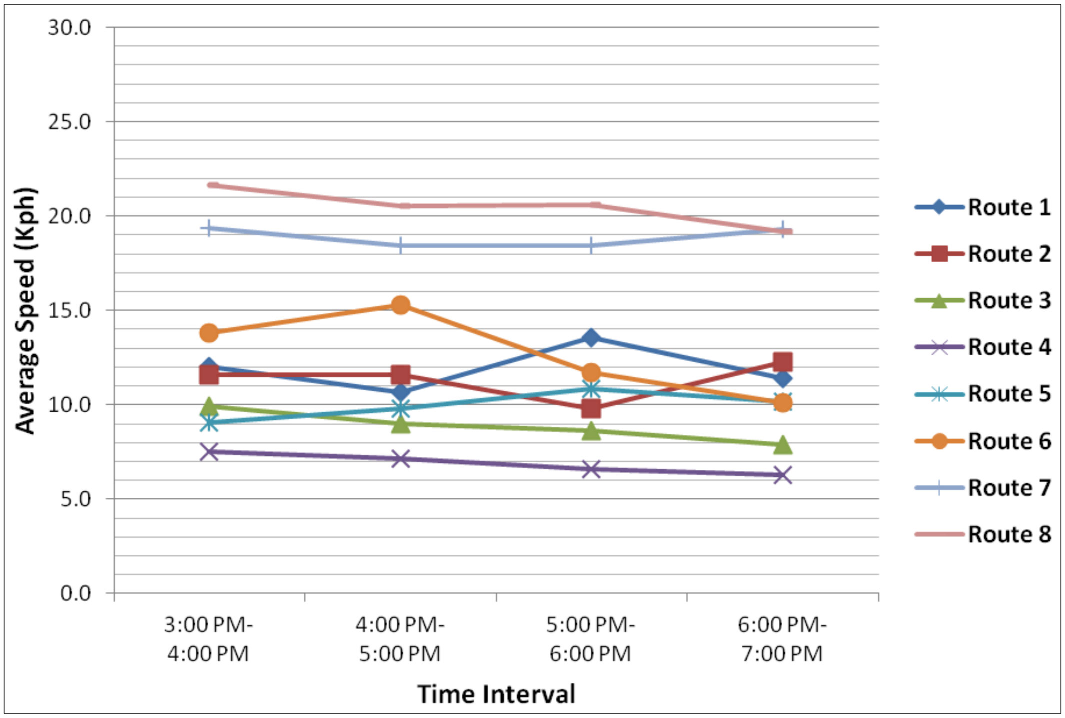


Figure 2.9 Average Speeds on 8 Sample Other Routes, PM Peak Period



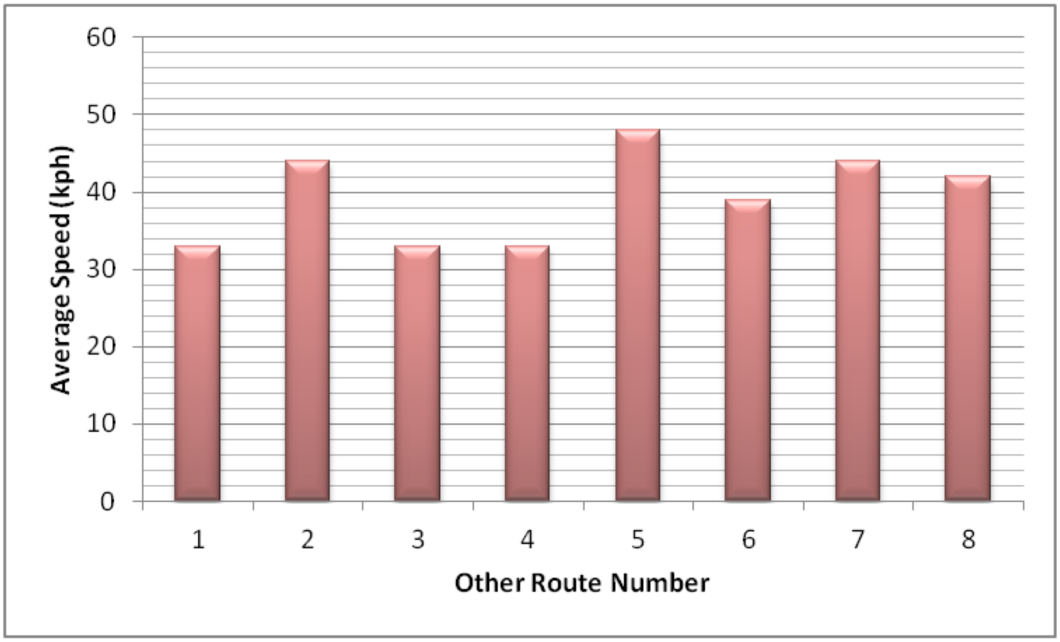
During the morning peak period, the average speeds on other routes are between 10 to 25 kph The lowest and highest values being 9 kph (Route 4 in Central Cairo) and 27 kph (Route 7 in East Cairo), respectively. During the evening peak period, the lowest and highest values are 6 kph (Route 4 in Central Cairo) to 22 kph (Route 8 in East Cairo), respectively. Finally, Routes 2, 3, and 4 – all in Central Cairo – have the lowest average speeds.

During the morning peak, average speeds for the local routes are slightly higher than in the evening peak. However, this difference is never more than 5 kph. Average speeds on the local routes exhibit a more uniform distribution during the evening peak period than during the morning peak.

Although morning peak traffic volumes are higher than traffic volumes during the afternoon peak, the average speeds during the morning peak period are slightly higher than the speeds observed during the afternoon peak. One possible explanation for the higher average speeds during the morning peak is that there fewer pedestrians earlier in the day. As the pedestrian numbers increase during the day, the interference with motorized traffic increases leading to lower average speeds despite the lower traffic volumes.

Figure 2.10 shows the average speeds between 5:00 a.m. and 6:00 a.m. This represents the off-peak period in this study. Average speeds during this off-peak period are between 30 and 50 kph. These speeds are assumed to represent free-flow speeds on these “other” routes.

Figure 2.10 Off-Peak Average Speeds on 8 Sample Other Routes

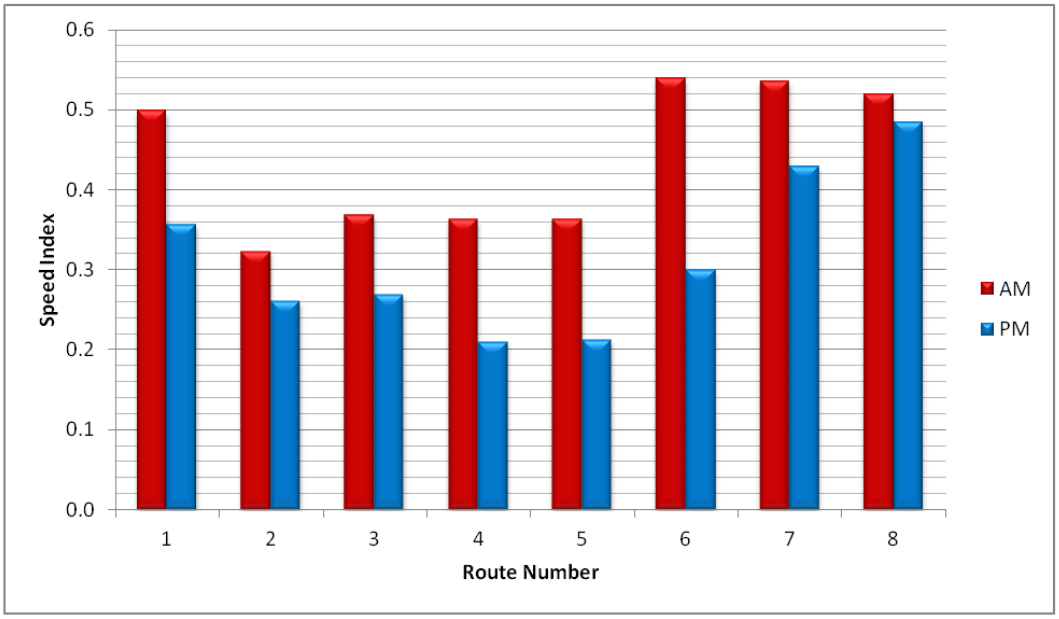


In Phase 1, the average speeds for the 11 major corridors, all of which are within the area contained by the Ring Road, were estimated to be between 20 to 45 kph. On the Ring Road itself, the speeds were higher; between 50 to 60 kph. Based on the Phase 2 estimates we see that the average speeds on the other routes are almost half of what they are on the major corridors. This indicates that the estimate of congestion from Phase 1 was an underestimate as we had used the average speeds on the 11 major corridors as a proxy for average speeds on the other roads.

Speed Indices

Speed indices, the ratio of the average speed to the free-flow speed, are estimated to enable a comparative assessment of the surveyed other routes. The speed indices range from 0.21 during the PM peak period to 0.54 during the AM peak period (Figure 2.11). These estimates are much lower than the speed indices estimated for the major corridors in Phase 1 – for the major corridors the minimum and maximum were 0.48 and 0.96, respectively. Consistently lower PM indices for each route indicate that congestion is worse in the PM peak period than in the AM peak period. The highest average speed index across both the AM and PM peaks is on Route 8 in East Cairo, with an average speed index of 0.5.

Figure 2.11 Speed Indices on 8 Sample Other Routes
AM and PM Peak Period



Reliability Analysis

We estimated reliability using two measures, the Coefficient of Variation (COV) and the buffer index.

Using the COV, reliability is measured by estimating the variability in observed travel speeds from multiple floating car runs. On average, 5 to 6 runs were recorded for each direction, of each route, for each peak period. The reliability analysis is based on the estimated coefficients of variation (COV) of the average speeds on each individual route.[3] Figure 2.12 shows the COV for the average speeds on the different routes.

The variability in travel speeds reflects the situational differences during the different times of day during which the survey was conducted. This variability could come from traffic influencing events (such random stops of transit vehicles or large volumes of illegal pedestrian crossings during particular survey runs), personal behavior (drivers' responsiveness or experience), or other reasons.

Another measure for travel time reliability is the buffer index. The buffer index is calculated by taking the difference between the 95th percentile speed and the average speed, and dividing it by the average speed. The buffer index represents

[3] The standard formulation of the COV, is the ratio of the standard deviation to the mean of a single variable. The COV aims to describe the dispersion of the variable in a way that does not depend on the variable's measurement unit. The higher the COV, the greater the dispersion in the variable.

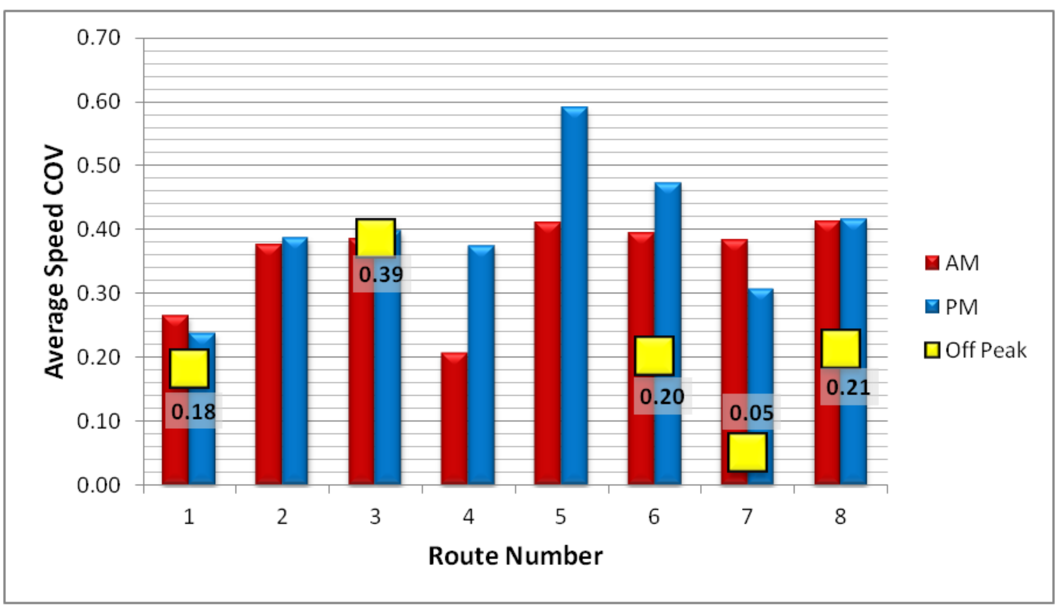
the extra time (or time cushion) that travelers must add to their average travel time when planning trips to ensure on-time arrival. As the buffer index increases, travel time reliability decreases.

Coefficient of Variation

For the morning peak, the estimated COVs for the surveyed other routes are between 0.21-0.41. For the evening peak, the estimated COVs for the surveyed other routes are between 0.24-0.59. With the exception of for Routes 1 (Tomanbey Street) and 7 (Abbas Al Akkad and Makram Obaid Streets) in East Cairo, the evening peak period has greater variability.

The largest variability in travel speed (COV of 0.59) was observed on Route 5 (Gameat El Qahera) in West Cairo during the evening peak period. The variability on this route can be explained by the presence of several academic institutions; including universities, high schools, and preparatory schools located along the street, each with different operating hours. The smallest variation in travel speed (COV of 0.21) was observed on Route 4 (El Gaish-Ahmed Said) in Central Cairo during the morning peak period. With the exception of Route 3 (El Gomhoreya Street and 26th of July Streets) in Central Cairo where the COV is higher (0.39), the variability in travel speeds is generally low, between 0.05 and 0.21, during the off-peak period.

Figure 2.12 Coefficient of Variation (COV) of Average Speeds for Eight Sample Other Routes
AM Peak, PM Peak, and Off-Peak



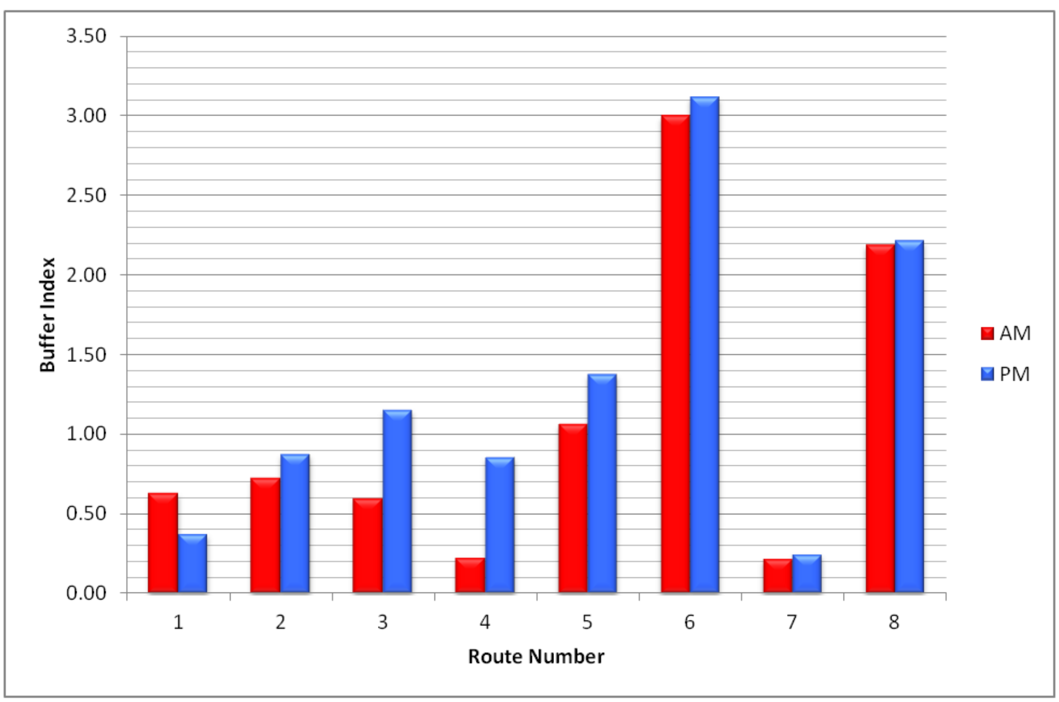
Buffer Index

Figure 2.13 shows the estimated values the buffer indices along the surveyed other routes. During the morning peak period, the values for the buffer indices are between 21 percent and 300 percent. During the evening peak, the values of the buffer indices for the surveyed routes are between 24 percent and 311 percent. Except for Route 1, the estimated values of the buffer indices are higher during the evening peak than during the morning peak. The difference, however, between the values of the buffer indices for morning and evening peaks is not very large.

Travel time reliability is at its highest on Route 7 (Abbas Al Akkad and Makram Obaid Streets); a traveler on this route needs to budget an additional 22 percent of the usual trip time to ensure on-time arrival. Though not captured through the COV analysis, travel time reliability is at its lowest on Route 6 (El Malek Faisal Street) according to the buffer index. This is likely due to the excessive delay experienced on the direction from El Haram to El Giza during both the AM and PM peaks.

Travel time reliability also is very low on Routes 3 (El Gomhoreya and 26th of July Streets), 5 (Gameat El Qahera Street) and 8 (Street No.9 in Al Mokatam), where the buffer index reaches 115 percent, 137 percent, and 222 percent, respectively. It should be noted that the excessive delay on Route 8 was experienced in the direction from Salah Salem Street to the Ring Road, during both the AM and PM peaks.

Figure 2.13 Buffer Indices for 8 Sample Other Routes
AM and PM Peak



CAUSES OF CONGESTION

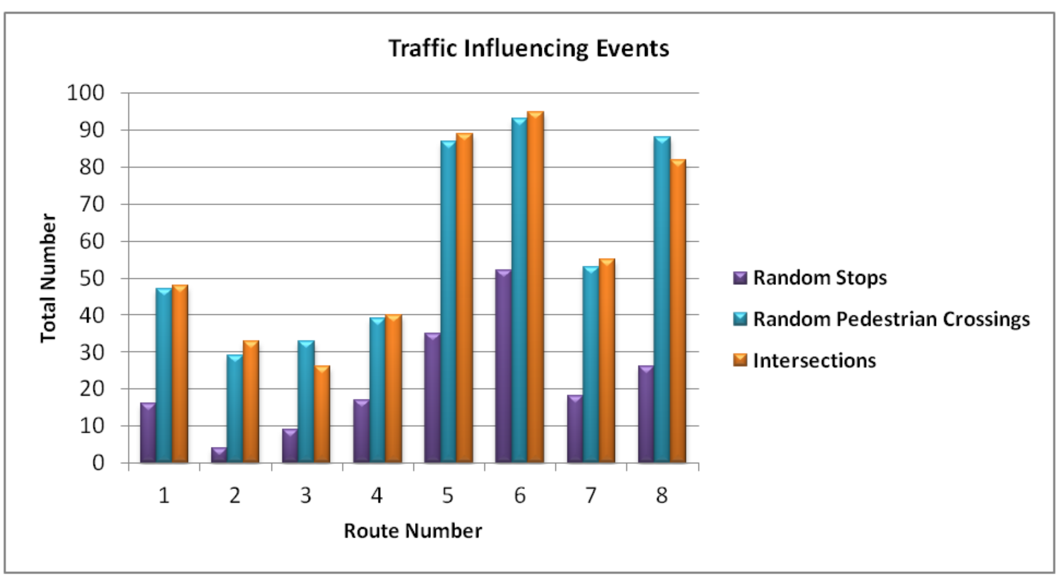
Analysis of Traffic Influencing Events

Traffic influencing events are one of the main causes of variability in travel time. For the surveyed routes, the three primary traffic influencing events are: random stops of vehicles, random pedestrian crossings; and intersections. Figure 2.14 shows the frequencies of these three main traffic influencing events during the morning and evening peak periods, no accidents, security checks or breakdowns were recorded during the times of the survey.

Some of observations we made regarding traffic influencing events are that:

- On local routes, "intersections" and "random pedestrian crossings" are the most disruptive events scoring almost similar frequencies during the survey with "random stops of vehicles" being third on the list.
- Routes 6 (El Malek Faisal Street), 7 (Abbas Al Akkad and Makram Obaid Streets) and 8 (Street No. 9 in Al Mokatam) have a frequency of the top 3 traffic influencing events.
- Route 2 (Qasr El Einy) has low frequencies of the top 3 traffic influencing events.
- The highest number of intersection stops is 95 (equivalent to 6 intersections per run) was recorded on Route 6 (El Malek Faisal Street) in West Cairo.
- The highest number of random pedestrian crossings is 93 (equivalent to 6 crossings per run) was recorded on Route 6 (El Malek Faisal Street) in West Cairo.

Figure 2.14 Traffic Influencing Features and Events for Eight Sample Other Routes



The figures in Appendix C illustrate the route schematics and time-space diagrams respectively for the 8 local routes, indicating the types of intersections along each route, start and end points, number of lanes, location of random on-street parking, intersections and other observed features on the roads, and travel speed variability throughout the day.

Routes 5 (Gameat El Qahera) and 6 (El Malek Faisal Street) have the largest variation in speed of all routes. The speeds measured during the off-peak period are higher than the speeds during the morning and evening peak periods. This is confirmed in the schematics of the roads whereby traffic is interrupted by either an intersection or U-turn at very short distances along Route 5 (200m on average), and a U-turn is located every 500m on average along Route 6.

Other causes of congestion that we noted (besides the top three causes given above) included:

- U-turns at signalized intersections or through median openings before the intersection. The large number of U-turns being made affects the performance of the intersections and the movements along the local roads, particularly on Routes 5, 7, and 8.
- Illegal on-street parking reduces road capacity and impedes the flow of traffic. Illegal on-street parking was observed most frequently on Routes 1, 2, 3, and 8. Double parking also was frequently observed on Route 3.
- Poor pavement conditions on Routes 4, 6 and 8 force traffic to drive more slowly.
- Speed bumps slow traffic on Route 5 (near Cairo University) and Route 8.

In Phase 1, a quantitative and qualitative assessment of congestion and its causes identified several causes of congestion and grouped them into operational and strategic causes. The operational causes of congestion included: 1) poorly designed infrastructure; 2) traffic demand patterns; and 3) traffic influencing events. The strategic causes of congestion included the lack of a multimodal transport system, high rates of car ownership, land use, and population growth.

Based on the floating car survey conducted in Phase 2, the important operational causes of congestion from Phase 1 were again identified as important causes of congestion on the other routes (see Table 2.5). For example, poorly designed roads, the lack of parking, driving behavior, nonobservance of laws, and the lack of enforcement of traffic laws are important on all functional classifications of roads, the relative importance of each of these causes, however, varies slightly from one functional classification to another. One difference in the causes of congestion for major corridors versus local routes is that the most important causes of congestion on major routes-vehicle breakdowns security checks and accidents – are not the most important causes of congestion on local roads. On local roads, U-turns at intersections, random stops of vehicles, and pedestrian crossings are the most important causes of congestion.

Table 2.5 Observed Operational Causes of Congestion

Rank	Category	Specific Causes
1	Design features of the road network	• Physical bottlenecks • U-turns • Poor road surface quality • Speed bumps
2	Awareness of road etiquette and manners by various entities	• No lane discipline • Ubiquitous jaywalking • Illegal stops by transit and other vehicles
3	Parking supply and behavior	• Limited parking capacity • Illegal on-road parking
4	Law observance and enforcement	• Poor observance and enforcement of traffic laws and road occupancy policies (e.g., on-street vendors, animal drawn carts).
5	Traffic influencing events	• Road accidents • Vehicle breakdowns • VIP motorcades
6	Traffic management and control	• Poor control at intersections • Lack of modern technologies for traffic management
7	Traffic demand-related factors	• Special events • Inflexible work hours

PREPARATION OF DATA FOR EVALUATION OF CONGESTION COSTS

Revising Free-Flow Speeds for Major Corridors

In Phase 1, free-flow speeds were calculated for the major corridors using knowledge of the traffic conditions and a set of standard kinematic equations from classical physics. However, these values may be too high relative to actual field conditions for Cairo. Thus, the World Bank recommended that the calculations to estimate congestion costs be based on baseline speeds that are lower than the free-flow speeds.

The Highway Capacity Manual outlines an approach for obtaining free-flow speed (FFS) from average speed data alone:

$$FFS = 85th\ percentile\ speed\ obtained\ while\ PCHPL < 1400$$

$$Where\ PCHPL\ is\ the\ number\ of\ passenger\ car\ hours\ per\ lane$$

Table 2.6 allows for a comparison of the free-flow speeds from Phase 1 with those obtained using the above method.

Table 2.6 Old and New Free-Flow Speeds for the 11 Major Corridors (kph)

Direction	1	2	3	4	5	6	7	8	9	10	11
Old FFS											
1	82.9	90	90	57.4	53.4	50.9	54.1	59.5	66.9	59.3	79.5
2	82.9	90	90	56.6	53.4	50.9	54.1	59.5	66.9	62.4	79.5
New FFS											
1		80.4			39.6	44.4	42.0	34.7	37.2	32.4	55.2
2	61.2	74.4		40.4	30.1	44.6	42.0			44.4	61.9

As shown in Table 2.6, data are lacking for certain corridors and/or directions, due to the fact that traffic volumes exceed 1,400 passenger cars per hour per lane (PCHPL) at these locations. Therefore, the following method is used to calculate an adjustment factor α:

$$\alpha = average\left(\frac{FFS_{new}}{FFS_{old}}\right)$$

Assuming that the average spans all corridors where volumes are below 1,400 PCHPL, then the final FFS can be estimated as follows:

$$FFS_{final} = \alpha \times FFS_{old}$$

Using these equations and the data reported in Table 2.6 above, with $\alpha = 0.73$, the FFS of the corridors are recalculated adopting the following process:

- For corridors where the new FFS is missing in one direction only and the old FFS are equal for both directions (e.g., major Corridors 1, 8, and 9), the same value for the new FFS is used for both directions.
- For corridors where the new FFS is missing in both directions (i.e., major Corridor 3):
  - If another corridor exhibits similar attributes (i.e., same road class, or same old FFS – in this case major Corridors 2 and 3), the values of the new FFS or its factor is used; OR
  - If no corridor exhibits similar attributes, the average "α" is used.

The final FFS results are shown in Table 2.7.

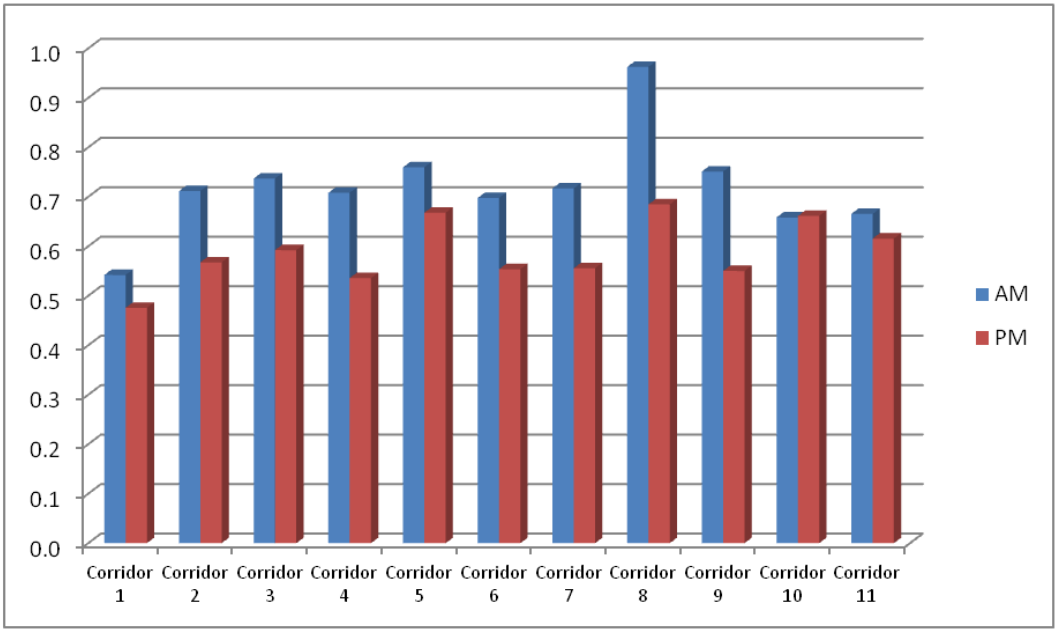
Table 2.7 Final Free-Flow Speeds for the 11 Major Corridors (kph)

Direction	1	2	3	4	5	6	7	8	9	10	11
1	61.2	80.4	80.4	41.0	39.6	44.4	42.0	34.7	37.2	32.4	55.2
2	61.2	74.4	74.4	40.4	30.1	44.6	42.0	34.7	37.2	44.4	61.9

Analysis of Speed Index

An adjustment to the free-flow speeds that were estimated in Phase 1 requires a recalculation of the speed indices for the major corridors. Figure 2.15 shows the average speed indices for the AM and PM peak periods for each of the main corridors.

Figure 2.15 AM and PM Peak Period Speed Indices



Definition of Congestion

To define the hours during which congestion actually occurs, TTI defines a measure called the Road Congestion Index (RCI). This measure is based on the density of traffic. However, as stated in the methodology, more relevant measures such as travel times are often used. Moreover, the RCI is a macroscopic measure of congestion and does not allow for an analysis of the conditions on individual routes. Thus, while we do not use the RCI to measure congestion in this study, as described below we do use definition of congested conditions to estimate congestion thresholds using the speed index.

The speed index is used to identify the congested periods during peak times. Consequently, the speed index was used as the measure for congestion. According to the TTI methodology, which uses the RCI, congested conditions exhibit the following characteristics:

- Typical commute time 25 percent longer than off-peak travel time;
- Slower moving traffic during the peak period on the freeways, but not sustained stop-and-go conditions;
- Moderate congestion for 1 1/2 to 2 hours during each peak period; and

- Wait through one or two red lights at heavily traveled intersections.

The RCI includes the effect of roadway expansion, demand management, and vehicle travel reduction programs. In urban areas, the congestion index aggregates all the developments within this area; whereby some locations may encounter worse congestion compared to the aggregate (average) congestion measure. The RCI does not consider the effect of operational improvements (e.g., promptly clearing accidents, coordination of traffic signals), person movement efficiencies (e.g., bus and carpool lanes) or transit improvements (e.g., transit signal priority). The RCI does not address traffic bottleneck dynamics where roadway capacity is reduced compared to demand over a short section of road (e.g., a narrow bridge or tunnel crossing a harbor or river).

Based on the TTI definition of what constitutes congestion, we can use the following equation to derive a congestion threshold using the speed index:

$$\frac{L}{V_{av}} = (1.25)\frac{L}{V_{ff}}$$

Where,

L is the length traveled

V_{av} is the average speed during congestion

$V_{ff}$is the free flow speed

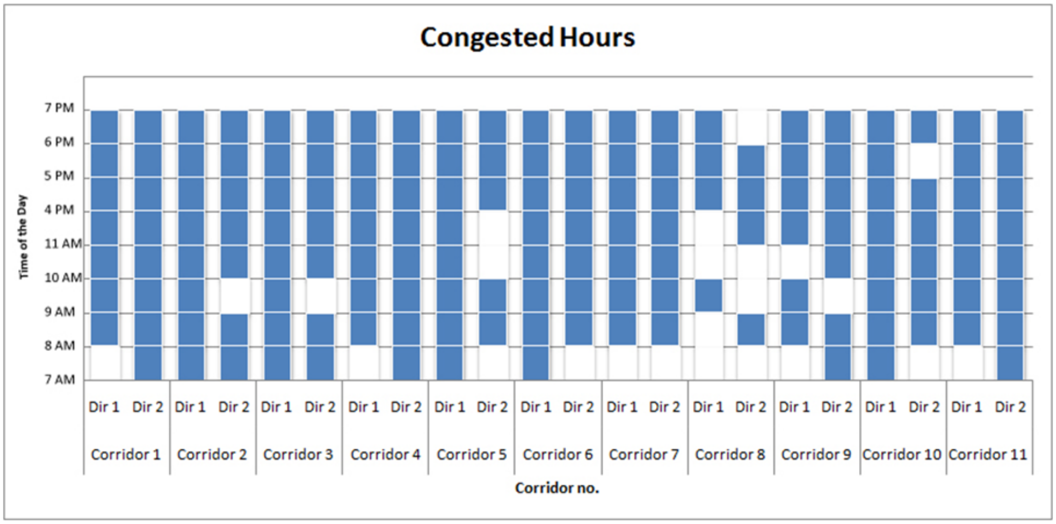
This implies,

$$\text{SpeedIndex} = \frac{V_{av}}{V_{ff}} = 0.8$$

Therefore, for a speed index less than 0.8 the period is defined as a congested period. Figure 2.16 visually displays the periods when congestion occurs for the 11 major corridors for each direction based on this threshold. All corridors experience congestion during the 8 peak hours in both directions. This implies that congestion may be present beyond these 8 hours, however in the current analysis congestion is considered to be constrained to the AM and PM peak survey periods. Corridors 1, 4, 5, 9, 10, and 11 exhibit the most congested hours while Corridors 2 and 3 exhibit the least congested hours. For Corridors 2 and 3, the average speed of direction 1 during the AM peak ranges from 45-60 kph and 30-65 kph during the PM peak, and the average speed of direction 2 during the AM peak ranges from 50-60 kph and 30-50 kph during the PM peak. The speeds of Corridors 4 through 11 fall in the range of 20-45 kph for the duration of the entire AM peak period for both travel directions and 15-30 kph in the PM peak period, also for both directions. Generally, compared to the AM peak, the PM peak period exhibits more congested hours. For the eight local routes, they all experience congestion during the eight-hour peak period in both directions.

These hours provide the basis for calculating and reporting traffic volumes and average speeds for the evaluation of direct and indirect costs of congestion.

Figure 2.16 Congested Hours for the 11 Major Corridors



3.0Travel Demand Forecasts

TRAVEL DEMAND MODEL DEVELOPMENT

Introduction

A model was developed for this study to forecast travel demand and costs of congestion to 2030, and assess the performance of policy measures to reduce congestion. The model for the GCMA is a sketch-level model, with a roadway network that represents the major corridors in the GCMA and fixed trip tables based on socioeconomic data. The model has no mode-choice component, meaning that transit or nonmotorized strategies are tested by making "off-model" adjustments to model inputs, inputting these revised values, and rerunning the model.

Models were developed for both the 2010 base year and the 2030 forecast year. Although actual 2010 observed traffic counts and speeds are used for all 2010 analyses, the 2010 model results were compared to the 2030 forecasts to determine the relative increase in traffic volumes and congestion. The forecasts for 2030 include forecasts for a baseline (medium) scenario, low and high socioeconomic growth scenarios.

The GCMA model used the model from Phase 1 as the starting point and involved the following steps:

1. Interpolate socioeconomic data from the JICA Study for 2010 and extrapolate to 2030.
2. Develop a regression model relating generated trips to socioeconomic variables (population, employment and number of students) to estimate the number of trips in 2010 and 2030 by zone.
3. Estimate the number of trips for the low and high growth scenarios.
4. Update the GCMA road network for 2010 with newly available GIS data.
5. Create the GCMA road network for 2030 by integrating all the planned and proposed road projects that will be implemented by the year 2030.
6. Assign the trips generated for the base year 2010 on the existing road network model and assign the trips generated for the year 2030 on the future road network.

In Phase 1, a travel demand model was created using the EMME modeling platform. The Phase 1 models was based on the JICA Study, and included the origin-destination (O-D) matrix between the 18 traffic analysis zones (TAZ) used in the JICA Study. The geographic area covered by the Phase 1 model (the GCMA study area, including the governorates of Cairo, Giza and Qalyobiya, New Cairo City, 6th of October City, 15th of May City, and 10th of Ramadan City, El-Obour City and Badr City) is consistent with the study area defined by the JICA Study.[4]

Obtaining the Socioeconomic Data for 2010 and 2030

The socioeconomic data from the JICA study (for the 18 zones in the GCMA) were used in Phase 2. This socioeconomic data included population, per capita income, household size, vehicle ownership, employment, number of students, and generated trips for each zone. This socioeconomic data was available for the years 2007, 2012, 2022, and 2027 (see Appendix D for more details). These data were used to estimate the relationship between trips generated and the socioeconomic variables using a simple regression model. This relationship was then used to forecasting future trips generated for different future values of the socioeconomic variables.

We needed the socioeconomic data and generated trips for 2010 (base year) and 2030 (future forecast) to calculate the cost of congestion in the GCMA in the 2030. For the base year 2010, we first estimated the annual growth rates from 2007 to 2012 using the JICA data. Then we used these growth rates to extrapolate the 2007 data to 2010. Figures 3.1 through 3.3 show the population, students, and employment for each of the 18 zones in the year 2010, respectively. (See Appendix D for detailed socioeconomic data.)

[4] Greater Cairo Urban Transport Master Plan – CREATS, 2003.

Figure 3.1 Estimated Population by TAZ
2010

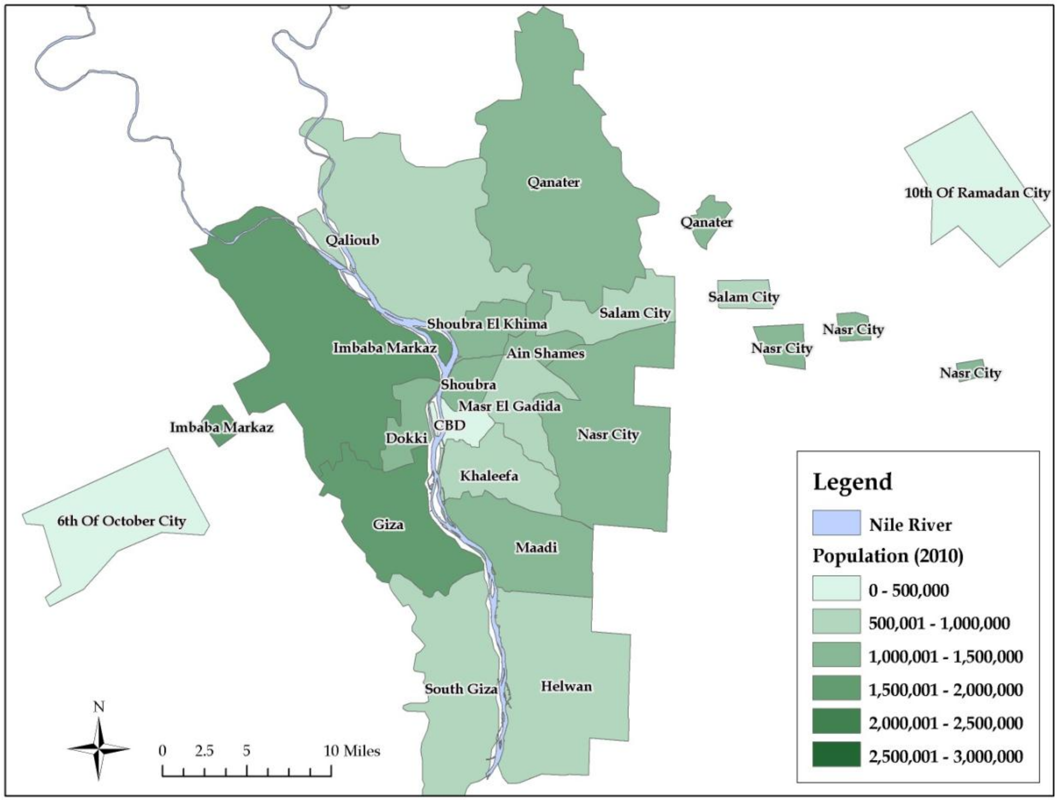


Figure 3.2 Estimated Students by TAZ
2010

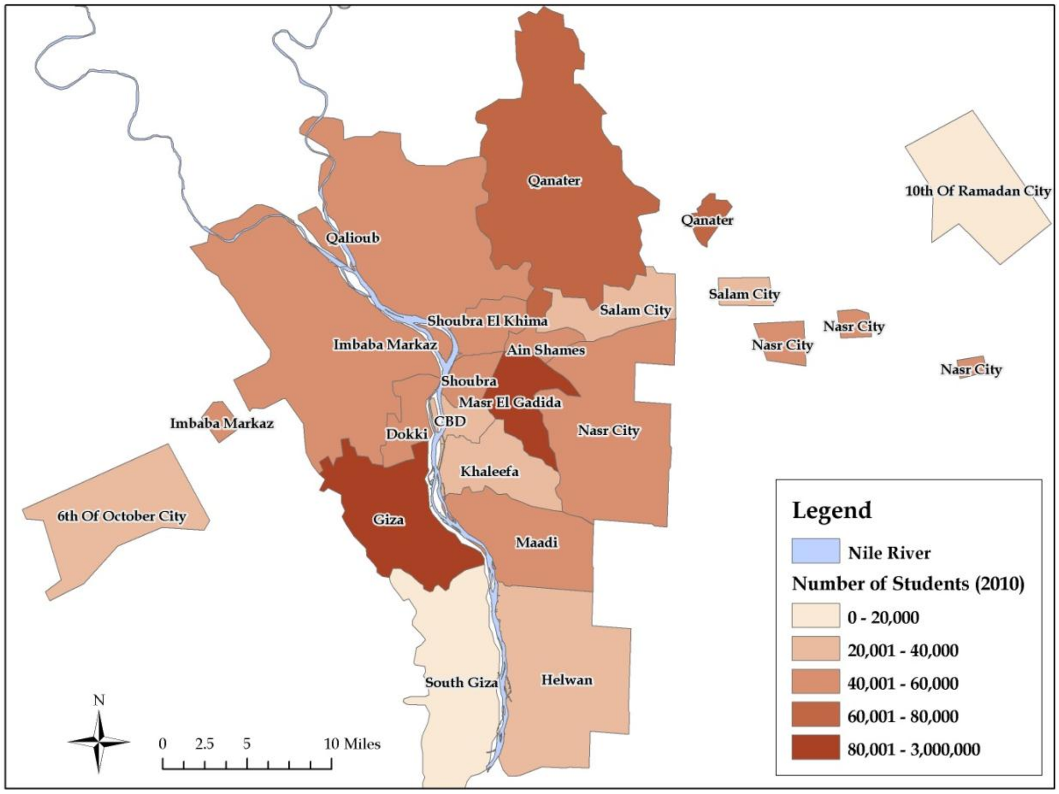
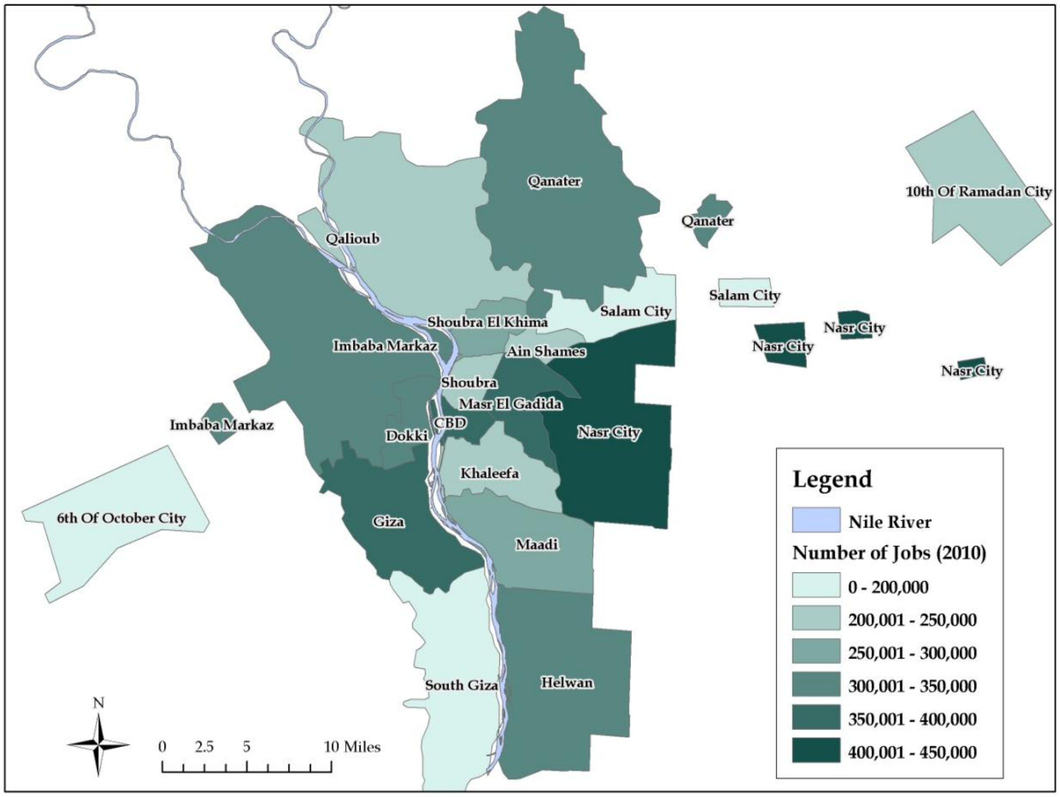


Figure 3.3 Estimated Employment by TAZ
2010



For 2030, we first estimated the annual growth rates between 2022 and 2027. Then we used these annual growth rates to extrapolate the 2027 data to 2030. (Table 3.1).

Table 3.1 Projections of Socioeconomic Data to 2030

		Employment			Students		
Sector	**Population**	**Primary**	**Secondary**	**Tertiary**	**Nonuniversity**	**University**	**Trips Generated**
6th of October	1,704,731	3,562	278,950	171,323	121,573	151,835	600,309
ImbabaMarkaz	2,775,930	96,443	119,882	287,883	197,867	12,888	691,951
Doqy	1,441,463	722	80,736	272,474	100,851	13,463	413,020
Giza	2,058,845	45,024	118,573	267,022	145,542	259,682	770,392
South Giza	600,362	41,763	35,483	52,615	41,498	217	221,565
Helwan	1,031,994	9,990	219,233	197,166	49,536	9,637	308,090
Maadi	1,740,631	22,013	215,019	273,905	87,352	16,252	450,102
Khaleefa	959,996	81	120,594	213,466	47,125	8,966	291,942
CBD	381,553	1	57,772	286,816	16,849	7,568	183,168
Shobra	1,042,739	4	131,355	203,196	51,835	14,128	312,517
Masr El Gedeeda	994,615	36,107	147,928	366,308	46,169	262,675	538,639
Nasr City	2,654,705	1,883	343,776	677,243	135,306	140,183	754,046
Ain Shams	1,440,938	5	159,179	243,482	68,291	13,456	384,564
Salam City	712,435	1,633	79,884	132,794	35,890	6,655	240,874
Shobra El-Kheima	1,452,193	20,159	139,422	185,803	89,708	13,561	403,962
Qalyob	1,315,323	67,564	115,985	133,451	82,376	2,697	367,191
Qanater	2,481,551	101,403	267,817	269,127	157,636	73,828	675,386
10th of Ramadan City	701,121	153	333,259	129,096	42,139	6,540	254,027
Total	**25,491,127**	**448,510**	**2,964,845**	**4,363,168**	**1,517,543**	**1,014,232**	**7,861,745**

Estimating Generated Trips for 2010 and 2030

To relate generated trips to the socioeconomic variables, we regressed generated trips on population, employment and total number of students in 2010 and 2030. Given the strategic nature of this study, this model represents an imperfect but adequate approach to relating generated trips to the socioeconomic variables. The relationship we estimated is shown below:

$$Y_{Trips} = 0.138\ X_{Population} + 0.0364\ X_{Employment} + 0.926\ X_{Students} + 95360$$

Figures 3.4 and 3.5 show the trips generated from each of the 18 zones for the years 2010 and 2030, respectively. Figure 3.6 shows the difference in generated trips between 2030 and 2010 for each of the 18 zones. As was expected, most of the growth in trips generated took place in the new peripheral cities.

Figure 3.4 Estimated Trips Generated
2010

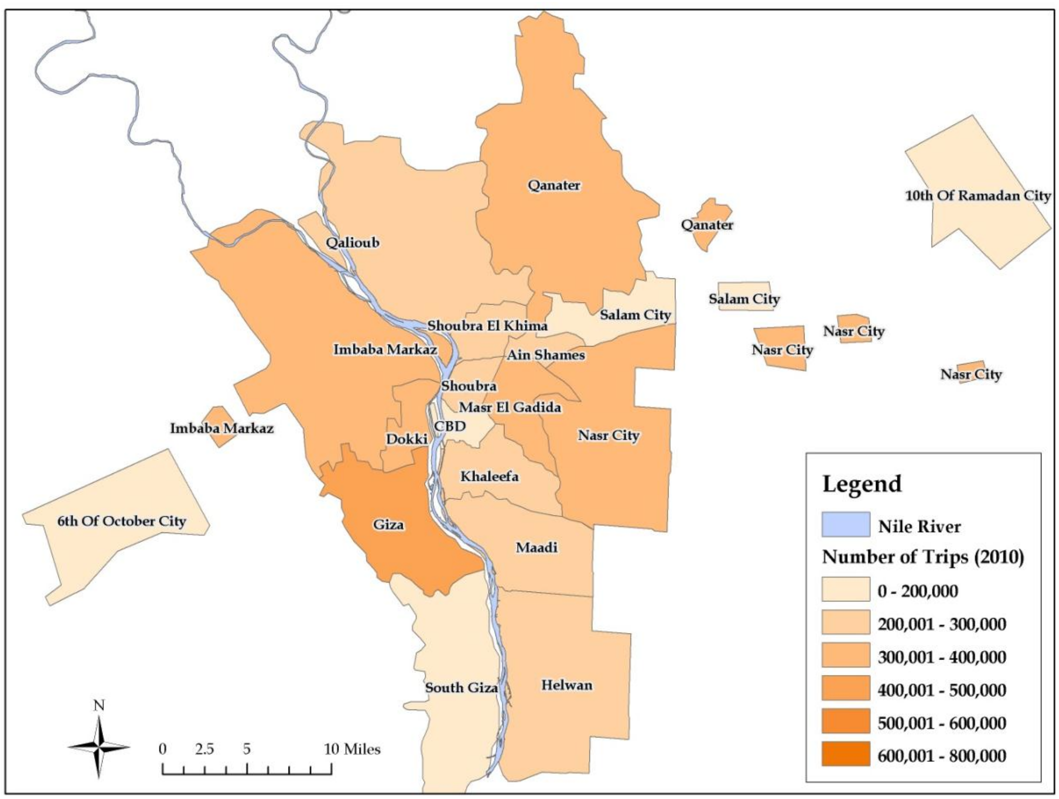


Figure 3.5 Forecasted Trips Generated
2030

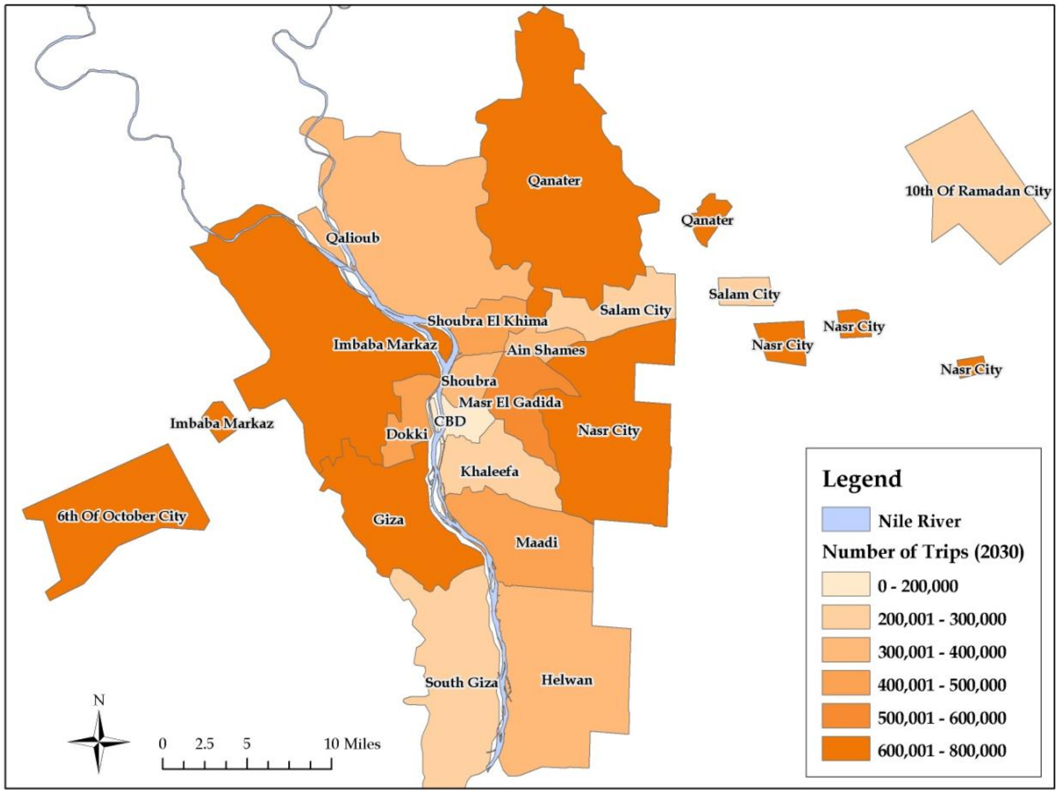
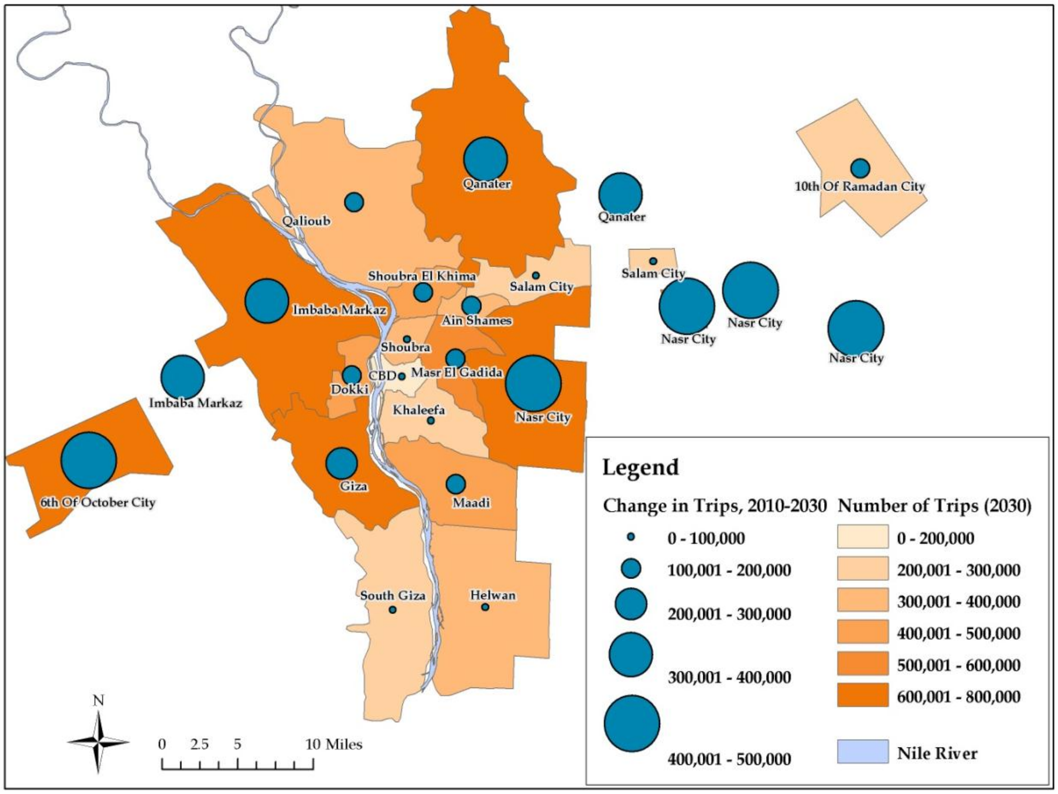


Figure 3.6 Growth in Trips by TAZ
2010 to 2030



Estimating Trips for Low and High Growth Scenarios

Given the uncertainty in the data about the factors affecting generated trips, we decided to estimate future trips for several different growth scenarios incorporating different growth rates relative to the baseline scenario. We varied the growth rates going from a minimum of 100 percent less growth relative to the baseline (shrinkage) to 200 percent growth relative to the baseline. The forecasts for each of these scenarios represent the bound of what we view as plausible futures.

Table 3.2 Range of Socioeconomic and Trip Generation Forecasts

Variation in Socioeconomic Growth Rates Relative to Baseline	Resulting Impact on Generated Trips
-100%	-31%
-50%	-15%
+50%	15%
+100%	31%
+200%	61%

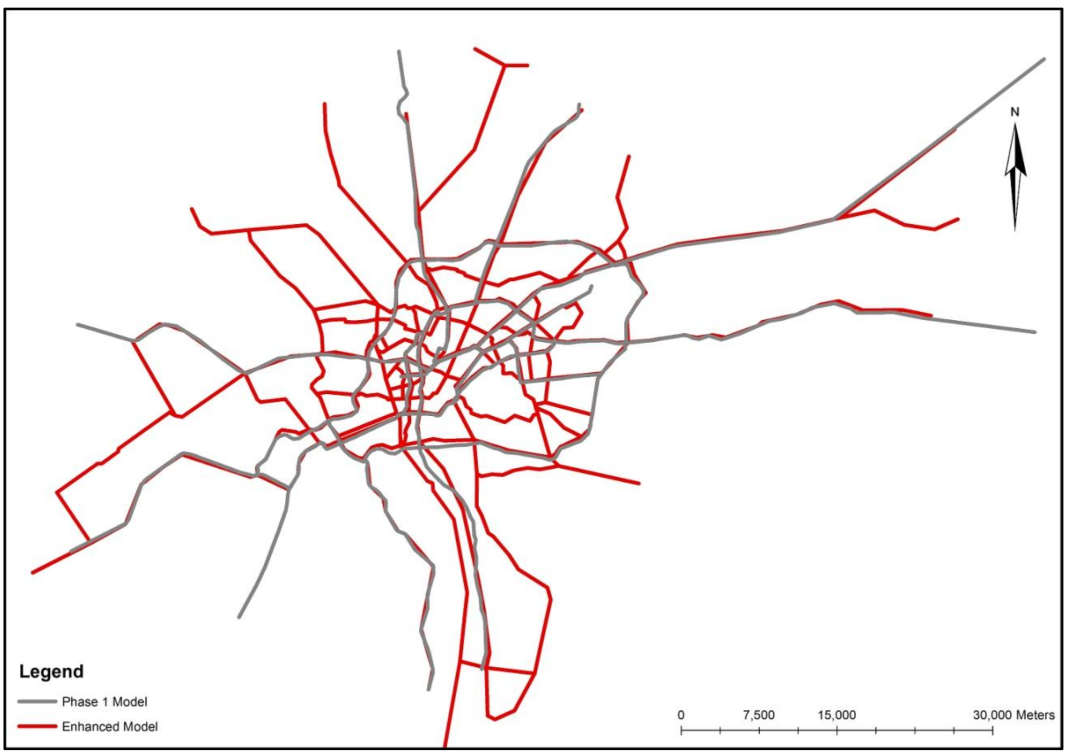
Development of Baseline Network for 2010

The road network used in Phase 1 included 11 major corridors with a total length of 640 km and 1,703 lane-km. The model road network included Inter-Urban Primary Highways, Regional Primary Highways, Urban Expressways, and Urban Primary Streets, with capacities ranging between 1,800-2,000 vehicles, per lane, per hour and depending on the type of road, speeds between 60 and 100 kph.

The Phase 1 road network was enhanced using new GIS data giving additional network details and attributes, namely: road hierarchy, number of lanes, and direction. Figure 3.7 compares the Phase 1 and 2 road networks for 2010.

The additional roads included in the Phase 2 GCMA model result in a total road network length of 865 km and 2300 lane-kilometers.

Figure 3.7 Phase 2 Model Network
2010



Development of Baseline Network in 2030

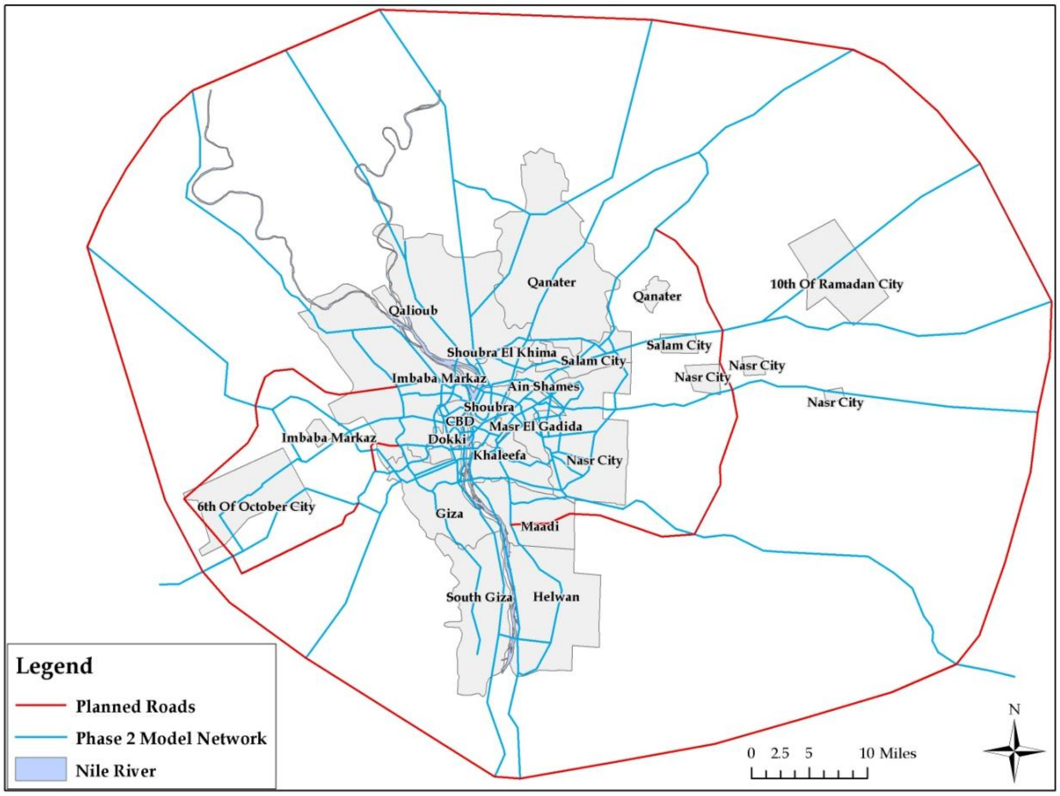
Assessing the performance of policy measures to reduce congestion in 2030 requires having a point of comparison in 2030. Thus, a baseline network is required for 2030. The 2030 baseline network that we used included proposed and planned major road projects that are likely to be ready and in operation by 2030. These projects were identified by reviewing previous studies and through stakeholder input. Table 3.3 summarizes the roads assumed to be ready and operational in 2030 (that currently are not in existence). Figure 3.8 shows the 2030 baseline network. Since the model only includes a road network, projects involving pedestrians, bicycles or transit were not considered as part of this exercise. Of course, if non-road infrastructure and/or services were to be available in 2030, this would have an effect on the level of congestion on the roads. Thus, the potential effect of such non-road infrastructure and facilities is considered through off-model analysis. Specifically, Metro Line 3 is included.

The traffic demand forecasts and their assignment to the model road network for both 2010 and 2030 are considered in the subsequent section.

Table 3.3 Planned and Programmed Roads through 2030

Road	Classification	Number of Lanes	Posted Speed	Capacity (Veh/Lane/Hr)
Route A	Urban Primary Street	2	60	1,800
Route B	Regional Primary Highway	4	90	2,000
Route C	Interurban Primary Highway	3	90	2,000
External Ring Road	Regional Primary Highway	4	90	2,000

Figure 3.8 Future Year Baseline Network with Planned and Programmed Projects
2030



TRAVEL DEMAND FORECASTS

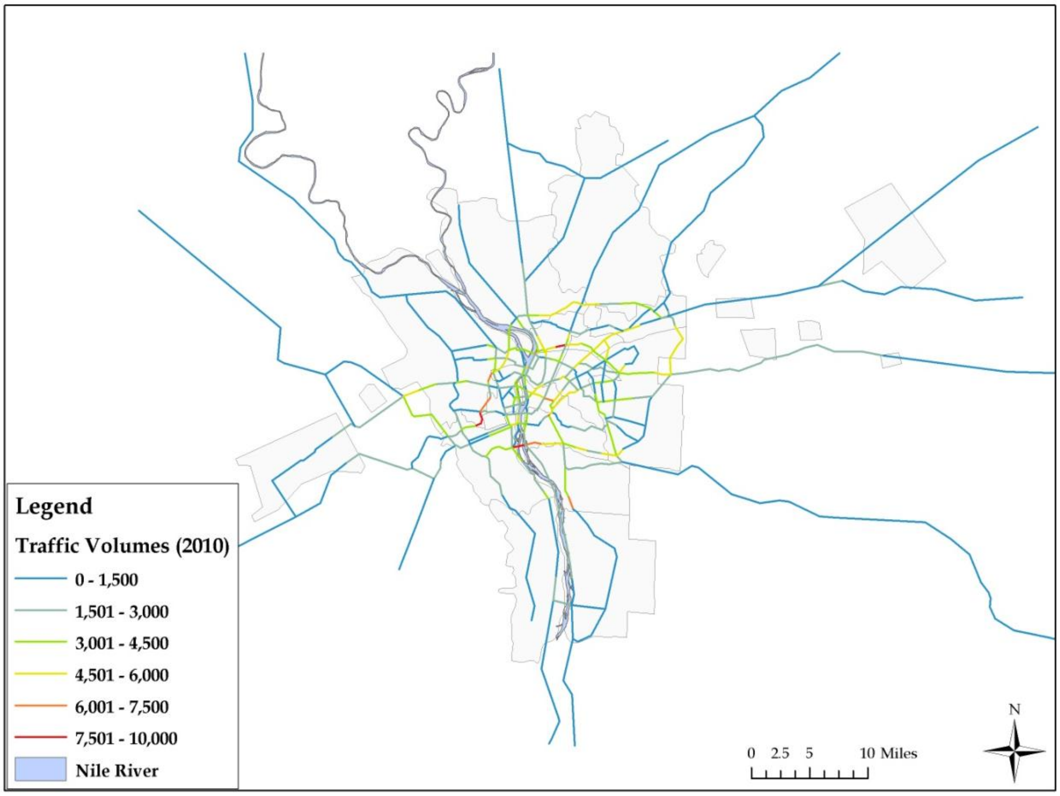
Origin-destination (O-D) matrices take trips generated for each TAZ and "distribute" them between zones. The relative distribution of trips from the JICA Study was used to construct both the 2010 and 2030 O-D matrices. The resulting matrices are provided in Appendix E.

2010 Estimated Traffic Volumes

The GCMA model was used to estimate traffic conditions for the year 2010 (the base year), as a means of helping to calibrate the model to existing conditions and serve as a relative comparison for 2030 forecasts. These relative changes could then be applied to actual 2010 volumes to estimate 2030 conditions under the baseline, no-build scenarios as well as with different congestion mitigation strategies.

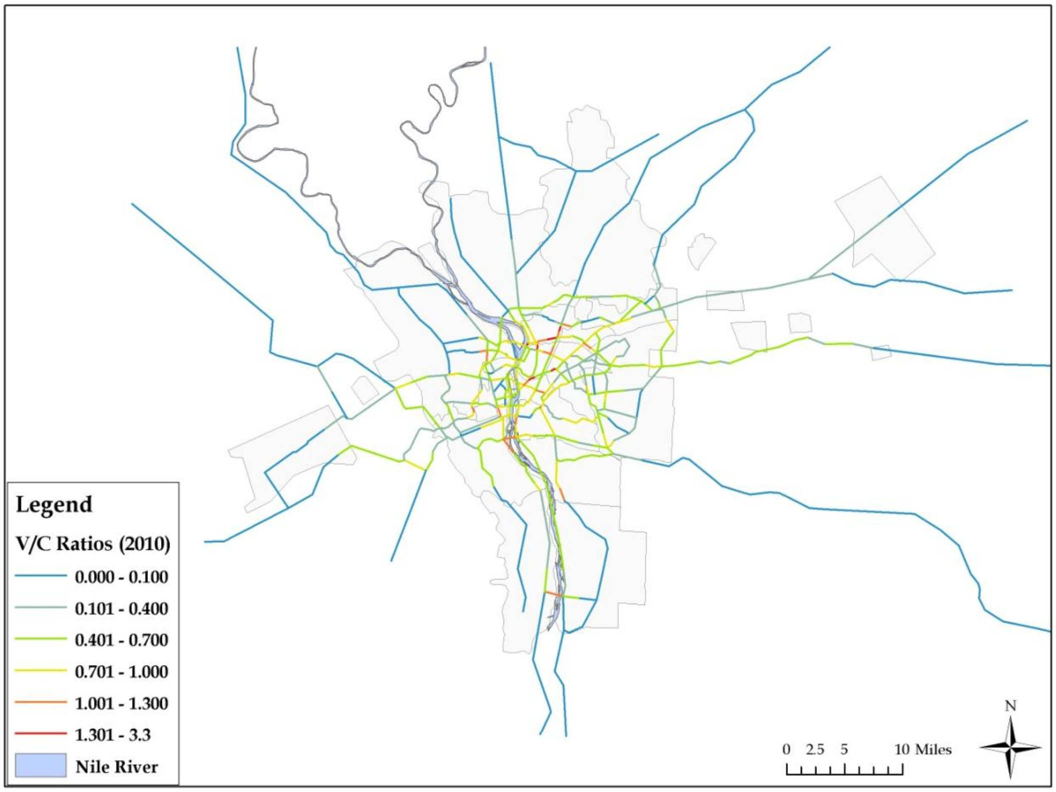
The estimated 2010 hourly traffic volumes on the road network, based on the GCMA model, are shown in Figure 3.9. Figure 3.10 shows the volume-capacity ratios for each road segment.

Figure 3.9 Estimated Traffic Volumes
2010



The highest hourly traffic volumes in the model, and the highest volume-capacity ratios (an indicator of congested conditions), are in the core of the GCMA. The relative distribution of high-volume segments is similar to observed conditions (Figure 3.10). The model network is only representative, covering only major corridors, while trips in the O-D matrix represent all vehicle trips in the region. This causes the model to "force" all traffic onto these major corridors, resulting in traffic volumes that are higher than observed conditions. However, the GCMA model is used only to compare relative changes in congestion between 2010 and 2030 for no-build and strategy scenarios.

Figure 3.10 Estimated Volume-Capacity Ratio
2010



2030 Forecasted Traffic Volumes

The 2030 O-D matrix for the baseline, medium growth scenario (Appendix E) was assigned on the 2030 model network. Figure 3.11 shows forecasted traffic volumes for 2030. Figure 3.12 shows the volume-capacity ratios. Some road sections with high traffic volumes have relative low volume-capacity ratios due to their high capacity. Figure 3.13 shows how traffic volumes are projected to increase from 2010 to 2030; Figure 3.14 shows how volume-capacity ratios (and therefore congested conditions) are expected to change as a result of these volume changes.

Figure 3.11 Forecasted Traffic Volumes
2030

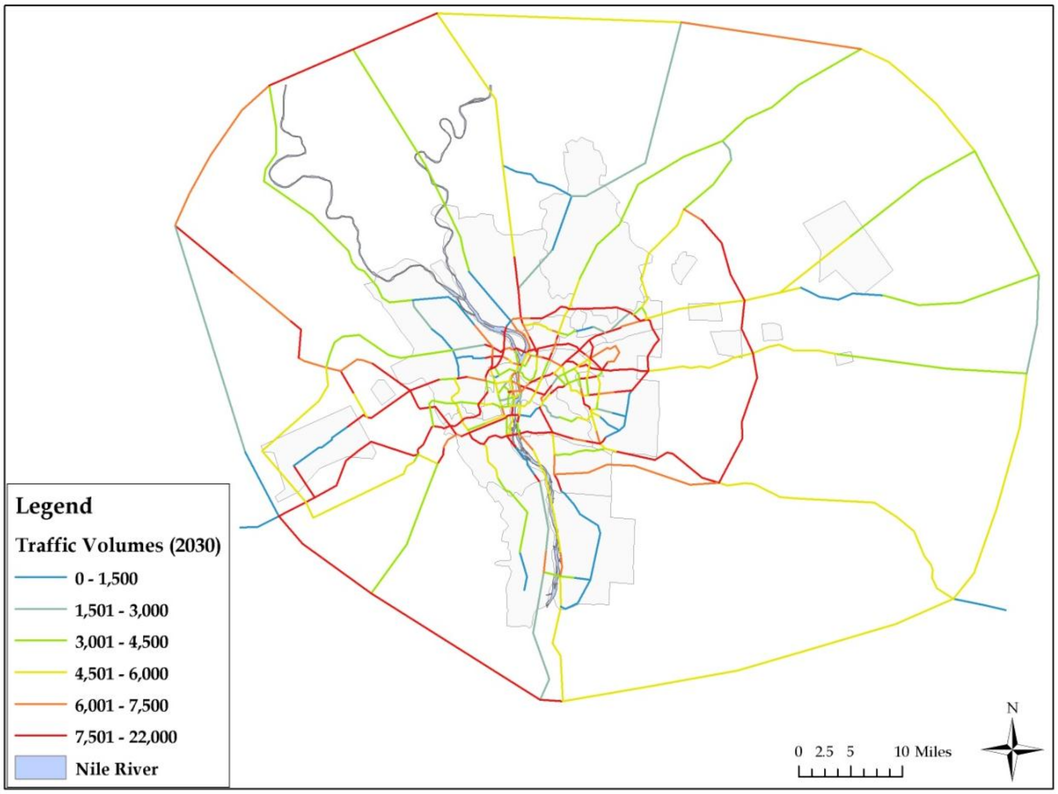


Figure 3.12 Forecasted Volume-Capacity Ratio
2030

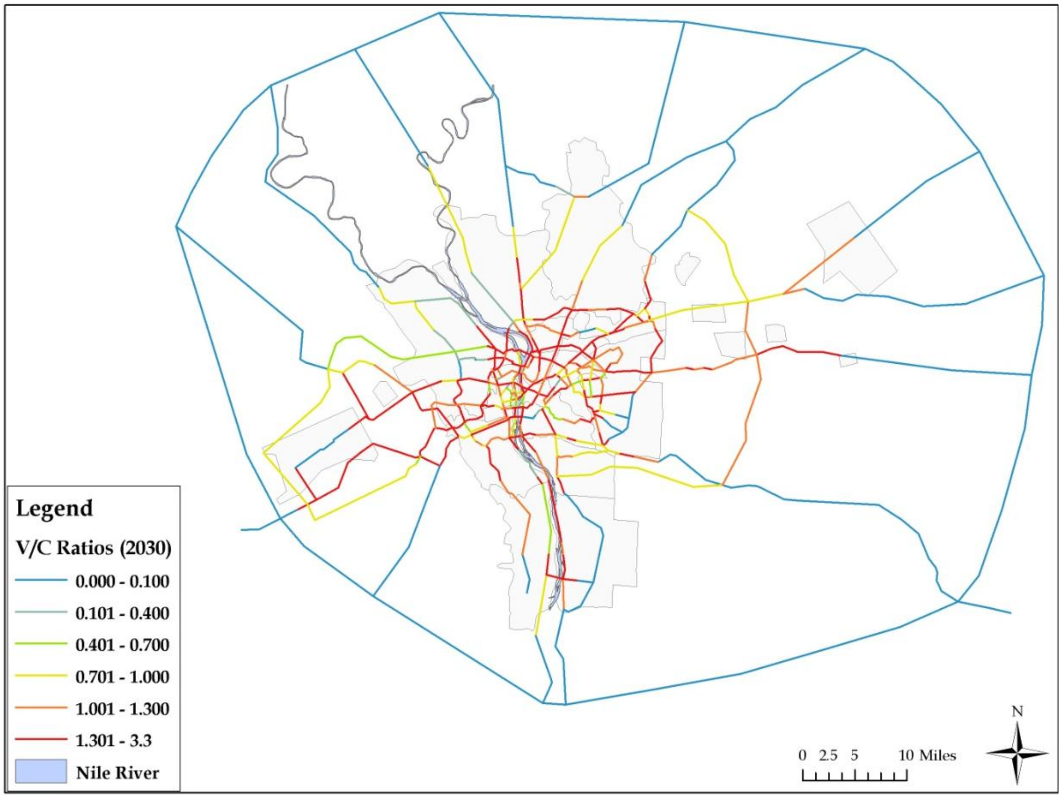


Figure 3.13 Growth in Traffic Volumes from 2010 to 2030

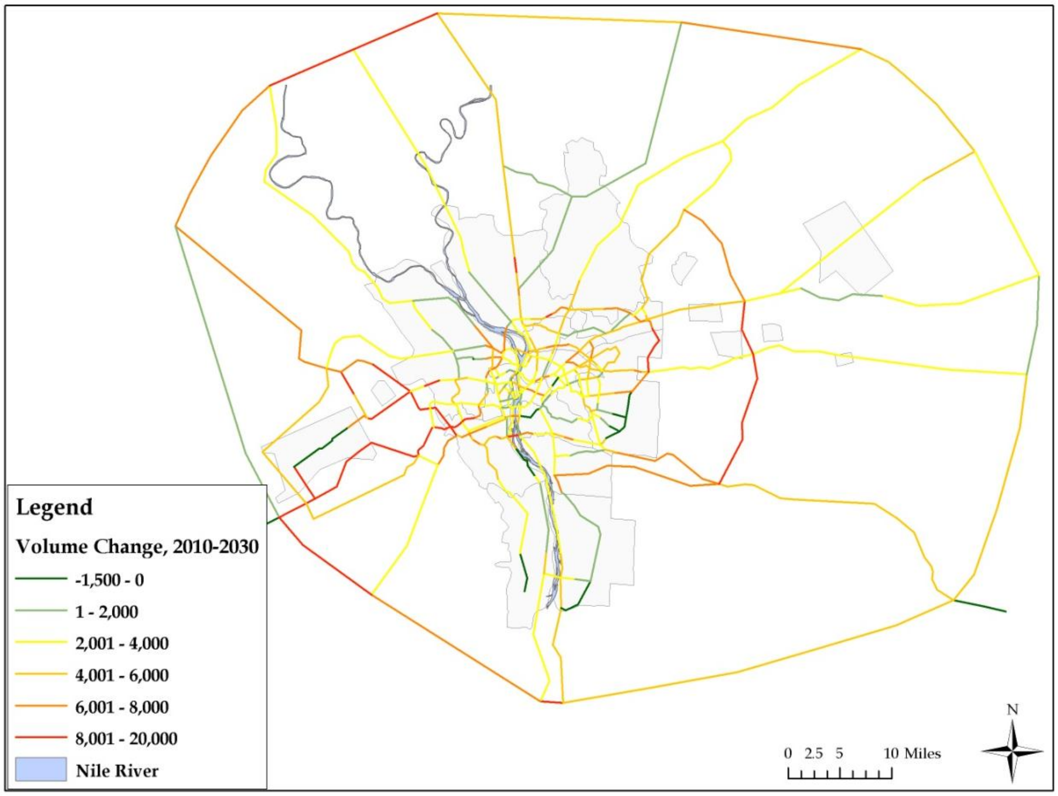
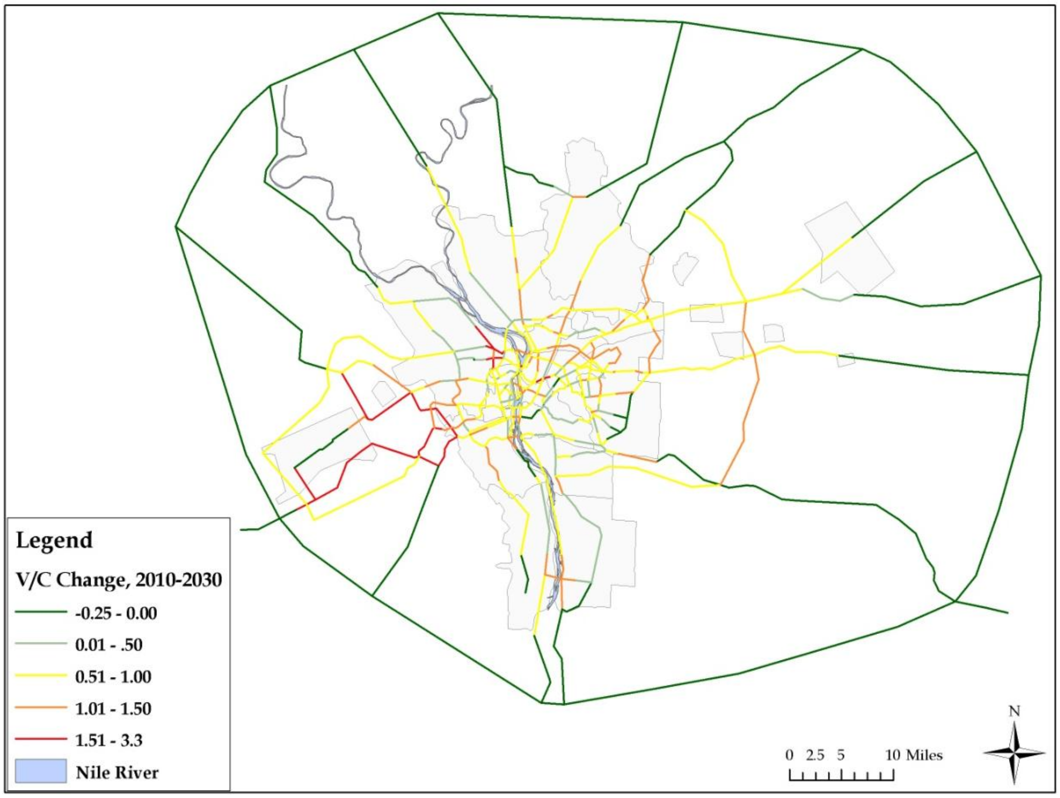


Figure 3.14 Changes in Volume-Capacity Ratios from 2010 to 2030



4.0 Direct Costs of Congestion

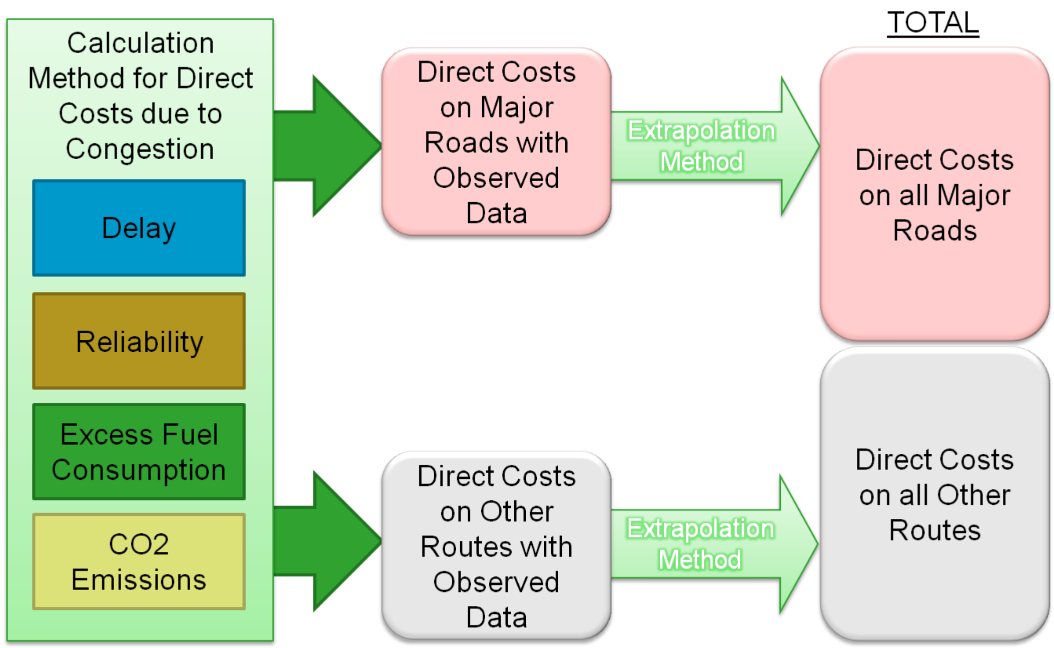
INTRODUCTION

The direct costs of congestion are estimated by calculating the costs of:

- **Travel time delay.** Travel time delay includes two types of delay that occur during congestion: recurring and nonrecurring delay. Recurring delay is the typical delay resulting from demand exceeding roadway capacity, while nonrecurring delay is a result of accidents, vehicle breakdowns, security checks, and other unpredicted occurrences.
- **Travel time reliability.** Reliability reflects the predictability of travel time of a corridor. A corridor where the travel time varies significantly is unreliable and passengers will avoid using it unless it is their only option. Thus, reliability is an important factor that should be included in the direct cost of traffic congestion.
- **Excess fuel consumption and excess fuel subsidy.** Traffic congestion results in an excess consumption of fuel, including diesel and gasoline, which contributes to the direct cost of congestion. The total cost of excess fuel consumption is borne by auto users as well as the government in the form of subsidy.
- **CO_2 emissions due to excess fuel consumption.** Increasing fuel consumption generates an increase in CO_2 emissions which contributes to global climate change. Emissions caused by excess fuel consumption during congestion are computed as part of the direct cost of congestion.

The process for estimating these costs is outlined in Figure 4.1. Each direct cost element is calculated for each of the 11 sample major corridors, with data from Phase 1, and 8 sample other routes with data from this phase. These costs are then extrapolated to the rest of the network to find total direct costs due to congestion.

Figure 4.1 Overview of Direct Cost of Congestion Estimation Approach



Calculating Direct Costs on the Sample Corridors

Travel Time Delay Costs

Delay cost usually comprises the largest percentage of direct and indirect costs of congestion, and it is the most fundamental: it represents the direct user cost of wasted time. The cost of travel time delay is divided into two components: recurring and nonrecurring delay. Recurring delay represents time wasted due to standard, daily congestion caused by demand that exceeds capacity of the system. Nonrecurring delay represents time wasted due to unexpected events, such as accidents. To estimate recurring and nonrecurring delay costs, the value of time, vehicle occupancy, and load factors should be determined for the diverse vehicular modes that exist in the GCMA.

These two elements of delay are calculated in the following steps:

1. For a speed index less than 0.8 on the surveyed routes (as indicated in Section 3.0), the average peak-hour speed and the volume of vehicles for each mode are computed for the corresponding peak period.
2. The vehicle occupancy and load factors for each mode are tabulated based on locally provided data and adjusted to the year 2010 (Tables 4.1 and 4.2).

Table 4.1 Passenger Vehicle Occupancy Factors (Passengers/Vehicle)

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

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

Table 4.2 Payload Factors (Tons/Vehicle)

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.

To estimate the number of vehicles on the local routes, classified counts have been conducted for Routes 3, 6, and 7. The average modal split calculated from these three routes – described in Section 3.0 – is generalized to split the unclassified counts of Routes 1, 2, 4, 5, and 8. In order to estimate the number of transit riders, the number of minibuses, microbuses and big buses are multiplied by their capacities (assuming the buses are almost at full capacity during the congested periods). The capacity of both minibuses and microbuses is assumed to be 15, and the capacity of big buses is assumed to be 60.

In addition, the calculated number of trucks is multiplied by the load capacities shown in Table 4.2 to convert the values to tons. Since in the modal split there are only two categories of trucks, for small trucks the factor is assumed to be average of light and medium trucks and is 7 tons/truck. For heavy trucks, the factor for large trucks is used which is 15 tons/truck.

3. In order to monetize the delays, values of time for passenger car users, taxi users, transit riders and trucks were used from local studies and adjusted to 2010 (Table 4.3).

Table 4.3 Value of Time for Transport User Classes

Passenger Car Users (LE/Hour)	Taxi Users (LE/Hour)	Transit Riders (LE/Hour)	Freight Transporters (LE/Ton)
13.8	5.4	3.5	4.2

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

Developing Harmonized European Approaches for Transport Costing and Project Assessment (HEATCO), May 2006.

The value of time of motorcyclists is assumed to be 5 LE/hr, which is close to the range of taxis and transit since passengers using these modes of transport in GCMA are assumed to have a similar range of income.

4. To compute the nonrecurring delay cost the incident delay ratio for each road is determined. 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 (i.e., daily traffic influencing events recorded in the floating car survey). In addition, a methodology developed by TTI is used to model the effect of incidents based on the design characteristics and estimated volume patterns.

   Incident delay occurs differently on streets than it does on freeways. While there are driveways that can be used to remove incidents on streets, 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. In Phase 1, the road incident delay factors for the major corridors were estimated as being between 110 to 160 percent of arterial street recurring delay depending on:

   – Number of accidents;
   – Security checks;
   – Vehicle breakdowns;
   – Random microbus stops; and
   – Random pedestrian crossings (see Table 4.4)

Table 4.4 Incident Delay Ratio for the 11 Major Corridors

	1	2	3	4	5	6	7	8	9	10	11
Incident Delay Ratio	1.3	1.1	1.6	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1

During the survey of other routes, no accidents, security checks, or vehicle breakdowns were recorded. Consequently, the incident delay factors in Table 4.5 were adopted based on the number of random pedestrian crossings and random vehicle stops, taking into consideration that the latter may cause accidents and therefore results in delays. A linear relationship was assumed between the number of random events and the incident delay ratio, bounded by the minimum and maximum ratios established for the major corridors.

Table 4.5 Incident Delay Ratio for the 8 Other Routes

	1	2	3	4	5	6	7	8	9	10	11
Random Vehicle Stops	16	4	9	17	35	52	18	26	16	4	9
Random Pedestrian Crossings	47	29	33	39	87	93	53	88	47	29	33
Incident Delay Ratio	1.2	1.1	1.1	1.2	1.6	1.6	1.2	1.6	1.2	1.1	1.1

5. 250 working days per year was assumed for annualizing the daily survey data.
6. The recurring delay is then estimated based on the time wasted due to road capacity failure and calculated using the following formula:

$$\textbf{Recurring Travel Time Delay}_{(\$)} = \sum_{for\ all\ vehicular\ modes} \begin{matrix}\textbf{Vehicle}\\ \textbf{Occupancy}\end{matrix}_{\left(\frac{passenger}{vehicle}\right)} \times \begin{matrix}\textbf{Value}\\ \textbf{of Time}\end{matrix}_{\left(\frac{\$}{\frac{hour}{ton}}\right)} \times 250\ \textbf{WorkingDays} \times \textbf{Length of Corridor}_{(km)} \times \textbf{Volume of Vehicles at Congested Period}_{(pcu)} \times \left(\frac{1}{\textbf{Average Congested Hour Speed}_{\left(\frac{km}{hr}\right)}} - \frac{1}{\textbf{Free Flow Speed}_{\left(\frac{km}{hr}\right)}}\right) \quad \text{eq. 1}$$

7. The nonrecurring delay is estimated by multiplying eq.3 for recurring delay with an incident delay factor which varies in accordance with the frequency of incidents that occur in the corridor (accidents, vehicular breakdown, etc.), calculated in step 4:

$$\textbf{Nonrecurring Travel Time Delay}_{(\$)} = \sum_{for\ all\ vehicular\ modes} \textbf{Incident Delay Ratio} \times \begin{matrix}\textbf{Vehicle}\\ \textbf{Occupancy}\end{matrix}_{\left(\frac{passenger}{vehicle}\right)} \times \begin{matrix}\textbf{Value}\\ \textbf{of Time}\end{matrix}_{\left(\frac{\$}{hour/ton}\right)} \times 250\ \textbf{Working Days} \times \textbf{Length of Corridor}_{(km)} \times \textbf{Volume of Vehicles at Congested Period}_{(pcu)} \times \left(\frac{1}{\textbf{Average Congested Hour Speed}_{\left(\frac{km}{hr}\right)}} - \frac{1}{\textbf{Free Flow Speed}_{\left(\frac{km}{hr}\right)}}\right) \quad \text{eq. 2}$$

Travel Time Reliability Costs

A variety of indicators, such as standard deviation, coefficient of variation, 95thpercentile, and the buffer time index, can be used to provide a range of perspectives on the reliability issue. In this study, the *Coefficient of Variation of Travel Time (COV)* is used based on the 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 corridor, for each peak period during the floating car survey. The reliability analysis is based on the estimated coefficients of variation of the corridors' average speeds, since there are variations in the length of the trips.

The observed variability in traffic speeds encapsulates 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 following approach was used to calculate the travel time reliability costs:

1. Based on the OECD research outcomes (2010) and the local conditions, the consultant assumed the following rates for monetizing travel time unreliability:

- **Passenger cars and motorcycles**: 1.0-minute travel time variation is equivalent to 0.9 minutes in travel time.
- **Public transport, including taxis**: 1.0-minute travel time variation is equivalent to 1.1 minutes in vehicle travel time.

The perception of reliability 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 a reliable source for economic valuation of the buffer time index, the standard deviation of travel time derived from the COV in economic analyses was used. Moreover, due to the lack of data for freight, this was not included in calculating the cost of reliability.

2. The following formula was then used to calculate the economic cost of reliability, using the average peak-hour speed and the volume of vehicles for each mode calculated in Step 1 for the Delay Costs and using the same values of time from Step 3:

$$\textbf{Reliability}_{(\$)} = \textbf{Monetization Factor} \times \left(\frac{\textbf{Coefficient of Variation (am)} + \textbf{Coefficient of Variation (pm)}}{2}\right) \times \frac{\textbf{Length of Corridor}_{(km)}}{\textbf{Average Congested Hour Speed}\left(\frac{km}{hr}\right)} \times \textbf{Vehicle Occupancy}_{\left(\frac{passenger}{vehicle}\right)} \times \textbf{Value of Time}_{\left(\frac{\$}{hour/ton}\right)} \times\times\ 250\ \textbf{Working Days} \times \textbf{Volume of Vehicles at Peak Period}_{(pcu)} \quad \text{eq. 3}$$

Excess Fuel Costs

As calculated by TTI, the fuel that is wasted due to congestion is the difference between the fuel consumed at peak and free-flow speeds. For the GCMA, it was calculated using the following approach for both diesel and gasoline use:

1. The percent split of the two fuel types is calculated for the major corridors. The average split of these 11 major corridors is applied to the remaining 8 local routes due to lack of data on the mode split for the local roads. Moreover, to calculate the total volume of vehicles during congested periods, each vehicle type is multiplied by its corresponding equivalent passenger car unit (PCU) volume and their sum represents the total volume of vehicles during the congested period (Table 4.6).

Table 4.6 Equivalent PCU Volume

Private Car	Taxi	Buses	Small Truck	Heavy Truck
1.00	1.25	2.25	2.00	2.75

Source: CREATS Phase 1.

2. The fuel price is based on an interview with a petroleum company 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; and

– Diesel: 1.10 LE.

Furthermore, both passengers and government, in the form of a subsidy, contribute to the cost of wasted fuel. A fuel subsidy of 2.2 LE/Ltr for gasoline and 1.1 LE/Ltr for Diesel has been assumed according to GTZ Transport Policy Advisory reported in International Fuel Prices (2009). Table 4.7 summarizes the fuel cost and fuel subsidy adopted in the calculations of the direct economic cost of congestion.

Table 4.7 Fuel Cost
Gasoline and Diesel

Fuel Cost (LE/Litre)		Fuel Subsidy (LE/Litre)		Total Cost(LE/Litre)	
Gasoline Cost	Diesel Cost	Gasoline Cost	Gasoline Cost	Diesel Cost	Gasoline Cost
1.8	1.1	2.2	1.8	1.1	2.2

Therefore, the cost associated with excess fuel consumption incorporates the subsidy cost paid by the government, as well as the cost borne by the users. Hence, the total amount of fuel wasted is multiplied by 4 LE/liter and 2.2 LE/liter for gasoline and diesel, respectively.

3. Next, the average fuel economy is calculated to estimate the fuel consumption of the vehicles in congested and uncongested conditions. The following equation is a linear regression applied to a modified version of fuel consumption reported by Raus (2).

$$\textit{Average Fuel Economy}_{\left(\frac{km}{L}\right)} = \left(8.8 + 0.25 \times \textit{Average Congested Hour Speed} \times \frac{miles}{1.6\ km}\right) \frac{miles}{gallon} \times \frac{1.6\ km}{miles} \times \frac{1\ gallon}{3.79\ litres} = 3.71 + 0.066 \times \textit{Average Congested Hour Speed} \quad \text{eq. 4}$$

4. Next, a formula is derived by considering both the travel time and the travel speed of the given period to calculate the amount of fuel used during the trip. The excess fuel is estimated as the difference between fuel consumed during the congested period and during the free-flow period and is calculated as follows:

$$\textit{Daily Fuel Wasted}_{(L)} = \textit{Congested Travel time}_{(hours)} * \frac{\textit{Average Congested Hour Speed}_{(km/hour)}}{\textit{Average Fuel Economy (peak hour)}} - \textit{Free Flow Travel Time}_{(hours)} * \frac{\textit{Free Flow Speed}_{(km/hour)}}{\textit{Average Fuel Economy (free flow)}}$$

eq. 5

5. The corresponding price of each type of fuel calculated above, along with the cost of the subsidy, is multiplied by the annual fuel wasted to compute the total cost of fuel wasted as stated in the formula:

$$\begin{aligned}\boldsymbol{Cost\ of\ Annual\ Fuel\ Wasted}_{(\$)} &= \boldsymbol{Daily\ Fuel\ Wasted}_{(L)} \times \mathbf{250} \\ &\times \boldsymbol{Total\ Volume\ of\ Vehicles\ During\ Congested\ Period}_{(pcu)} \\ &\times \%\ \boldsymbol{of\ Vehicles\ Using\ this\ Fuel\ Type} \times (\boldsymbol{Cost\ of\ Fuel\ Type}_{(\$/L)} \\ &+ \boldsymbol{Subsidy\ Cost\ of\ Fuel\ Type}_{(\$/L)})\end{aligned}$$

eq. 6

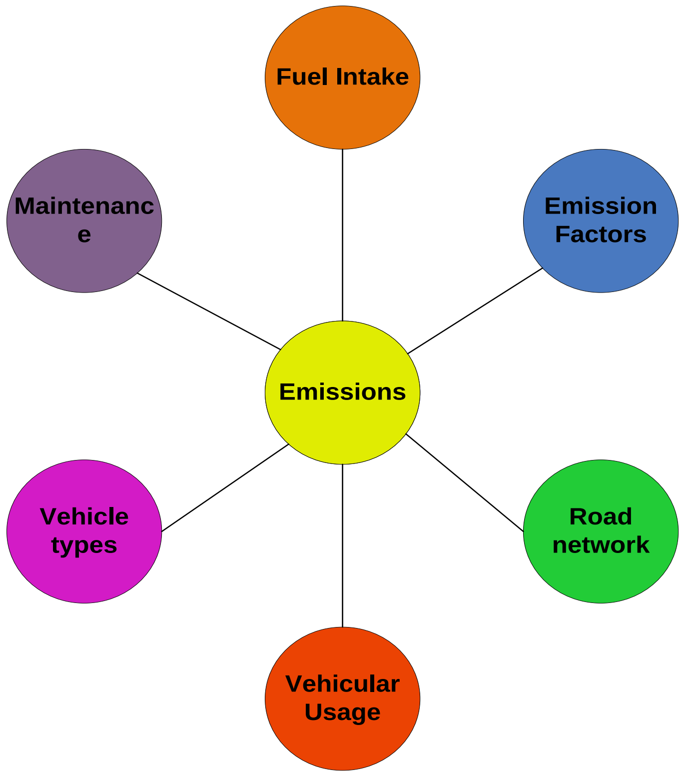
6. The total economic cost of fuel wasted paid by the passengers due to congestion is calculated by adding the cost of annual fuel wasted for each fuel type.

Associated Cost of CO_2 Emissions Due to Excess Fuel Consumption

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

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 means emissions increase and air quality will only get worse. Figure 4.2 provides the framework for the emissions from road traffic. The fuel intake is one of the elements determining the level of emissions.

Figure 4.2 Factors Impacting CO_2 Emissions



1. First CO_2 emissions rates by mode were found from the literature (Table 4.8). For the purpose of calculating emission costs, the excess gasoline wasted is multiplied by a factor of 2.4 kg/l, and the excess diesel fuel wasted is multiplied by 2.41 kg/l.
2. Thus, the annual CO_2 emission caused by excess fuel consumption due to congestion is estimated using the following formula:

$$\boldsymbol{CO_2\ Emission\ Cost}_{(\$)} = [\boldsymbol{Excess\ Gasoline\ Wasted} \times \boldsymbol{Emission\ Factor} + \boldsymbol{Excess\ Diesel\ Wasted} \times \boldsymbol{Emission\ Factor}] \times \boldsymbol{Cost\ Factor}_{(LE/Ton)} \times \frac{\boldsymbol{ton}}{\boldsymbol{1000}_{kg}}$$

eq. 7

Table 4.8 CO_2 Emissions Rates by Mode

Mode	Rate (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. http://www.sim-air.org.

3. The emission cost for each corridor is estimated by converting emission weights to costs. A conversion factor 57 LE/ton was used based on World Bank estimates.

ESTIMATE OF DIRECT COSTS ON SAMPLE CORRIDORS

Based on the methodology described in the previous sections, the estimated direct congestion costs for the major and other sample roads are shown in Table 4.9. As was done in Phase 1, the cost calculations for the main corridors are based on the traffic volumes derived from the manual classified traffic count data of the JICA study dated 2005 and projected to the year 2010. Other routes come from surveys performed in this Phase 2 study.

The consultant also replicated the above calculations using the traffic volumes and the vehicle classification obtained from the traffic count survey conducted in July 2010 as part of Phase 1 for the major corridors, after using a seasonal adjustment factor of 6 percent calculated as follows:

$$\textbf{Seasonal adjustment} = \frac{\textbf{No of peak hour vehicles (pcu) JICA}}{\textbf{No of peak hour vehicles (pcu) SETS}} = \mathbf{1.06}$$

Table 4.9 Direct Cost Estimates for the Survey Data (Million LE)

	Major Corridors – Estimate 1	Major Corridors – Secondary Estimate	Other Routes
Source of Traffic Data:	**JICA Study Traffic Data**	**Phase 1 Traffic Data with Seasonal Adjustment**	**Phase 2 Traffic Data**
Travel Time Delay	2,689	2,305	450
Travel Time Unreliability	1,680	1,335	121
Excess Fuel Consumption	1,905	1,706	187
Excess CO_2 Emissions	70	62	7
Total Direct Cost	**6,343**	**5,408**	**765**

As a result, a second set of lower cost estimates on the major corridors was calculated as shown in Table 4.9. As discussed earlier in this report, this second set of estimates adjusts the baseline speeds from free flow speeds (initially) to off peak observed speeds, and takes into account travel seasonality as well.

Compared to the Phase 1 results, the first estimate (using the JICA data) for the corridors decreased by 11 percent and the second estimate (using the manual count data from Phase 1) decreased by 24 percent. Both values are retained to determine a lower and an upper bound for the congestion cost in GCMA.

EXTRAPOLATING COSTS TO THE ENTIRE GCMA

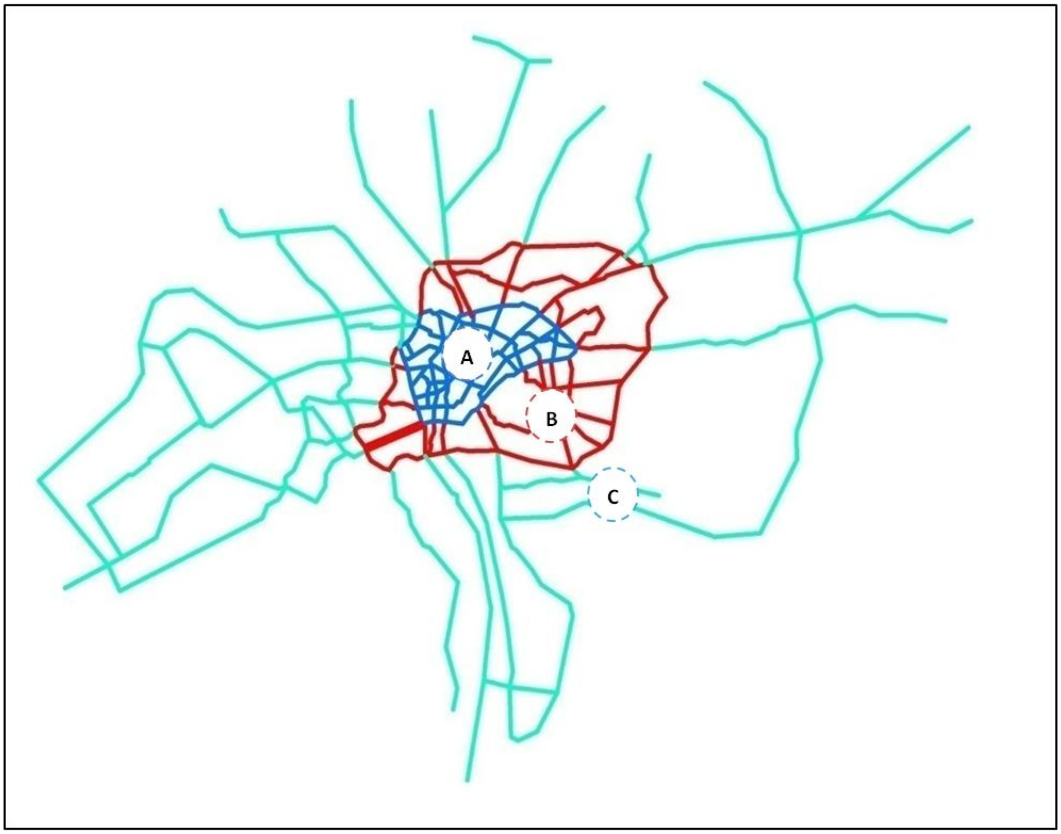
In Phase 1, an EMME model was developed based on the O-D matrix of the JICA study (representing GCMA with 18 traffic analysis zones), while the road network was defined as being the 11 major corridors. The total traffic in Cairo was then distributed on the corridors, and compared to the traffic count results obtained for the same corridors. The results were 50.4 percent (AM) and 50.9 percent (PM), and consequently the 50 percent ratio was used to extrapolate the cost to GCMA.

The procedure based on traffic volumes used in Phase 1 was not used in Phase 2 due to the dispersion and discontinuity of the survey sample and the data deficiencies for other roads in Cairo. This did not permit the development of the EMME model for the other road network. Instead, an alternative approach was used to extrapolate from the survey sample and estimate the cost on all major corridors and other roads in GCMA, within the time and budget limitations of this study.

Although the other roads were not modeled in EMME, the volume and capacity data of other road sample was used to calculate the V/C ratios in the extrapolation of both the major corridor and other road congestion cost. Two different approaches were used: one weighting the V/C ratios by lane-kilometers, and the other weighting the V/C ratios by traffic volumes. The extrapolation procedure treats the congestion cost of Cairo's central area versus two external areas differently by developing different weighted V/C averages for each.

This alternative approach that we used in Phase 2 is based on calculating a unit cost for each lane-km of the surveyed routes and then extrapolating it to the whole GCMA. The total numbers of lane-km per major corridor and other routes were calculated for both the sample and the entire GCMA. In addition, lane-kilometers were calculated for each of the central and external areas, since the roads within the central area are generally more congested than the roads lying outside this area. The central area is defined as the area delimited by Al Sudan Road and a segment of the Ring Road to the west, Manshiat El Gamal and El Kablat Road to the north, Hussein Kamel Road to the northeast and El Nasr Road to the East and the South. Figure 4.5 shows the delineations of the three zones overlaid on the model roadway network.

Figure 4.3 Three Zones Used for Extrapolating Costs



Further details and equations are provided in Appendix F. The cost of congestion on all major corridors is estimated to be 10.79 billion LE and is estimated to be 19.97 billion LE on local roads. This results in total direct costs in the GCMA for 2010 of 30.76 billion LE.

Forecasting Costs to 2030

To compute the forecasted direct cost of congestion in GCMA in the year 2030, the following steps were followed:

1. Similar to the methodology used in estimating the direct cost of congestion in the year 2010, the lane-kms of the total road network were calculated separately for each of the three zones for each road category (Major Corridors and Other Routes).
2. Two 2030 v/c ratios were calculated using the weighted lane-kms and the weighted traffic volumes for the three zones.
3. New sample costs on major corridors and other routes for the year 2030 are calculated to take into account the impact of the increased traffic on the cost of congestion on the sample roads. The new sample cost also takes into account the presence of Metro Line 3, which currently is under construction and is expected to be operational before the forecast year 2030. The impact of

this new metro line is accounted for in off-model adjustments to the sample cost and not in the traffic model as the model contains no public transport component. Traffic volumes of all road-based modes of transport included in the model (using the observed mode split) on the sample corridors impacted by the new metro line were adjusted by a certain percentage corresponding to the expected metro ridership, and then the sample costs were recalculated.

4. Using these weighted v/c ratios, the sample direct cost of congestion is extrapolated to produce the total GCMA direct cost of congestion.

Similar to 2010, the v/c ratios for major corridors were calculated based on the results of the EMME model using the volumes obtained from the EMME traffic assignment. As for the other routes, they were not represented in the EMME model due to lack of data related to this category of the road network, and therefore it was not possible to obtain v/c ratios from the EMME model. Accordingly, the v/c ratios were calculated based on the sample of selected roads belonging to this category of roads in each of the three zones.

The major difference between 2010 and 2030 calculations is that prior to extrapolating the sample cost to the entire GCMA in 2030, we first need to forecast (i.e., adjust) the 2010 sample costs on major corridors and other routes to the year 2030, in order to account for the increase in traffic volume on these sample roads. Further details on the methodology are provided in Appendix F

SUMMARY OF BASE YEAR DIRECT COSTS

Introduction

The approaches described in the previous sections for delay, reliability, fuel, and CO2 were used to estimate costs for the sample corridors, including both major and other routes, followed by the procedure to extrapolate them to the rest of the network. This section summarizes the total direct costs across the entire network in the GCMA.

Costs by Element

Delay

Travel time delay is highest for passenger cars and taxis on the major corridors, followed by transit ridersCorridors 1 and 3 exhibited the highest travel time delay. Transit riders incurred the largest travel time delay costs on other routes, followed by passenger cars, taxis and freight vehicles. Route 6 showed the highest cost of travel time delay due to transit usage in that route. In total across the entire GCMA network, travelers experienced an estimated 2.2 billion hours of delay in 2010, resulting in 112 hours of wasted time per year per resident. More than 14 billion LE, or 2,442 million USD, is wasted due to time spent delayed in congestion. About 35 percent of that occurs on major corridors. While there was not enough data to precisely determine the cost of delays from freight, a rough estimates indicates that the delay cost associated with freight taking place within the ring road in the GCMA is about 5%.

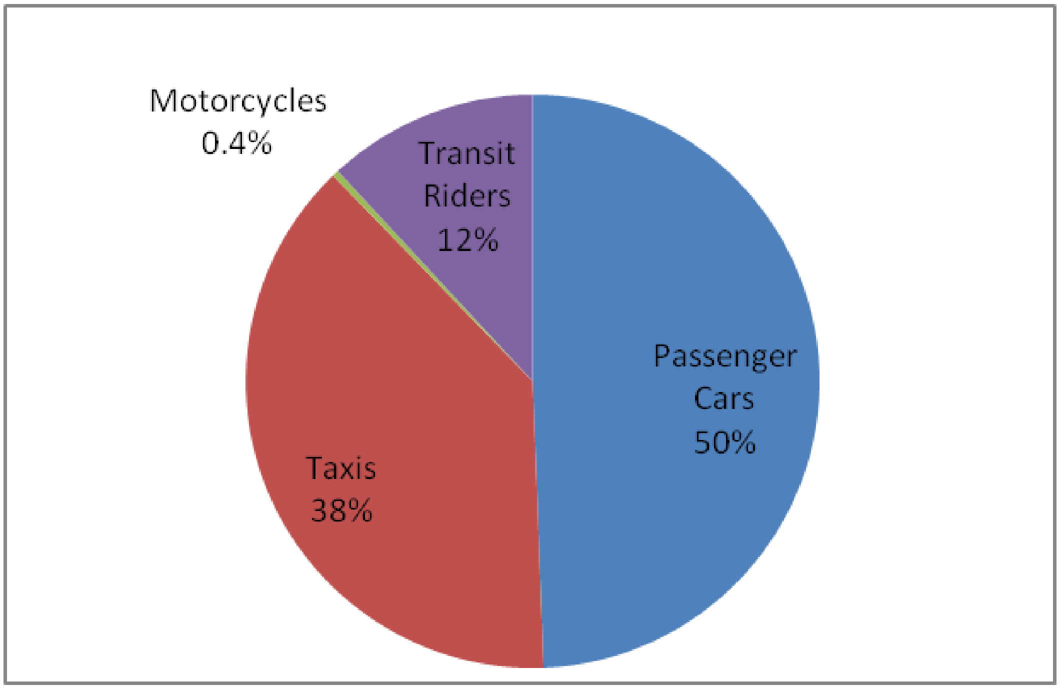
Figure 4.4 Share of Travel Time Delay Cost by Mode
2010

Reliability

Travel time reliability cost on the major corridors consists mainly of passenger cars, taxis and freight, with motorcycles being the lowest contributor for this cost. However, on other routes, transit incurs the highest costs from travel time reliability, followed by passenger cars. Taxis have a somewhat lower impact from this cost type. Since freight data are not available for analysis of reliability impacts on freight, results for freight impacts are not shown. However, the literature indicates that shippers are extremely concerned with reliability of the transport system and reliability has a major impact on shipping costs.

In total, over 9 billion LE are wasted by transportation system users due to unexpected delays. Over 64 percent of these occur on the lower functional classification other routes. This amounts to 70 hours of wasted time per resident per year due to reliability. Combined with lost time due to delay, it is nearly 200 hours per resident.

Figure 4.5 Share of Travel Time Reliability Cost by Mode
2010



Fuel

Excess fuel cost is mainly due to gasoline use rather than diesel. Corridors 1, 2, and 3 show the highest costs from excess fuel consumption, as do other Routes 5 (Gameat El Qahera) and 6 (El Malek Faisal Street).

In total 6.6 billion LE is wasted by both users and the government – through the government fuel subsidy – through vehicles setting in congestion, operating and inefficient, slower speeds, and frequent acceleration and deceleration due to congestion and unexpected incidents. About 35 percent of this occurs on major corridors, and about 89 percent of this cost is due to gasoline. This amounts to 1.9 billion liters wasted (Table 4.10), or about 100 liters per resident per year. Using the JICA origin-destination trip table that was utilized in the Phase 2 model for this study, this amounts to slightly under 2 liters per vehicle trip.

Table 4.10 Breakdown of Excess Fuel Consumption by Fuel Type
Millions of Liters

	Major Corridors	Other Routes	GCMA Total
Gasoline	548	1,018	1,566
Diesel	117	218	335
Total Fuel	665	1,235	1,900

CO_2

CO2 emissions are largely driven by fuel consumption and so follow a similar pattern. Corridors 1, 2, and 3 show the highest costs, as do other routes 5 (Gameat El Qahera) and 6 (El Malek Faisal Street). In total this amounts to more than 300 million LE, with 35 percent being due to congestion on other routes. About 86 percent of this cost is due to gasoline emissions. As shown in Table 4.11, in total that's 7.1 billion kilograms of CO2 emitted due to congestion, or 360 kilograms per resident per year or over 7 kilograms per vehicle trip. Total emissions due to all travel, including uncongested travel, is much higher that this total.

Table 4.11 Breakdown of CO_2 Emissions by Fuel Type
Millions of Kilograms

	Major Corridors	Other Routes	GCMA
CO_2 emission – Gasoline	2,130	3,956	6,086
CO_2 emission – Diesel	359	667	1,026
Total Fuel	2,489	4,622	7,111

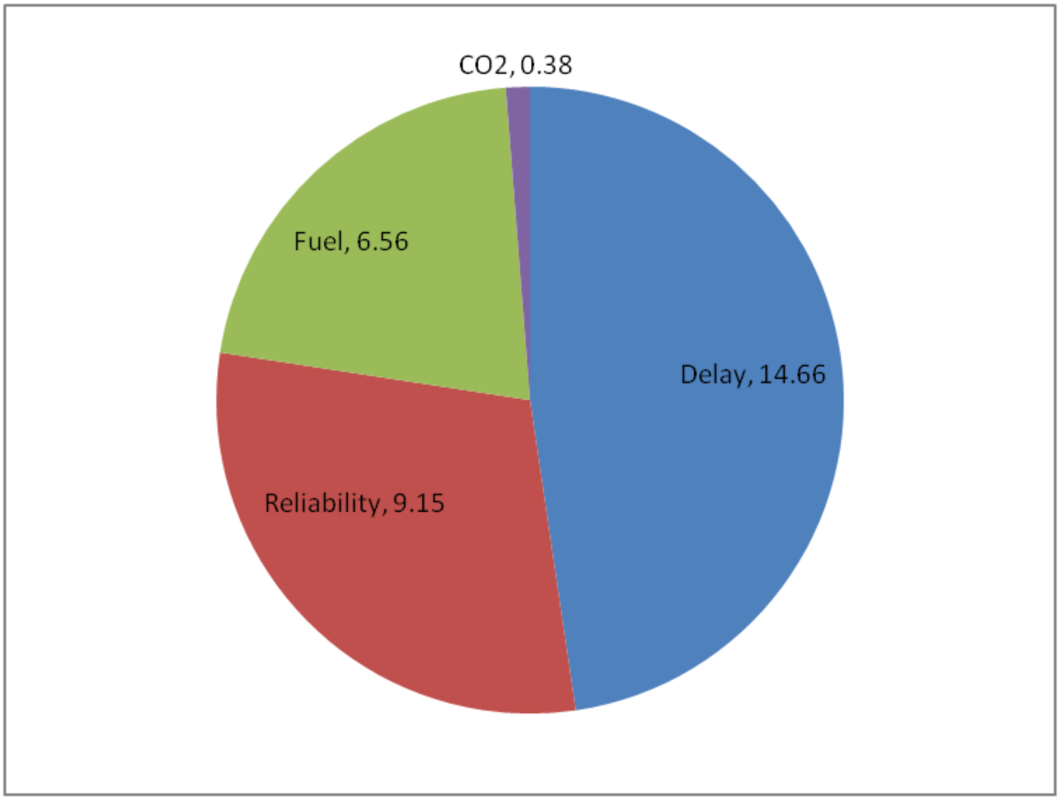
Summary of Costs

Table 4.12 summarizes the estimates of direct costs for 2010 in the GCMA. As a percent of combined direct and indirect costs, the direct costs account for about 64 percent of total costs. Lost time due to delay contributes to over 48 percent of direct costs in the GCMA (Figure 4.6). Approximately 2.2 million hours are wasted in congestion every year for citizens traveling in the GCMA, 14.7 billion LE of loss. Reliability is the second largest direct cost, at 30 percent, followed by fuel at 21 percent. CO_2 emissions contribute a relatively small amount to total costs of congestion; other emissions are included in the indirect cost calculations in Section 5.0.

Table 4.12 Summary of Base Year Direct Costs

Cost Component	Value	Annual Cost (Million USD)	Annual Cost (Billion LE)	Annual Cost/Capita (USD)	Percent on Major Roads
Delay	2.2B hours	2,442.6	14.66	125	35%
Reliability	1.4B hours	1,525.8	9.15	78	35%
Fuel	1.9B liters	1,093.6	6.56	56	35%
CO2	7.1B kg	63.3	0.38	3	35%
Total	**–**	**5,125.2**	**30.75**	**261**	35%

Figure 4.6 Distribution of Total Direct Costs (Billion LE, 2010)



Summary of Future Year Direct Costs

As shown in Table 4.13, the forecasted cost of congestion in the GCMA in the year 2030 was estimated to be 68.40 billion LE (in 2010 currency values). This amounts to a 122 percent increase in the cost of congestion over a 20-year period. For other socioeconomic scenarios, Tables 4.14 shows how the cost of congestion varies with increases or decreases in population and employment growth relative to the baseline forecast. For example, with -50 percent change in the growth rates, the trips generated varied by 15 percent whereas the cost of congestion varied by 21 percent. In all growth scenarios, however, the GCMA roads will be heavily congested in the year 2030 even if very optimistic low growth rates are assumed.

Table 4.13 Summary of 2030 Yearly Direct Costs

Cost Component	Value	Annual Cost (Million USD)	Annual Cost (Billion LE)	Annual Cost/Capita	Percent on Major Roads

				(USD)	
Delay	4.5B hours	5,435.0	32.61	192	35%
Reliability	2.9B hours	3,391.7	20.35	120	35%
Fuel	4.0B liters	2,431.7	14.59	86	35%
CO2	14.9B kg	141.7	0.85	5	35%
Total	**–**	**11,400.0**	**68.40**	**402**	35%

Table 4.14 Range of Direct Costs Based on Socioeconomic Growth Scenario

Percent Difference in Annual Growth from Baseline	-100%	-50%	+50%	+100%	+200%
Total projected cost on Major Corridors (B LE)	13.86	18.93	29.16	33.69	42.66
Total projected Cost on Other Routes (B LE)	25.64	35.01	53.96	62.35	78.95
Relative total increase to base scenario	-42%	-21%	21%	40%	78%
Total Projected Cost	**39.50**	**53.94**	**83.11**	**96.05**	**121.61**

5.0Indirect Costs of Congestion

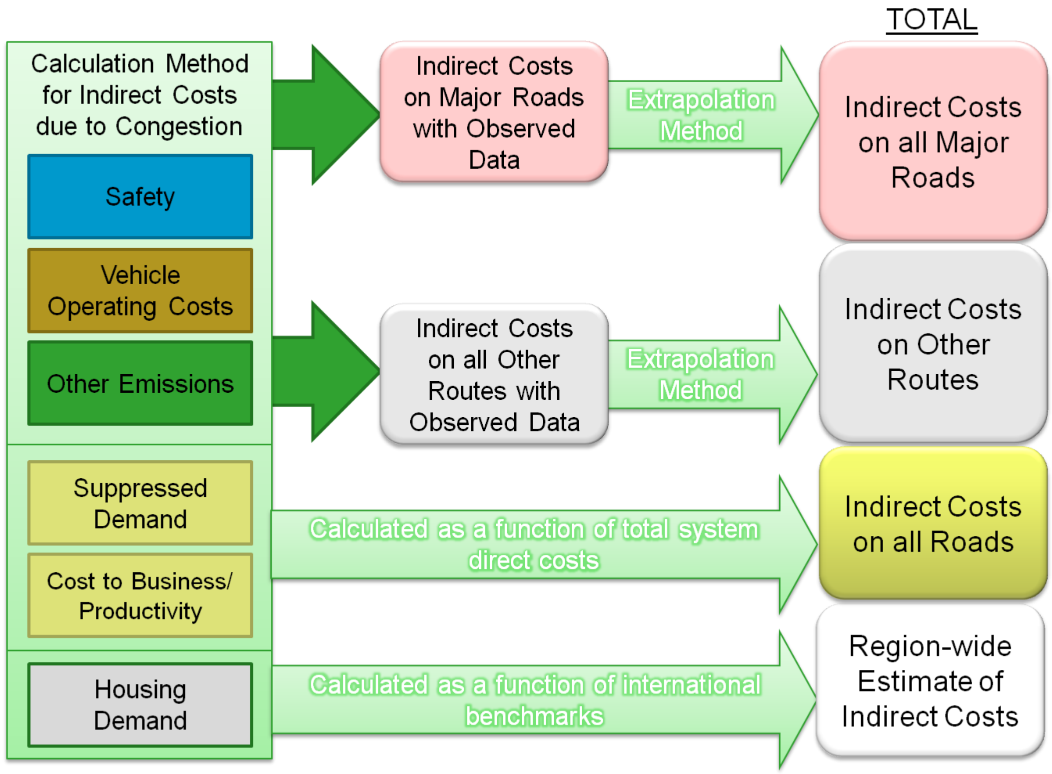
INTRODUCTION

In this section, we outline the estimation of and results from the analysis of indirect costs of congestion. The indirect costs included in this analysis of indirect costs include the costs arising from:

- Road safety;
- Vehicle operating costs;
- Health and environmental impacts from poor air quality;
- Labor productivity, business operations, and agglomeration effects;
- Housing; and
- Suppressed demand.

The remainder of this section is structured as follows. Each section begins with a literature review of one of the elements of indirect cost. This review examines the relationship between the particular element of indirect costs and congestion, and the magnitude of the costs associated with the element in question. Subsequently, we apply what we have learned about the relationship and costs to the situation in the GCMA to arrive at a cost for the concerned element of indirect cost. This is done for each of the elements of indirect cost listed above. It should be kept in mind that the treatment of the elements of indirect costs is at times a bit uneven. This is a result of the research done on the concerned element of indirect cost – there is more data, information, and research on some elements than on others. Figure 5.1 provides a summary of the approach used to calculate each of these indirect costs for the GCMA.

Figure 5.1 Overview of Indirect Cost of Congestion Estimation Approach



APPROACH FOR ESTIMATING INDIRECT COSTS

Road Safety Costs

Two data elements are needed to estimate the additional road safety costs due to congestion: 1) the relationship between the number of accidents (characterized by severity) and the level of congestion; and 2) the costs of these accidents in terms of the cost of treating the injury and the value of the loss of life. We reviewed the literature to identify approaches for estimating the costs of road safety resulting from congestion, the available data from past studies in Cairo, in other cities and countries. The review also examined crash data in Cairo and the relationship between crash rates and motorization for different levels of congestion.

There is limited data on crashes in Cairo and the literature on the relationship between congestion and safety is scarce and inconclusive, and there is little agreement on the correlation between congestion and traffic accident frequency and severity.

There is, however, evidence indicating that the number of upstream accidents increases when congestion occurs downstream, especially on high-speed roads. Suddenly approaching stopped traffic can lead to rear-end collisions.[5]

Recent research has attempted to unravel the relationship between road safety and capacity. The results of this research suggest that when additional capacity (lanes) is added, it briefly improves road safety by lowering the density of vehicles on the facility. However, as vehicle density increases, the injury and fatal crash rates rise again.[6] When vehicle density reaches a certain level, research suggests safety deteriorates and offsets any gains which may have been achieved by adding road capacity (by building additional lanes). In fact, the conflict opportunities (the probability of an accident) increase as additional lanes are added, and more lanes tend to increase the average speed and the speed differential among the users, two major contributing factors for crash occurrence.[7]

Overall, on a road with significant congestion and average speeds well below the speed limit, it can be expected that the serious injury crash rate will be less than on a road where traffic speeds are equal to or greater than the same speed limit.[8] Recent (2007) data from CAPMAS support this: the Cairo and Giza Governates have the highest accident rates in Egypt, but in terms of fatalities and injuries per accident these two Governates are not even in the top 10 among all Governates. However, at the segment level, some variations may occur; transition zones from uncongested to congested segments may experience an increase in severity (and frequency) of accidents as indicated by the research above (e.g., rear-end collisions).

To estimate the number and severity of expected accidents on a segment of roadway, the FHWA's HERS-ST model attempts to apply rates for the frequency of traffic accidents, grouped by property damage only (PDO), injuries, and fatalities, to traffic volumes on the roadway segment. Egyptian data from CAPMAS can be used to adjust these rates to local conditions. While the local data do not include PDO accidents, these are a relatively small cost compared to injury and fatality costs, particularly given the high average number of fatalities and injuries per crash (approximately 2 according to the CAPMAS data). This large number of fatalities and injuries per crash also is an indication of high crash

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[5] FHWA.http://ops.fhwa.dot.gov/freewaymgmt/publications/frwy_mgmt handbook/chapter10.

[6] Kononov, J., Bailey, B., and Allery, B.K. (2008). *Relationships between Safety and Both Congestion and Number of Lanes on Urban Freeways*. Transportation Research Record: Journal of the Transportation Research Board, No. 2083, Washington, D.C.

[7] Cambridge Systematics (2011). *Crashes vs. Congestion – What's the Cost to Society?* American Automobile Association.

[8] International Road Assessment Program (2010). *Vehicle Speeds and the iRAP Protocols*.

severity, but it also could result from underreporting of minor (PDO) accidents.[9] Estimated ratios of PDO accidents to other types of crashes were taken from other developing countries and adjusted to GCMA conditions.[10,11]

Given the above, our approach for estimating cost of safety due to congestion involved the following:

1. The HERS-ST fatality, injury, PDO, and total accident rates were used as the basis for crash rates in this analysis. The HERS-ST rates for divided highways/principal arterials were used for major corridors; and the rates for minor arterial/major collector and minor collectors were averaged to represent local streets. While these factors may not be representative of the safety situation in Egypt, there are no studies and data specific to Egypt (GCMA) would support the estimation of such factors for the GCMA. These rates are used as a starting point and adjusted (described below) to reflect the situation in the GCMA.
2. *The Egyptian Cabinet – Information and Decision Support Center (IDSC) Report on Road Accidents in Egypt – 2008* provides the total annual number of accidents for Cairo and Giza in 2007, as well as total numbers across Egypt for total accidents, fatalities, and injuries. The national average for the ratio of fatalities and injuries to total number of accidents was applied to the Cairo and Giza Governates. These annual numbers were adjusted to daily figures by dividing by 365 and adjusted to represent just the peak period by multiplying by 60 percent: assuming a linear relationship between distance traveled and the number of accidents given that approximately 60 percent of the regional travel occurs during the eight-hour peak, we assume that approximately 60 percent of the accidents occur during the peak period.
3. The total VKT in Cairo and Giza Governates during the eight-hour peak period was calculated based on the analysis used to extrapolate direct economic costs of congestion from the sample to the entire network that was provided in Section 4.0.
4. Total number of accidents was divided by VKT to get crash, fatality, injury, and PDO rates per million VKT.

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9 In many developing countries accidents are treated as a criminal offence. This leads to an underreporting of accidents, often only accidents where fatalities or severe injuries are involved are reported, resulting in large number of fatalities and severe injuries per accident.

10 Sabreena Anowar et al., Bangladesh: Analysis of Accident Patterns at Selected Intersections of an Urban Arterial.

11 Ali. S. Al-Ghamdi, Road Accidents in Saudi Arabia: A Comparative and Analytical Study.

5. The fatality, injury, and total accident rates from HERS-ST were adjusted to conditions in Cairo by applying the ratio of Cairo-Giza rates to total U.S. rates and converting from VMT to VKT (Table 4.1).

Table 5.1 Adjusted Accident Rates

	Fatalities per Million VKT		Injuries per Million VKT	
Volume (Thousands)	Major Roads	Other Routes	Major Roads	Other Routes
0-2	25.9	40.0	96.9	105.9
2-4	25.9	49.1	96.9	105.9
4-8	23.6	34.5	96.9	106.8
8-16	23.6	29.2	99.5	123.1
16-24	21.2	22.6	103.1	140.9
24-36	18.9	21.2	78.4	138.1
36-58	18.9	21.2	78.4	138.1
58-76	18.9	21.2	78.4	138.1
76+	18.9	21.2	78.4	138.1

6. For each of the 11 major corridors, the directional traffic volumes for the peak period (four hours in the a.m. and four hours in the p.m.) and the length of the corridor from Phase 1 that were used for analysis of direct costs in Section 4.0 were utilized to calculate total VKT for each corridor and direction.

7. Accident rates from step 5 above were matched to the peak volume conditions in each corridor/direction. Since the rates are a function of volume and not speed, a hypothetical "free-flow volume" needed to be calculated. A volume-capacity ratio of approximately 0.8 (approximately LOS C or D) was assumed to be the point beyond which free-flow conditions were no longer met. This point was used to calculate the highest volume for which a corridor was "uncongested." This was done for every corridor. These "free-flow volumes" were used to determine the accident rates to be applied to each corridor. The accident rates were multiplied by VKT to determine total fatalities, injuries, and PDO accidents for the corridor/direction during peak period and the hypothetical uncongested condition.

8. Total fatalities, injuries, and PDO accidents were summed across all sample corridors/directions.

9. Steps 6 through 8 were repeated for other routes (surface streets).

10. The World Bank calculates the value of a statistical life as 70 times a country's GDP per capita. The World Bank estimates the 2010 GDP per capita of Egypt

to be $2,700, resulting in a value of a statistical life of $189,000. The World Bank estimates the value of a serious injury at 25 percent of this value, or $47,250. Finally, the value of a PDO was taken from a typical U.S. value of $12,000, converted to Egyptian conditions considering the ratio of Egyptian to U.S. gross national income per capita, purchasing power parity. This results in a value of $1,500 per PDO accident. These values were multiplied by 5.939 to convert USD to Egyptian pounds (LE).[12]

11. The adjusted values for fatalities, injuries, and PDO accidents from Step 5 were applied to the total fatality, injury, and PDO differences between congested and uncongested conditions to arrive at the economic costs for fatalities, injury and PDO due to traffic congestion.

Vehicle Operating Costs

Vehicle Operating Costs (VOC) is the costs for the maintenance and operation of a vehicle. They include fuel, oil, tires, depreciation and value of vehicle time, and maintenance costs. In this study, the price of fuel is not included in the VOC calculation as it already was included in the direct cost estimations in the analysis during Phase 1 of this study.

VOC are usually calculated using local data on the cost of oil, tires, vehicle depreciation and maintenance for the registered fleet of vehicles in a country. However, these data were not available for this study. For the vehicle mix, estimates by type of vehicles were made using the classified vehicle counts in Phase 1.

The literature was reviewed for information on data and tools that could provide suitable estimates for VOCs by speed and vehicle class for the GCMA. While the FHWA's HERS-ST provides equations for deriving such values, which have in turn been applied by several state departments of transportation (DOT), such as the Indiana DOT in its NET-BC model. These data and models are not transferable to Egypt. The World Bank Road User Costs Study (June 2006), provides a more appropriate set of data. This study collected vehicle fleet economic unit costs and basic characteristics from 44 applications of the World Bank's HDM-4 Road User Costs Model worldwide to obtain an order of magnitude of current unit road user costs in developing countries. The estimated vehicle fleet economic unit costs can be used as inputs into the World Bank Road User Cost Knowledge System (RUCKS), HDM-4 RUC Model Version 2.00 (February 18, 2010) to derive a VOC versus speed table by vehicle class. For the purposes of this study, a constant set of road condition criteria, such as pavement condition, were assumed.

The VOCs was calculated as follows:

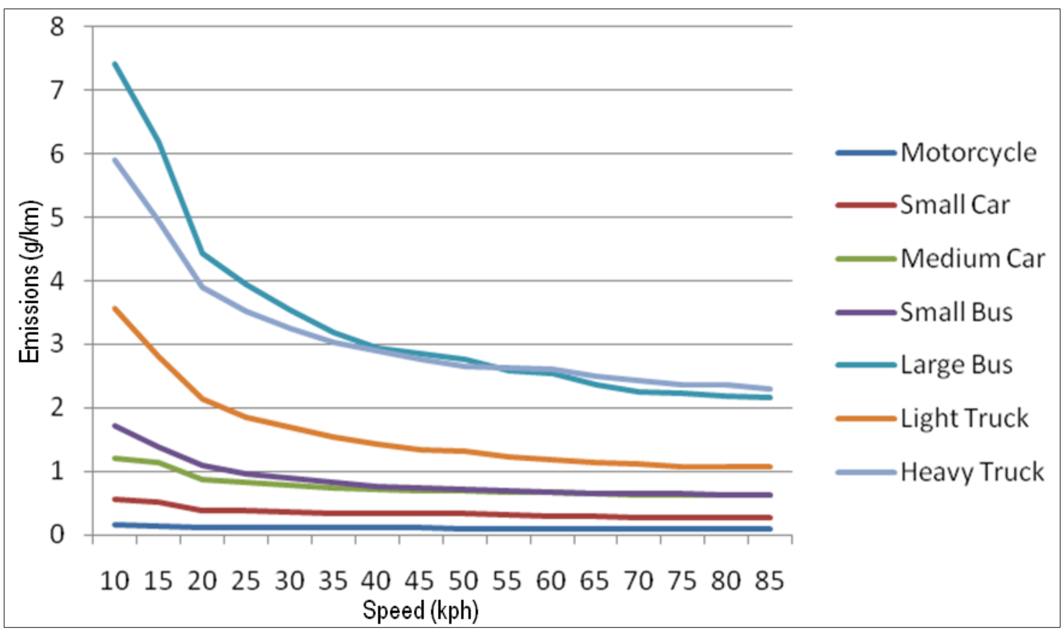
[12] Exchange rate as of 1 July 2011 from: http://wwp.greenwichmeantime.com/time-zone/africa/egypt/currency/.

12. VOC per VKT were developed as a function of traffic speed for different vehicle types (Figure 5.2). The HDM-4 RUC Model Version 2.00, using the vehicle fleet economic unit costs and basic characteristics for developing countries from the Road User Costs Study as inputs, was used to calculate VOCs by speed and by vehicle class. The costs include:

- Lubricants such as oil and grease;
- Tires;
- Maintenance parts and labor;
- Crew time for buses and trucks; and
- Depreciation, interest, and overhead.

These costs exclude fuel, as this was calculated as part of the direct costs during Phase 1 of this study.

Figure 5.2 Vehicle Operating Cost Rates by Vehicle Type



Source: HDM-4 RUC Model Version 2.00, using vehicle fleet economic unit costs and basic characteristics for developing countries from the World Bank Road User Costs Study and a sample roadway segment simulating urban conditions

13. Composite VOCs by speed were developed based on the modal split (percent of vehicles) from classified traffic counts for principal corridors from the Phase 1 report. For a given average speed, the VOC rate for each vehicle type was weighted by the modal split percentage for that vehicle type and then summed together. The modal split is shown in Table 5.2. The composite VOCs by average speed are shown in Table 5.3.

Table 5.2 Modal Split Used in Analysis (Percent of Vehicles)

Passenger Car	Taxi	Minibus	Bus	Medium Truck	Heavy Truck	Total
70	15	7	1	5	2	100

Table 5.3 Composite VOCs by Speed

Average Speed (KPH)	VOC ($/VKT)	VOC (LE/VKT)
10	$ 0.18	1.05
15	$ 0.16	0.93
20	$ 0.12	0.71
25	$ 0.11	0.66
30	$ 0.10	0.61
35	$ 0.10	0.57
40	$ 0.09	0.55
45	$ 0.09	0.53
50	$ 0.09	0.53
55	$ 0.08	0.50
60	$ 0.08	0.49
65	$ 0.08	0.47
70	$ 0.08	0.45
75	$ 0.08	0.45
80	$ 0.08	0.45
85	$ 0.07	0.44

14. For each of the 11 major corridors, directional traffic volumes for the peak period (four hours in the a.m. and four hours in the p.m.) were obtained along with the length of the corridor and average peak period and free-flow speeds. This data was used to compute total VKT for each corridor and direction.

15. A corresponding composite VOC per VKT from Step 2 above was matched to the average peak and free-flow speed in each corridor/direction. The VOC was multiplied by VKT to determine total costs for the corridor/direction during peak period conditions, and for a hypothetical uncongested condition with the same traffic volume.

16. Total VOCs were summed across all corridors/directions.

17. Steps 3 through 5 were repeated for each of the "other" routes.
18. These values were multiplied by 5.939 to convert USD to Egyptian pounds (LE).[13]

Health and Environmental Impacts from Poor Air Quality

There is clear evidence that traffic congestion and the accompanying air and noise pollution adversely affect human health. Traffic emissions have been linked to increased morbidity (illness) and premature mortality (early death) rates, and hence continues to be a very serious issue in increasing concerns about the health of populations living in urban environments. Vehicle traffic is a large contributor to the outdoor air pollution.

The ideal way to evaluate environmental and health costs of congestion would be to evaluate ambient air pollution concentrations, determine the contribution of transportation sources (and in particular, excess emissions under congested conditions) through ambient air quality modeling, and apply risk models (risk of exposure to pollutants) to translate pollutant concentration levels (with and without congestion) into effects on human health. This, however, is well beyond the scope of this study. Thus, a simplified approach was adopted to estimate the environmental and health costs of congestion.

This simplified approach estimates changes in emissions due to congestion and applies damage values (, expressed in terms of cost per unit of pollutant emitted) from the literature to estimate the health and environmental costs of congestion. The damage values are approximations and take factors (for example) local topographical and meteorological conditions that affect pollutant dispersion) into account.

The following steps were applied to estimate the health and environmental costs of congestion:

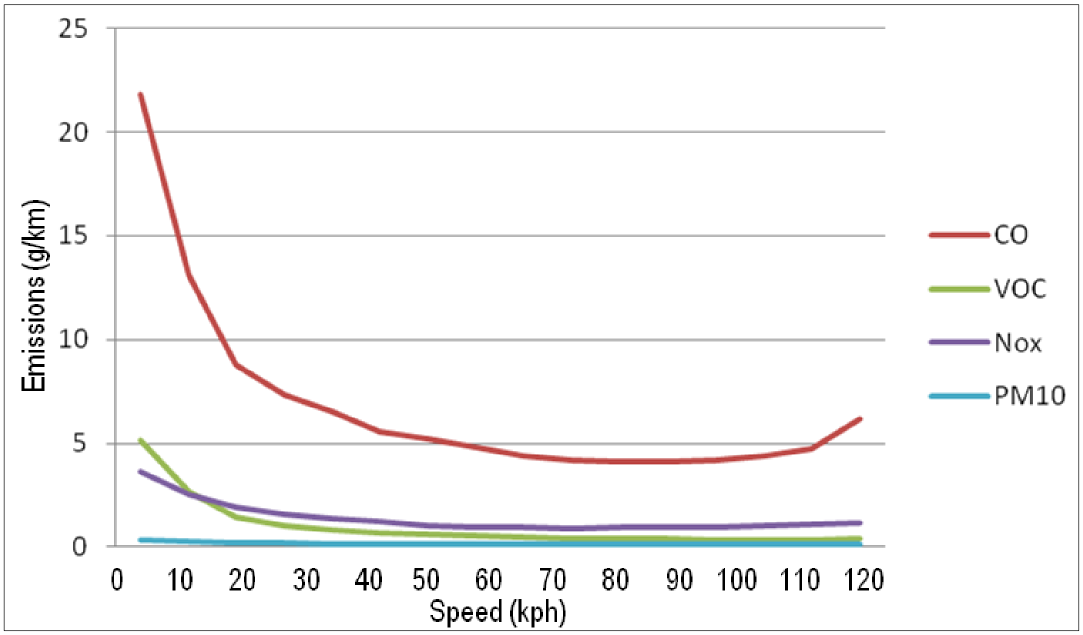
19. Emission rates per vehicle (in grams per kilometer or g/km) as a function of traffic speed for different vehicle types were developed. The International Vehicle Emissions (IVE) model was used to produce emission rates for Istanbul, the city most similar to Cairo of all the cities in the IVE model. The IVE model provides emission rates for carbon monoxide (CO), volatile organic compounds (VOC), oxides of nitrogen (NO_x), and coarse particulate matter (PM_{10}), for an average speed, for a variety of vehicle categories.
20. The vehicle categories in IVE were mapped to vehicle categories for which traffic count data were available in Cairo.

[13] Exchange rate as of 1 July 2011 from: http://wwp.greenwichmeantime.com/time-zone/africa/egypt/currency/.

21. Speed-dependent emission rates were developed for each category of vehicle included in the vehicle fleet in the GCMA using the U.S. Environmental Protection Agency's MOVES model (see Appendix G).

22. The modal split together with the emission rates from (3) above were used to develop a composite emission rate (see Figure 5.3).

Figure 5.3 Composite Emission Rates as a Function of Speed



Source: Based on IVE Model run for Istanbul, extrapolated to speed bins using MOVES

23. The emission rates from (4) were multiplied by VKT, together with the peak period and free-flow speeds, provided the total emissions for each corridor/direction during peak period and uncongested traffic condition.

24. Total emissions were summed across all corridors/directions to get total emissions for both congested and free-flow conditions, and the difference in emissions.

25. Steps 5 through 6 were repeated for the all the sampled routes.

26. Damage values for each pollutant, expressed in U.S. dollars per kilogram ($/kg), were taken from Delucchi (2004) and the U.S. EPA (2012).[14] Delucchi provides values for CO and HC, whereas more current EPA estimates from

[14] Delucchi, M.A. (2004). *Summary of the Nonmonetary Externalities of Motor-Vehicle Use.* Report #9 in the series: The Annualized Social Cost of Motor-Vehicle Use in the United States, Based on 1990-1991 Data. October 2004. Publication No.UCD-ITS-RR-96-3 9) rev. 1. "Midpoint" values are interpolated from low and high values provided in the source study.

2012 are used for PM and NO_x, adjusted upwards for nonattainment areas. As the damage values are uncertain, the authors provide a range. Here, we used the midpoint of this range as the damage value. Finally, these values were adjusted for differences in income per capita, purchasing power, and population density in Egypt. This adjustment was done as follows:[15]

- Inflated the 1991 dollars for the Delucchi HC and CO values to 2010 dollars by multiplying the 1991 dollars by 1.6.[16]
- Multiplied the damage values by 20.7 to adjust for differences in population density. This is the ratio of the estimated population density of the Cairo metropolitan area (44,600 persons per square mile)[17] to the density of a U.S. reference city from Delucchi and McCubben (2,150 persons per square mile).[18] This adjustment is to account for the fact that a unit of pollution will have more health costs the more people are exposed to it.
- Divided the damage values by 7.96, the ratio of purchasing power parity of per capita real income in the U.S. versus Egypt.[19]
- Multiplied by 5.939 to convert USD to Egyptian pounds (LE).[20]

Table 5.4 shows the original values from the source studies and the adjusted values for Cairo in both U.S. dollars and Egyptian pounds.

27. The adjusted damage values for each pollutant were applied to the total difference in emissions for that pollutant (congested versus uncongested) to determine the economic cost of excess air pollution associated with traffic congestion.

[15] Sengupta, R., and S. Mandal, Health Damage Cost of Air Pollution: Cost/Benefit Analysis of Fuel Quality Upgradation for Indian Cities.

[16] U.S. Bureau of Labor Statistics, http://www.bls.gov/data/inflation_calculator.htm.

[17] Wikipedia, citing a 2006 population of 7.8 million over 175 square mile.

[18] As reported in Delucchi (2005), page 48.

[19] Per capita real income of $47,010 in the U.S. vs. $5,910 in Egypt in 2010, expressed in International Dollars. Source: World Development Indicators database, World Bank, 1 July 2011.

[20] Exchange rate as of 1 July 2011 from: http://wwp.greenwichmeantime.com/time-zone/africa/egypt/currency/.

Table 5.4 Pollutant Damage Values

	U.S. Values			Adjusted for Cairo and 2010					
	USD/kg			USD/kg (2010)			LE/kg (2010)		
Pollutant	Low	Mid	High	Low	Mid	High	Low	Mid	High
CO	0.02	0.10[1]	0.17	0.04	0.26	0.42	0.24	1.54	2.49
HC	0.13	0.79[1]	1.45	0.54	3.29	6.05	3.21	19.54	35.94
NO_x	2.06	16.20[2]	30.32	5.37	42.13	78.85	31.90	250.25	468.37
PM_{10}	116.22	851.00[2]	1,585.78	302.23	2,213.03	4,123.83	1,795.25	13,145.40	24,495.55

Notes: 1. Delucchi (1991 values). 2. EPA (2010 values).

Suppressed Demand

Suppressed demand is the demand that is not realized (remains latent) because of excessive travel times. When a road or a highway system is improved, the suppressed demand becomes visible. This "new" demand also is called induced demand. There has been significant research on the "induced demand" effect which is quantified as elasticity of VKT with respect to highway travel time or lane miles. This elasticity indicates the expected percentage change in VKT from a one percent change in travel time or lane miles.

Dowling studied induced demand from the viewpoint of "travel budgets" – the time people has available to allocate to travel as it competes with other activities.[21] He borrowed the concept of the Price Consumption Curve which showed that when travel costs are high, reductions in cost result in an increase in demand. When travel costs are low, reductions in cost result in a partial shifting of activities to non-travel activities, but not all the travel time savings go into new travel.

(See Appendix H for additional information on suppressed demand).

[21] Dowling, Richard G., *A Framework for Understanding the Demand Inducing Effects of Highway Capacity,* paper submitted to 73rd Annual TRB Meeting, October 1993.

Table 5.5 Summary of Induced Travel Studies

Study	Primary Data Sources	Long-Run Elasticity of VMT with Respect to		Comment
		Travel Time	Lane-Miles	
Gorina & Cohen[22] and Barr[23]	1990 and 1995 NPTS	-.3 to -.5		Elasticity's may be overstated because of the tendency for longer trips to have higher average speeds than shorter trips. Reanalysis suggests elasticity's of -.1 to -.4.
Goodwin[24]	Time series travel data	-0.57		For urban roads; used in SMITE
SACTRA[25]	Fuel price elasticity's	-1.0		Elasticity may be overstated because of differences in opportunities available to motorists to reduce travel time and fuel costs.
Noland[26]	Highway Statistics		0.8	Elasticity may be overstated because of 1) shifts of VMT and lane-miles among highway systems; and 2) highways that are widened have more VMT/lane-mile than other highways.
Strathman[27]	1995 NPTS, Texas Transportation Institute Urban Mobility Study dataset		0.32	Elasticity includes direct effects of lane-miles on household VMT and indirect effects due to changes in density.
Marshall[28]	Texas		0.76 to 0.85	Elasticity may be overstated because of

[22]Gorina, Y. and H. Cohen. Cambridge Systematics, Inc. Draft report of ITS Deployment Analysis System (IDAS) Progress Meeting. June 1998.

[23]Barr, L.C. "Testing for the Significance of Induced Highway Travel Demand in Metropolitan Areas". Transportation Research Record No. 1706. Washington, D.C. 2000.

[24]Goodwin, Phil, *Empirical Evidence on Induced Traffic*, Transportation, Volume 23, No. 1, pages 35-54.

[25]Standing Advisory Committee on Trunk Road Assessment (SACTRA), *Trunk Roads and the Generation of Traffic*. HOMS. London. 1994.

[26]Noland, R. Relationships Between Highway Capacity and Induced Vehicle Travel. Presented at 78th Annual Meeting of the Transportation Research Board. Washington, D.C. 1999.

[27]Strathman, J.G., K.J. Dueker, T. Sanchez, J. Zhang, and A. Riis." Analysis of Induced Travel in the 1995 NPTS".Center for Urban Studies, College of Urban and Public Affairs, Portland State University, Portland, Oregon. June 2000.

[28]Marshall, Norman. "Evidence of Induced Demand in the Texas Transportation Institute's Urban Roadway Congestion Data Set." Presented at 79th Annual Meeting of the Transportation Research Board. Washington, D.C. 2000.

Study	Primary Data Sources	Long-Run Elasticity of VMT with Respect to		Comment
		Travel Time	Lane-Miles	
	Transportation Institute Urban Mobility Study dataset			roadway classification issues and diversion from outside urban areas.
Cervero[29]	Freeway project and Census building activity data (15 years)		0.39	Elasticity may be overstated because some travel that is diverted from other nearby corridors is included.
Noland[30]	Highway Statistics time series		0.41	Elasticity may be overstated because of failure to account for the reverse causality whereby road building responds to actual or anticipated traffic (growth in VMT is anticipated, therefore it is not causing excess demand to be generated).

A 2009 U.S. Department of Transportation (DOT) study evaluated induced/suppressed demand and attempted to monetize the impact, for different urban areas, as lost productivity resulting from trips that were not made.[31] The actual elasticity's used in the analysis for different urban areas are not publicly available, but the estimate for personal travel varies across areas between -0.4 and -0.6. The elasticity of demand for business travel (passenger vehicles) was set at 40 percent of the personal travel elasticity. For truck travel, the assumed elasticity was -0.97. The resulting measure of cost of lost productivity due to suppressed travel, generally accounted for a small proportion (three to five percent) of the total overall costs of congestion presented in the DOT report.

1. The findings from the 2009 U.S. DOT study, which estimated the cost of productivity lost due to suppressed demand to be 3 to 5 percent of total direct congestion costs, were applied to the total direct costs of congestion in the GCMA.

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[29]Cervero, R. (2003) "Road Expansion, Urban Growth, and Induced Travel: A Path Analysis", *Journal of the American Planning Association*, 69(2): 145-163.

[30]Noland, R.B. (2001) "Relationships Between Highway Capacity and Induced Vehicle Travel", *Transportation Research Part A.*, 35:47-72.

[31]HDR Engineering for U.S. Department of Transportation, *Assessing the Full Costs of Congestion on Surface Transportation Systems and Reducing Them through Pricing*, February 2009.

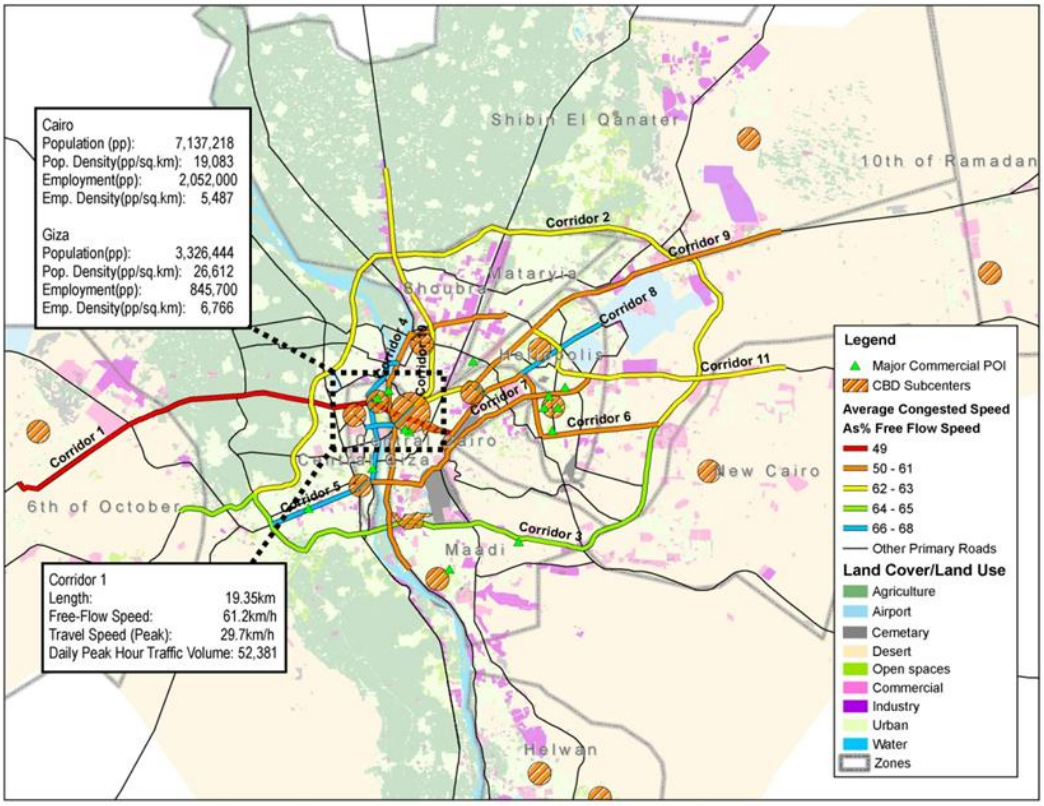
Labor Productivity, Business Operations, and Agglomeration Effects

This section investigates the agglomeration economies and their relationship with congestion. The results of an extensive literature review examining the nature and magnitude of the impact of congestion on labor productivity and business operations are provided in Appendix H. Here we simply summarize the conclusions of this review and note that the available literature and quantitative evidence on agglomeration economies and their relationship to congestion is limited. There is no GCMA-specific data on this topic either. Thus, the subsequent discussion is based on case studies, examples, benchmarks, and anecdotal evidence.

Theory links the agglomeration economies to urban public infrastructure by suggesting that agglomeration economies exist when firms in an urban area share a public good as an input to production. Shareable inputs include close proximity of businesses and labor, which generates positive externalities that in turn lowers the production cost of one business as the output of other businesses increases. The positive externalities result from businesses sharing non-excludable inputs, such as a common labor pool, technical expertise, general knowledge and personal contacts. Another more tangible type of shareable input is urban public infrastructure. Public capital stock, such as highways, water treatment facilities, and communication systems, directly affect the efficient operation of cities by facilitating business activities and improving worker productivity.

There is a widespread belief that that agglomeration economies exist in the GCMA. This belief stems from the cluster of economic activities and high population density in the central Cairo-Giza area (Figure 5.4). Assuming that these agglomeration economies do exist, congestion, which increases travel times, will erode the benefits of agglomeration economies in the central Cairo-Giza area. As shown in Figure 5.4, Corridor 1 runs through the cluster of economic centers in the central area and it is the most congested major corridor evaluated in this study, with observed travel speed at 49 percent of the free-flow speed during peak hours.

Figure 5.4 Central Business Districts and Major Corridors by Congestion Levels



Standard Approach

If the right data, and enough of it, were to be available, one could start to unravel the impact of congestion on agglomeration benefits in the study by:

- Measuring of industrial agglomeration;
- Estimating agglomeration effects on labor productivity; and
- Estimating congestion impacts on agglomeration effects.

Measurement of Industrial Agglomeration

Industrial agglomeration can be estimated by:

- Collecting time series data (2005-2010) on employment, industry output, and associated number of businesses by industry for each city/governorate in the study region and country-wide would be collected;
- Estimating the Helfindahl-Hirshman Index (HHI) – the HHI measures the market concentration of each industry – and the share of each industry's employment within the study region;

- Estimating the EG index (explained below) of industries in the study region between 2005 and 2010 would be estimated; and
- Analyzing the trend in EG index between 2005 and 2010; an increasing trend suggests increasing agglomeration and vice versa.

The EG index (Ellison and Glaeser, 1997), premised on Krugman (1991), simultaneously accounts for an industry's share of employment in a region, the proportion of aggregate manufacturing employment in a region, as well as the market concentration of industry in the estimation of agglomeration. Other measures of agglomeration, such as the Gini Index (Krugman, 1991), may work better when the share of manufacturing employment varies significantly across the study region that the existence of agglomeration can be inferred from the Gini Index.

Estimation of Agglomeration Effects on Labor Productivity

The relationship between agglomeration and productivity can be estimated using a regression model with relative labor productivity as the dependent variable, and the EG index (industrial agglomeration), square of the EG index, industry output, number of firms, and firm size as possible explanatory variables. A positive coefficient of the EG index would suggest increased agglomeration increases labor productivity and vice versa. For a nonlinear relationship, a positive coefficient of the square of the EG index would suggest that the effects of agglomeration on labor productivity enjoys increasing returns, while a negative coefficient indicates diminishing returns.

Effects of Congestion on Agglomeration Benefits

Once the effects of agglomeration on labor productivity are established, the regression model specification should be expanded to account for congestion. The measure of congestion could be based on travel speed. For example, congestion could be expressed as a ratio of observed travel speed to free-flow speed. A negative sign for the congestion variable in this expanded regression model would suggest that congestion has diminishing returns on labor productivity, a positive sign for the congestion variable would suggest increasing returns to labor productivity.

Applied Approach

Given the lack of data we used a simplified approach methodology based on the Gini Index as the measure of agglomeration. Based on Krugman (1991), the Gini Index is used for measuring localization or agglomeration. This approach is outlined below:

1. The Balassa Index (Krenz, 2011), a function of employment by industry, was utilized to estimate the Gini Index for four industries: construction, manufacturing, retail and wholesale trades, and other services (see Appendix H for complete equations). To estimate the Gini Index, the Balassa Index is ranked in descending order and a Lorenz curve is plotted. The Gini

Index ranges from zero to one, and the level of agglomeration is directly proportional to the Gini Index. A Gini Index of zero implies that the industry in evenly distributed across the study area, therefore agglomeration is nonexistent. Agglomeration increases as the Gini Index approaches one. Consequently, for this study agglomeration classifications were developed based on the estimated Gini Index:

- Low: 0-0.3;
- Medium: 0.3-0.7; and
- High: 0.7-1.0.

From Table 5.6, low levels of agglomeration are associated with construction and manufacturing industries, while medium levels of agglomeration are associated with wholesale/retail trades and other services in Cairo. Therefore, the effects of congestion on agglomeration (if any) in the retail/wholesale and services sectors are examined in the next step. It should be noted that while agglomeration has a positive impact on labor productivity in manufacturing, it has a negative impact on labor productivity in services (Agarwalla, 2011).

Table 5.6 Gini Index by Industry in Cairo

Industry	Gini Index	Agglomeration Level
Construction	0.11	Low
Manufacturing	0.14	Low
Wholesale/Retail Trades	0.41	Medium
Other Services	0.39	Medium

Source: Cambridge Systematics Analysis.

Having established agglomeration in the study area, the next step was to estimate the effects of congestion on agglomeration in the GCMA. The approach is based on the model employed by Graham (2006), which measures effective density for proximity (UD) and travel cost (UG) for a firm in industry *'o'* and located in city *'i'* (Cairo), as shown in Appendix H. This methodology replaces UD with a measure of effective density for congestion (UV).

As congestion increases, travel speed decreases and the difference between travel speeds at peak and nonpeak periods increases as well, thus a relatively large ratio of UD to UV indicates the presence of congestion and vice versa. To estimate the proximity of the employment centers, Cairo was selected as the central location. The distance between Cairo and other cities/governorates, including Alexandria, Giza, 6th October, and Port Said were selected from Table 5.6.

Table 5.7 Distance Between Cairo and Other Cities in Egypt

From Cairo to	Kilometers (km)	Miles (m)
Alexandria	224	138.9
Port Said	192	119.0
Giza	5.86	3.6
6 October	32	19.8

Source: http://distancecalculator.globefeed.com/Egypt_Distance_Calculator.asp.

The road corridors included in this study and their observed travel speeds are mapped to the selected cities/governorates (shown in Table 5.7). These corridors either pass through or lead to the cities to which they have been mapped. Due to paucity of data within GCMA, cities/governorates outside of the study region are utilized as proxies for this analysis. Travel speed is used as a proxy to estimate generalized cost of travel. The generalized cost of travel increases as travel speed decreases (or congestion increases).

Based on the value of time by vehicle type and average volume of vehicles by classification from Section 2.0 of this report, and the assumption that 30 percent of all non-truck trips are commute-related, the weighted average value of time for commuting is estimated to be 9.4 LE/hr.

Using UV, generalized cost of travel, corridor lengths, employment, and Euclidean distance between Cairo and the selected cities, the ratio of effective density related to proximity (UD) and the effective density related to travel cost (UV) are estimated. From Table 5.7 congestion is severe in the study region and also affects agglomeration in the retail/wholesale and other services sectors. This confirms the hypothesis that congestion affects agglomeration in the GCMA.

Table 5.8 Ratio of (UD) to (UV)

City/Governorate	Wholesale and Retail Trade	Other Services
Alexandria	10,165	15,586
6-Oct	28,426	43,597
Giza	23,272	34,954

Source: Cambridge Systematics Analysis.

2. Assuming 30 percent of all non-truck travel is commute-related, the value of lost working hours is estimated at 8 billion LE in 2010. The value of the lost working hours is further distributed across industries in the Cairo-Giza area based on the relative industry value-added recorded in 2010. Next, the effect of congestion on agglomeration is measured based on travel delay. This analysis utilizes a typical effect of delay for a kilometer of travel on Major Corridor 1: -0.16 LE/hour

3. Congestion lowers labor productivity by 0.16 LE/hr, which represents 1.7 percent of the weighted average value of time (9.4 LE/hour). Therefore, the congestion effect on agglomeration is 1.7 percent of the total productivity loss (Table 5.7).
4. In addition to agglomeration, congestion leads to productivity loss. Based on direct congestion cost related to freight and business travel, industry elasticity and industry output in 2010, the loss in output for manufacturing, construction, wholesale and retail trades and other services is estimated as shown in Table 5.8. An estimated loss of 1.4 billion LE in output is associated with the manufacturing sector, while that of wholesale and retail trades is estimated to be 968 million LE.
5. Values by industry are summed from Tables 5.9 and 5.10 to achieve total costs.

Table 5.9 Change in Value-Added Due to Increased Commute Time

Industry	Change in Value Added (Million LE)	Amount Attributable to Agglomeration
Manufacturing	(502)	n/a
Construction	(218)	n/a
Wholesale	(114)	(18)
Services	(286)	(21)
Total	**(1,119)**	**(39)**

Table 5.10 Productivity Loss Due To Increased Business Cost

Industry	Output Change (Million LE)
Manufacturing	(1,411)
Construction	(751)
Wholesale and Retail Trades	(968)
Other Services	(926)

Demand for Housing

Besides the monetary costs associated with congestion, congestion also influences the choice of people about where they want to live. The ease of commuting from home to work and access to retail outlets are but two factors that play a role in the choice about residential location, and both are affected by congestion. Therefore, accessibility is capitalized in housing markets where there is a tradeoff between commute cost and property value. Various studies on the estimation of the tradeoff between commute cost and property value employ the Euclidean distance between the residence and the central business district as a proxy for commute cost. This approach is based on the assumption of constant speed on the route, thus it ignores the effects of congestion.

Zhang and Hui-Fai (2006) compared housing values inside and outside congestion charge zones, as well as the sensitivity of housing values to the distance from the zone boundary both inside and outside the zone. The methodology employed for this study mirrors that of Gibbons and Machin (2003), who's variable of interest was proximity to rail stations and their train frequencies. Gibbons and Machin (2003) used cross-sectional time series data and argued that this approach has pitfalls in employing solely cross-sectional studies as experienced by Ihlandfeldt (2001), Landis and Zhang (2001).

Zhang and Hui-Fai (2006) predicted that the effects of congestion cost inside the zone should be different from the effects of outside the zone. While residents within the zone have benefited from traffic reduction and discounted charges, business may have been adversely affected especially if the bulk of their customers used to originate from outside the congestion cost zone, thus making the area within the zone less desirable due to businesses relocating. The study found that inside the charge zone, every kilometer of movement to or away from the boundary changed property prices from 40 percent to 24 percent. This means that the congestion mitigation measure within central business district caused 16 percent crop in property values within a kilometer radius. Alternatively, 16 percent of property value in the central business prior to the congestion mitigation measure is attributed to traffic congestion.

On the flip side, there is no data on traffic flow outside the congestion cost zone, but increased traffic flows are observed on the boundary of the congestion cost zone (avoiding entry into the charge zone). This phenomenon is expected to have a negative impact on residents outside the charge zone, while businesses in the same zone are expected to be impacted positively. The study also found that, outside of the charge zone in the central business district, every kilometer movement to or away from the boundary can change property price from 7 percent to 6 percent, representing one percent change. This suggests that traffic congestion has a marginal effect on property values outside the central business district. This finding is consistent with Kockelman and Kalmanje (2004).

The housing market within the GCMA is distorted.[32] These distortions result in adverse impacts on the middle-income and poorer sections of the population, urban inequity and the spread of informal economic activities.[33] Among the salient factors causing the distortions are:

- **Semiformal housing market**: The housing market in Cairo, for rental or sale, is active but operates mostly based on straightforward contractual

[32] Cairo, A City in Transition, United Nations Human Settlement Programme (2011).

[33] Ibid.

agreement. This private, semiformal mechanism operates by word of mouth or by neighborhood agents. Many housing exchanges take place outside of any market-based arrangement, comprising family gifts, inheritance or other informal arrangements. The market is mainly cash-based, and up to only three percent of a housing payment is financed.[34]

- **Top-end concentration**: Housing demand in Egypt continues to outpace supply due to the high population growth rate and the existing housing deficit. While there is over-supply in the high-end residential segment, a low housing supply continues to plague low- and middle-income properties, where the majority of demand exists. High-end housing developments on the outskirts of Cairo and the beach resorts have provided incentives to wealthy Egyptians to migrate to the eastern and western suburbs of Cairo. Annual low- and middle-income housing supply is 150,000 units, representing a deficit of about 350,000.[35] This undersupply of medium- to low-cost formal housing creates a demand that the informal sector has filled for many years.
- **Vacant housing units**: The housing unit vacancy rate is very high in Egypt's urban areas. The vacancy rate is reported to be in excess of 20 percent of the housing stock. In Cairo in 2008, an estimated half million units were empty (representing 17 per cent of the available stock). These high vacancy rates are partly due to freezing of rents in some areas, as well as administrative difficulties surrounding sale of property.

Although housing price data are available, it is unclear the role congestion plays in determination of the prices in Egypt. House prices in Egypt are influenced by other factors, including:

- Availability of infrastructure/utilities;
- Perceived status of the neighborhood; and
- Proximity to the central business district and recreational areas.

Using the above, the following approach was used to make an order-of-magnitude estimate of the impact of congestion on the demand for housing in the GCMA:

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[34] ALARGAN Market Research, Market Overview of New Cairo City, Egypt.

[35] Ibid.

1. Egypt's statistical yearbook was used for housing data. The yearbook reports 196,060 housing units in the urban areas of Egypt in 2010. These housing units are valued at 16.5 billion LE.
2. Based on the 2010 and 2030 socioeconomic data presented in Section 3.0, the population of central core of the GCMA – assumed to consist of the densest, most congested CBD-like zones – is 21 percent of the total GCMA population.
3. Based on the core's proportion of the GCMA population, and the GCMA proportion of Egypt's population, housing units in the CBD are estimated to be 4,509 with a related value of 0.38 billion LE.
4. Following from Zhang and Hui-Fai (2006), 16 percent of property prices of properties located in the core is attributed to traffic congestion. This yields a value of 60.7 million LE.

SUMMARY OF BASE YEAR INDIRECT COSTS

The approaches described in the previous sections for safety, VOC, and emissions costs were used to estimate costs for the study network (covering both the major corridors and other routes). These costs were extrapolated to the complete road network in the GCMA using the same procedure as the one used to extrapolate direct cost in Section 4.0. Agglomeration/productivity costs, housing demand costs, and suppressed demand costs were all calculated at a macro, regional level as described above.

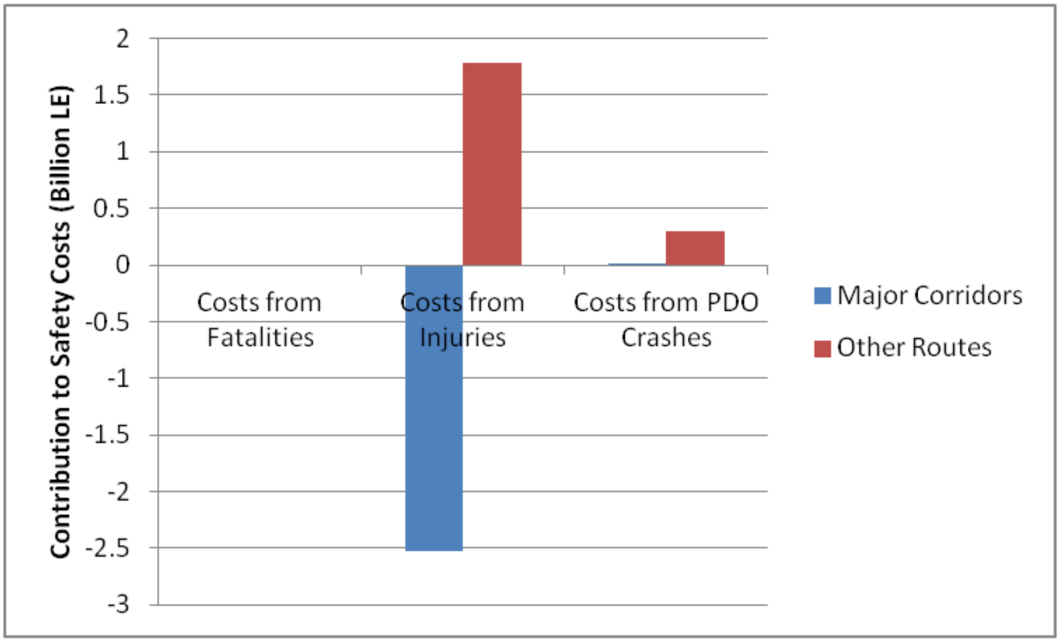
Costs by Element

Safety Costs

Safety costs due to congestion amount to -0.5 billion LE, or -91.8 million USD. A large share of these costs, 55 percent, occurs on major corridors. This negative value, indicating that congested conditions are actually causing a slight improvement in safety, are attributable primarily to lower speeds which in turn result in reductions in injuries (-3,100 across the system). However, PDO accidents actually increase do to congestion (34,800). The economic costs of PDO crashes are relatively low relative to serious injuries, so that the resulting costs are still negative. Figure 5.5 shows the contribution of each type of crash to the total safety congestion cost. Results differ on major corridors and other routes, as the analysis is sensitive to the traffic volumes on the roadways and the relationship between level of traffic volume and crash rate differs by functional classification.

The rates applied assume that severity of accidents increase for very small volumes, but then generally decrease as roads become congested. This is reflected in the cost of safety due to congestion, which is negative. While this may be a counterintuitive result, in congested urban environments, as average speeds fall, the number of fatal and severe accidents also falls. However, it should be recognized that as congestion declines, unless appropriate measures are put in place, the number of fatal and severe accidents will increase. Further, though the marginal safety costs specifically due to congestion are negative, in fact the overall safety costs in Cairo are still relatively high. Many of the same traffic-influencing events, behaviors, and designs that are causing congestion also are likely to cause safety issues.

Figure 5.5 Contribution of Each Crash Type to Total Congestion Cost



Vehicle Operating Costs

Vehicle operating costs contribute 2.2 billion LE, or 371.2 million USD, to indirect costs of congestion in the GCMA. Approximately 35 percent of this is incurred on major corridors. This is about USD 20 per resident of the GCMA per year.

Health and Environmental Impacts from Poor Air Quality

Tables 5.11 and 5.12 summarize the calculations for the evaluation of emissions beyond CO2 and their monetized environmental and health impacts on major corridors and other routes, respectively. This amounts to 5.5 billion LE, or 928.7 million USD in total. Major corridor congestion contributes to 42 percent of that total. In total more than 2 kilograms of excess pollutants due to congestion are emitted per resident per year in the GCMA. Total vehicle emissions due to all travel in the GCMA, including non-congested travel, are much higher.

Table 5.11 Calculation of Excess Emissions
Major Corridors

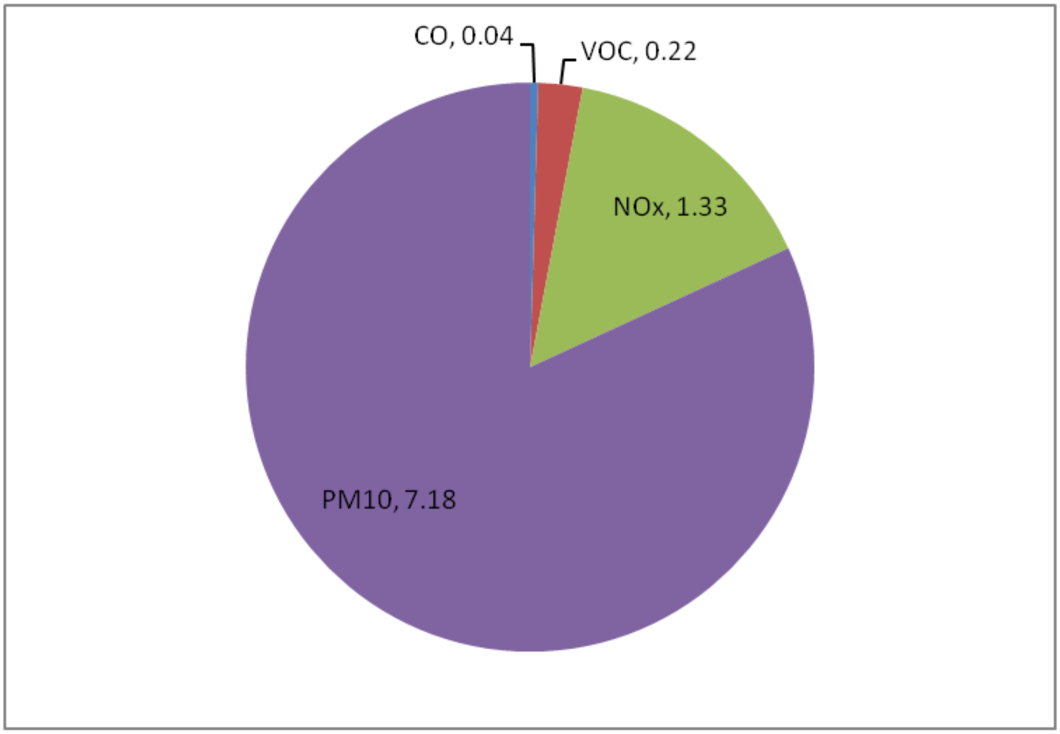
Pollutant	Sample Corridor Emissions (kg) Free-Flow	Congested	Excess	Total Excess Emissions	Total Cost (B LE)
CO	21,479,956	27,539,981	6,060,024	11,315,437	0.02
VOC	2,436,774	4,442,038	2,005,264	3,744,282	0.07
NO_x	4,680,613	5,819,903	1,139,290	2,127,312	0.53
PM_{10}	506,671	631,158	124,487	232,445	3.06
Total	**29,104,015**	**38,433,080**	**9,329,065**	**17,419,478**	**3.68**

Table 5.12 Calculation of Excess Emissions:
Other Routes

Pollutant	Sample Route Emissions (kg) Free-Flow	Congested	Excess	Total Excess Emissions	Total Cost (B LE)
CO	969,151	1,591,269	622,119	15,819,242	0.02
VOC	119,495	426,673	307,177	7,626,649	0.15
NO_x	205,177	334,003	128,826	3,198,516	0.80
PM_{10}	21,719	34,356	12,637	313,754	4.12
Total	**1,315,542**	**2,386,301**	**1,070,759**	**26,584,997**	**5.10**

Figure 5.6 shows the distribution of these costs among the four pollutants analyzed for this study. While CO emissions are the highest in terms of actual weight of pollutants emitted, PM_{10} has the highest actual health costs. While this study is focused on congestion mitigation strategies as a means of reducing indirect costs, it is recommended that other environmental strategies focus on ways to reduce PM_{10} emissions.

Figure 5.6 Distribution of Congestion-Related Emissions Costs by Pollutant (Billion LE)



Suppressed Demand

Table 5.13 displays the results and provides an order of magnitude estimate of the cost associated with suppressed demand by mode. The lower bound estimate is derived by applying the lower bound estimate of the cost associated with lost productivity due to suppressed demand from the U.S. DOT study (three percent) to the lower bound estimate of direct congestion costs. Likewise, the upper bound is derived by applying the upper bound estimate from the U.S. DOT study (five percent) to the upper bound estimate of the direct congestion costs. For analysis in this study, the midpoint between these two bounds was used. Based on this simplified approach, the suppressed demand resulting from congested conditions in GCMA gives rise to productivity losses in the order of 1.23 billion LE, or 204 million USD. This equates to USD 10 lost per resident per year.

Table 5.13 Estimates of Productivity Costs Associated with Suppressed Demand

Mode	Lower Bound (Million USD)	Upper Bound (Million USD)	Lower Bound (Million LE)	Upper Bound (Million LE)
Passenger Cars	$26.5	$44.3	158	263
Taxis	$26.2	$43.8	156	260

Mode	Lower Bound (Million USD)	Upper Bound (Million USD)	Lower Bound (Million LE)	Upper Bound (Million LE)
Motorcycles	$0.2	$0.3	1	2
Transit Riders	$90.5	$150.7	537	895
Freight	$11.9	$19.9	71	118
Total	**$155**	**$259**	**923**	**1,538**

Labor Productivity, Business Operations, and Agglomeration Effects

Total productivity loss due to delay in this analysis is a combinations of productivity loss due to freight delay and productivity loss due to commute, including agglomeration effects. Total productivity loss arising from congestion is estimated to be approximately 5.2 billion LE in 2010 (Table 5.14). Of the total, manufacturing accounts for 37 percent, followed by services sector (except retail/wholesale), with 23.4 percent. The construction sector is the least impacted with 18.7 percent of the total loss in productivity. In total, this is equivalent to USD 45 wasted per resident per year.

Table 5.14 Total Change in Output Due to Delay

Industry	Change in Output (Million LE)	Change in Output (Percent of Total)
Manufacturing	(1,913)	-37.0%
Construction	(968)	-18.7%
Wholesale	(1,082)	-20.9%
Services	(1,212)	-23.4%
Total	**(5,175)**	**-100%**

Demand for Housing

Total impacts of congestion on the housing market in the GCMA are estimated at 60.7 million LE. Spread across the population of the GCMA, this is equivalent to less than USD 1 per capita per year.

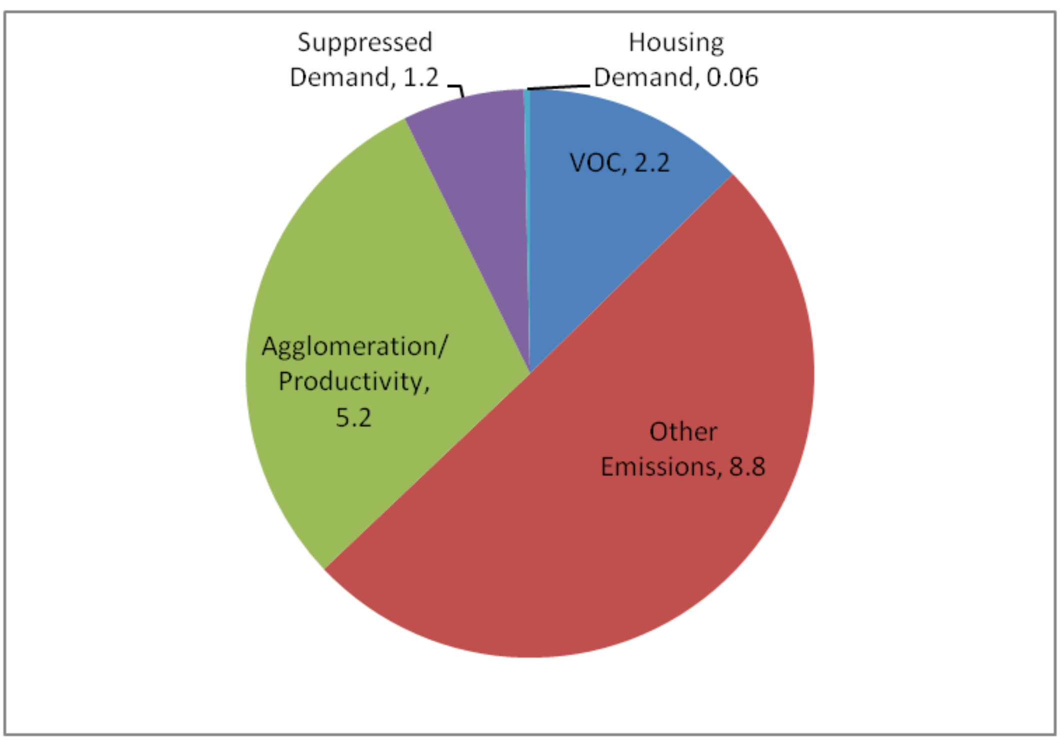
Summary of Costs

Table 5.15 summarizes the estimates of indirect costs for 2010 in the GCMA. Combined with direct costs, the indirect costs account for about 36 percent of total costs. Health and environmental impacts from vehicle emissions, except for CO_2 which is covered in the direct costs, is the largest driver of the indirect costs (Figure 5.7). Approximately 44 million kg are emitted every year in the GCMA, resulting in 2.2 billion LE of loss. Agglomeration and productivity loss, driven largely by commuter and freight delay, is the second largest contributor to indirect costs at 37 percent. Safety costs, due to the slightly reduced severity resulting from heavy congestion, reduce the indirect costs by -0.5 billion LE. Of the network-level costs (safety, vehicle operating costs, and emissions), nearly 60 percent is due to congestion on other, non-major routes.

Table 5.15 Summary of Base Year Indirect Costs

Cost Component	Value	Annual Cost (Million USD)	Annual Cost (Billion LE)	Annual Cost/Capita (USD)	Percent on Major Roads
Safety	0 fatalities; -3,100 injuries; 34,800 PDOs	-91.8	-0.5	-5	55%
VOC	N/A	371.2	2.2	19	35%
Other Emissions	44 M kg	1,477.5	8.8	75	42%
Agglomeration/productivity	N/A	875.4	5.2	45	N/A
Suppressed Demand	N/A	203.9	1.2	10	N/A
Housing Demand	N/A	10.2	0.06	1	N/A
Total	**N/A**	**2,846.5**	**16.9**	**145**	**N/A**

Figure 5.7 Distribution of Total Indirect Costs



SUMMARY OF FUTURE YEAR INDIRECT COSTS

Future year indirect costs are estimated using the growth estimates from the model, which are applied to the base year indirect costs: this follows the same methodology as described for the direct costs in Section 4.0, resulting in an increase of about two times over 2010 estimates on the sample roadways. After using the model to extrapolate from the sample to the entire network, total indirect costs are projected to increase by about 2.2 times over 2010 estimates, for a total of 36.1 billion LE in indirect costs per year in 2030 (Table 5.16).

Table 5.16 Summary of 2030 Yearly Indirect Costs

Cost Component	Value	Annual Cost (Million USD)	Annual Cost (Billion LE)	Annual Cost/Capita (USD)	Percent on Major Roads
Safety	0 fatalities; -6,890 injuries; 78,570 PDOs	-191.7	-1.1	-7	55%
VOC	N/A	836.7	5.0	30	35%
Other Emissions	99.2 M kg	3,329.4	19.8	117	42%
Agglomeration/Productivity	N/A	1,677.4	10.0	59	N/A
Suppressed Demand	N/A	418.1	2.5	15	N/A
Housing Demand	N/A	10.7	0.06	0.5	N/A
Total	**N/A**	**6,080.6**	**36.1**	**215**	**N/A**

Due to the uncertainty in forecasting future demand, a series of different growth scenarios were modeled as described in Section 3.0. Table 5.17 shows how the indirect costs differ under these different scenarios, providing a range of cost estimates for the year 2030.

Table 5.17 Range of Indirect Costs Based on Socioeconomic Growth Scenario

Percent Difference in Annual Growth from Baseline	-100%	-50%	+50%	+100%	+200%
Relative total increase to base scenario	-40%	-23%	12%	29%	60%
Total Projected Costs (B LE)	**21.4**	**27.7**	**40.6**	**46.4**	**58.0**

6.0International Comparison

THE SITUATION IN CAIRO

Approximately 47 billion LE, or 8 billion USD, are wasted every year in the GCMA due to congestion. About 65 percent of this is due to the direct costs defined in this study, driven primarily by delay, which contributes 31 percent (Figure 6.1). Delay represents the most fundamental, and most directly and anecdotally relatable "cost" of congestion: it is the time users spend setting in congested conditions. Paired with reliability, also a measure of wasted time but due to unexpected delay that requires travelers to build extra time into their trips, the value of wasted time constitutes 50 percent of all congestion cost to the region.

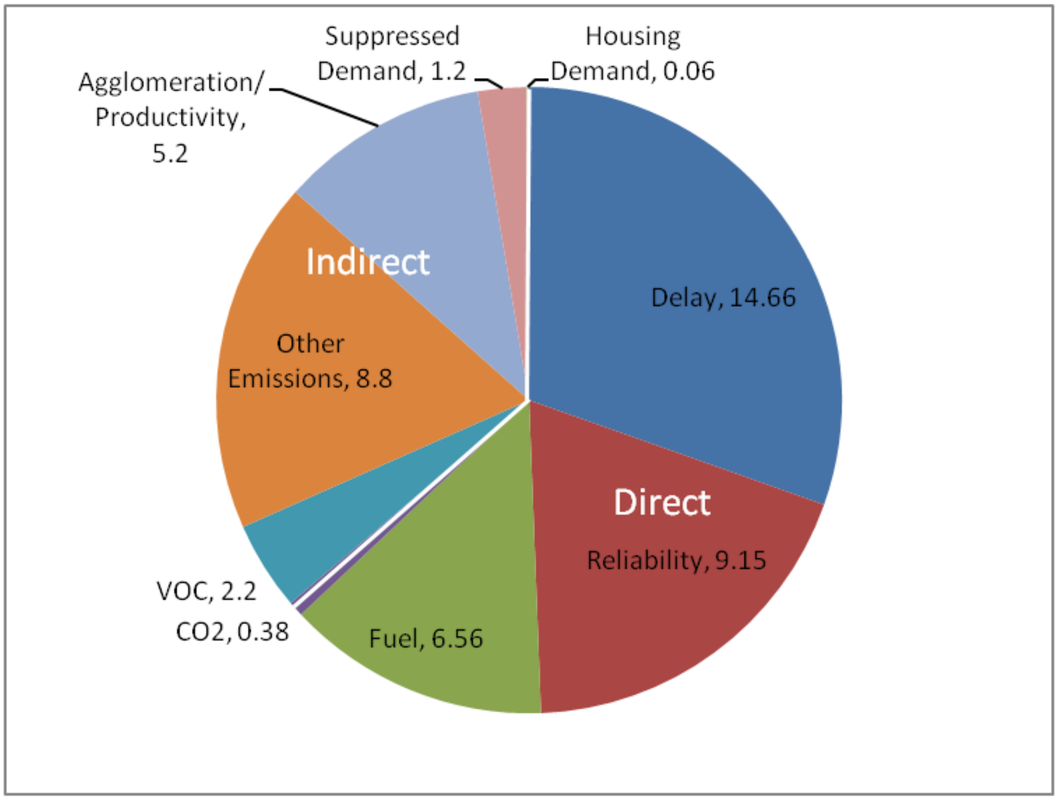
Emissions of carbon monoxide (CO), volatile organic compounds (VOC), nitrous oxide (NO_x), and particulate matter (PM_{10}), are the second largest contributor to congestion costs, largely due to their impacts on public health and the environment. Though smallest in terms of actual volume of pollutant, PM_{10} comprises 82 percent of emissions costs due to its high impacts on human health. CO_2 contributes a relatively small amount to total costs (about one percent).

Wasted fuel is the third largest contributor to costs (14 percent), both in terms of its cost to the government due to the subsidy and the direct cost to users. Fuel on the order of 1.9 billion liters of gasoline and diesel is "wasted" annually due to congestion in the GCMA. Congestion increases emissions and the volume of wasted fuel, and significantly increases vehicle operating costs.

Agglomeration and business productivity losses that can be linked to congestion constitute 11 percent of the total costs. These losses are critical for the GCMA region, as they directly and negatively affect the economy; loss in productivity and other direct costs to business results in fewer employees being hired, fewer new businesses locating in the GCMA, lower output, and a smaller tax base. Suppressed demand and the impacts on demand for housing together constitute about 3 percent of total costs – less is known about the complex relationships between these effects and traffic congestion, but the literature suggests that these negative impacts are likely present in the GCMA.

Somewhat counter to what one may first think, congestion helps to improve the safety situation in the GCMA; reducing the cost of congestion by 0.5 billion LE. Fatality, injury, and PDO crash rates are complex and nonlinear, affected by the functional classification of roadway and the level of volume on that roadway, among other factors. The literature, as well limited crash rate data, tend to support the theory that severely congested conditions tend to reduce the severity of crashes while increasing the frequency.

Figure 6.1 Distribution of All Estimated Costs for GCMA (Billion LE, 2010)



The direct and indirect costs of congestion are distributed across a population of 19.6 million people living in the GCMA, resulting in a per capita cost of about LE 2,400 (USD 400). The estimated congestion cost per capita is about 15 percent of the total GDP per capita for Egyptians, estimated at USD 2,700 in 2010 by the World Bank.

The World Bank estimates total Egyptian GDP to be USD 218.5 billion, roughly equivalent to the economies of Sydney or Toronto in absolute terms. Adjusting for purchasing power parity (PPP), Egypt's GDP is approximately USD 525 billion. According to a 2008 Price-Waterhouse Cooper estimate, the GRP at PPP for the city of Cairo proper is USD 150 billion. Adjusting back to absolute terms, and scaling for population within the city of Cairo relative to the entire GCMA, the GRP for the GCMA remains at aroundUSD 150 billion.

BENCHMARKING CONGESTION COSTS IN GCMA

A comparison of the congestion costs in the GCMA with congestion costs in other regions and cities of the world provide benchmarks for this study, and help in establishing the reasonableness of our calculations and puts congestion in the GCMA in context. The literature and data for making this comparison, however, are quite limited. This is especially true when trying to find information on cities that are roughly similar to Cairo in terms of size and economic development.

Lacking such data we have relied on data from the United States, Canada, and Australia to benchmark Cairo's congestion problem and provide a sanity check for the calculations in this report.

The comparison of the GCMA with other cities and regions was made harder by the fact that most studies reported in the literature tend to define congestion and its costs differently; sometimes the direct and indirect costs are combined together, other times individual components of the costs of congestion are combined in different ways. For example, excess fuel costs are generally incorporated into vehicle operating costs, and CO_2 emission costs are generally included with other emissions impacts. Finally, the estimates of the costs of congestion are often calculated using different approaches and methodologies which further complicate the comparison.

Delay

Despite the difference in approach and definition, all studies that consider direct and indirect costs clearly show that the costs of delay are a large share of total costs of congestion. Thus, this result is very much in line with the results of this study.

Fuel

Fuel consumed in the GCMA due to congestion was estimated at 1.9 billion liters. For the entire transport sector in 2007 across all of Egypt, fuel consumption was reported at 11 billion L.[36] Assuming there are 19.6 million people in the GCMA, the average amount of fuel wasted per capita is about 10L. TTI has estimated that 80-140L of fuel is wasted per commuter, per year for several large U.S. cities. Obviously, fuel is less expensive in Egypt than in the United States, average trip distances per commuter in the United States tend to be high, and we have the volume of wasted fuel per capita and not per commuter. Thus, adjusting for the differences in prices and the number of commuters would bring the numbers closer together. Based on this, we can conclude that if anything, our estimate of fuel wasted due to congestion is conservative.

Vehicle Operating Costs

Vehicle operating costs in the GCMA would be expected to be lower as a percentage of total costs than in more developed cities due to the age and value of the fleet. Estimates for the GCMA put VOCs at about 5 percent of total costs. A U.S. DOT study for Los Angeles, New York City, and Chicago estimated VOCs

[36] Impact of Energy Demand on Egypt's Oil and Natural Gas Reserves (Based on IEA, BP data).

at 9 to 11 percent of total cost, including only delay, reliability, emissions, VOCs, and mobility costs in the total.[37]

CO_2 and Other Emissions

Ongoing air quality measurements from several stations in Cairo by the World Bank – while not an emissions inventory – does provide two critical pieces of information for this study. First, ambient PM levels in Cairo are very high. Average concentrations of $PM_{2.5}$ exceed the U.S. annual standard (15 ug/m^3) by a factor of 2 to 3. Second, motor vehicles make a significant contribution to PM emissions: about one-third of $PM_{2.5}$ and 10 to 20 percent of PM_{10}.

This information supports the large estimate, 7.2 billion LE, of the contribution of PM_{10} emissions to indirect costs estimated in this study: it constitutes 82 percent of all emissions costs from congestion and 15 percent of total costs. A 2002 World Bank study estimated 9 to 30 billion LE in health costs from PM_{10} alone in all of Egypt from the transport sector at that time, including both congested and uncongested travel. Levy et al. (2010) indicated that in Los Angeles, 20.8 billion LE in health costs were incurred for NO_x, $PM_{2.5}$, and SO_x due to congestion.

CO_2 comprises a very small portion of all emissions costs due to congestion, at 0.38 billion LE (less than one percent of all congestion costs). Transport Canada developed congestion indicators and estimated social costs of congestion for the nine largest urban areas in Canada, limited to a range of estimates for only delay, fuel, and greenhouse gas (CO_2) costs. The study found that CO_2 was a relatively small contributor to total costs, ranging from about a 1:100 to a 3:100 ratio with delay costs. This compares with the GCMA estimate of CO_2 to delay costs of 2:100.

Cost Relative to GDP and Population

Adding up all the different elements of direct and indirect costs of congestion in the GCMA and comparing these costs to the region's estimated GRP, congestion costs add up to 5.2 percent of the GCMA GRP.

The UITP estimates costs of congestion at around 2 percent of GDP; A UNESCAP study puts it at 3 percent of GDP for Seoul and 4 percent for Bangkok. An OECD 1991 report (Bouladon, 1991 – cited in Quinet, 1994) identifies the cost of congestion as a proportion of GNP as 2.1 percent in France, 3.2 percent in the UK, 1.3 percent in the USA and 2 percent in Japan.

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[37]Office of Economic and Strategic Analysis, U.S. DOT, Assessing the Full Costs of Congestion on Surface Transportation Systems and Reducing Them through Pricing, February 2009. http://ostpxweb.dot.gov/policy/reports/Costs%20of%20Surface%20Transportation%20Congestion.pdf.

However, these figures do not identify the exact components of congestion included, and are likely less thorough than this study. A study by Bombardier estimates congestion costs – based on delay and wasted fuel only – at 3 percent of GDP. If we only use these two components of congestion costs, the similar estimate for the GCMA is 2.6 percent. Thus, we are of the view that our estimates of the total costs of congestion in the GCMA are certainly reasonable estimates of these costs, and because of the conservative assumptions we have made throughout the study,[38] they may in fact represent an underestimate of the costs of congestion.

Table 6.1 compares congestion cost estimates for 11 different cities, normalized by population and percent of GRP, to the GCMA. Only the components of congestion cost identified in each benchmark region are included in the GCMA comparison to each.

In general, costs per capita in the GCMA are lower than those in benchmark regions (usually about half). Costs as a percent of GRP, however, are higher, with the exception of Jakarta. The GCMA's GRP per capita also is more closely aligned with Jakarta. It is, however, anywhere from one-quarter to one-eighth the GRPs per capita of the remainder of the cities where GRP data are available. This explains the middle ground of the GCMA estimates between the cost per capita and cost as a percentage of GRP for every benchmark region.

[38] Whenever we had to make an assumption we made it so that it could not be said that the assumptions were inflating the costs of congestion.

Table 6.1 Congestion Cost Benchmarks Normalized by GRP and Population

Urban Area	Costs Included	Cost (Million USD)	Cost per Capita	Percent of GRP	GCMA Cost Equivalent (Million USD)	GCMA Cost per Capita	GCMA Percent GRP	GCMA Difference with Benchmark	
Jakarta (2010)[a]	Fuel, other VOC, delay	$5,200	$542	5.7%	$3,908	$199	2.6%	-63%	-55%
Connaught Place, New Delhi CBD[b]	Fuel, delay, other emissions (not CO_2)	$29	$644	N/A	$5,015	$256	3.3%	-60%	N/A
Sydney (2005)[c]	Fuel, other VOC, delay, reliability, CO_2, other emissions	$3,500	$761	1.6%	$6,975	$356	4.6%	-53%	179%
Chicago Area (2010)[d]	Fuel, delay	$8,200	$921	1.1%	$3,537	$180	2.3%	-81%	108%
New York-Newark, NY-NJ-CT (2010)[d]	Fuel, delay	$9,800	$527	1.8%	$3,537	$180	2.3%	-66%	26%
Los Angeles-Long Beach-Santa Ana (2010)[d]	Fuel, delay	$11,000	$618	1.5%	$3,537	$180	2.3%	-71%	55%
Chicago Area (2010)[e]	Fuel, delay, other emissions (not CO_2), reliability, VOC	$4,599	$517	0.6%	$6,912	$353	4.5%	-32%	627%
New York-Newark, NY-NJ-CT (2010)[e]	Fuel, delay, other emissions (not CO_2), reliability, VOC	$7,137	$384	1.3%	$6,912	$353	4.5%	-8%	239%
Los Angeles-Long Beach-Santa Ana (2010)[e]	Fuel, delay, other emissions (not CO_2), reliability, VOC	$11,986	$673	1.6%	$6,912	$353	4.5%	-48%	179%
Beijing, inside ring road[f]	Delay	$4,718	$472	N/A	$2,443	$125	1.6%	-74%	N/A
Toronto[g]	Fuel, delay, CO_2	$1,282	$233	0.5%	$3,600	$184	2.4%	-22%	366%
GCMA	All direct and indirect	–	–	–	$7,972	$407	5.2%	–	–

a Congestion Costs Jakarta Rp 46 Trillion, The Jakarta Post, 16 March 2011. http://www.thejakartapost.com/news/2011/03/16/congestion-costs-jakarta-rp-46-trillion.html.

b Determination of Congestion Cost in Central Business District (CBD) of New Delhi – A Case Study, Singh and Sarkar, 2009.

c Estimating Urban Traffic and Congestion Cost Trends for Australian Cities, Bureau of Transport and Regional Economics, Australian Government, 2005.

d 2011 Urban Mobility Report, Texas Transportation Institute, 2011.

e Office of Economic and Strategic Analysis, U.S. DOT, Assessing the Full Costs of Congestion on Surface Transportation Systems and Reducing Them through Pricing, February 2009. http://ostpxweb.dot.gov/policy/reports/Costs%20of%20Surface%20Transportation%20Congestion.pdf.

f Felix Creutzig, Maximillian Thess, Jiang Ping Zhou, Michael Replogle, Trapped in tremendous congestion – Can Beijing find a road towards harmonious and sustainable transport? http://www.user.tu-berlin.de/creutzig/CreutzigThessZhouReplogle2011.pdf.

= Estimates of the Full Cost of Transportation in Canada, Transport Canada, 2008

SENSITIVITY ANALYSIS

Numerous assumptions, observed data, and look-up tables of rates from the literature guide the analysis of direct and indirect costs in this study. This section includes an assessment of the sensitivity of the analysis to these variables.

The overall cost estimate is most sensitive to the value of time (Table 6.2). Delay and reliability, comprising the largest component of all costs, are a direct product of value of time, driving this high sensitivity. Agglomeration and productivity loss are, in turn, a function of delay. Incident delay factors and monetization factors for emissions also are key variables. Testing of fuel price sensitivity is sensitivity of the analysis procedure, not the sensitivity of the public to changes in prices – these types of policy strategies are tested in Section 8.0.

Table 6.2 Sensitivity of Analysis to Several Key Variables

	Direct Costs	Indirect Costs	Total Costs
+/- 1% Change in	**Yields a Change of +/-**	**Yields a Change of +/-**	**Yields a Change of +/-**
Value of Time	0.74%	0.36%	0.60%
Fuel Price	0.25%	0.02%	0.17%
Incident Delay Factor	0.51%	0.04%	0.34%
VOC per Mile	0.00%	0.13%	0.05%
Monetized Impact per kg of Other Emissions	0.00%	0.52%	0.19%

7.0Stakeholder Outreach

INTRODUCTION

The GCMA is one of the largest mega cities in the world. Cities of this size are by definition complex and unique environments. In studying the problem of congestion in such a large city, and making recommendations about policy measures to address this problem it is important that the characteristics of the city that make it complex and unique are adequately taken into consideration. In this study, we engaged in an extensive outreach campaign to both inform and inform relevant stakeholders during the course of the study. The objectives of our outreach campaign were to:

- Inform stakeholders about the purpose of the study and its progress;
- Gather input for developing a comprehensive list of policy measures;
- Carry out an initial screening of policy measures based on their potential effectiveness, and the feasibility of their being implemented in the GCMA;
- Understand local priorities; and
- Gather information that could be relevant for the conduct of the study.

The outreach campaign relied on interviews and a discussion questions sent by e-mail. The interviews were done in person and by telephone. The interviews were undertaken to help identify policy measures, assess the feasibility of their implementation in the GCMA, and any barriers that may exist to their implementation. Further, the interviews were focused on understanding the institutions, organization of and practices to the legal, policy, and regulatory framework for transport in the GCMA, i.e., transport planning, infrastructure development, management and financing, traffic management, enforcement and policing, relevant taxation and subsidies, and land use.

The discussion questions were administered by e-mail via the web. Respondents were asked to rate policy measures on a scale from 1 through 5 for three dimensions of feasibility – financial, political, and institutional and five dimensions of effectiveness (traffic flow, trip reduction/mode shift, safety, equity, and other benefits). This resulted in eight scores for each policy measure. Respondents were then asked to indicate which policy measures (on a list of policy measures) they viewed as being the most important (see Section 8.0 for a description of the process used for developing the comprehensive list of strategies). The discussion questions allowed for participants to add suggestions for including policy measures that were not included on the list of measures provided to them and their comments.

The list of policy measures (see Section 8.0 for how the list of policy measures was developed) were grouped in seven categories, namely:

1. **Infrastructure capacity and design –** Measures to increase the capacity of existing transport infrastructure. For example measures to increase the capacity of the road network, design improvements, development of a mass transit system, and providing infrastructure and facilities for bicycles and pedestrians;
2. **Traffic operations and control –** Measures such as providing traffic signals at intersections, more efficient use of street space, and use of Intelligent Transportation Systems (ITS);
3. **Public transit –** Measures to improve and add to the quality and capacity of public transport services and operations;
4. **Travel demand management –** Measures to manage demand by, for example, limiting space available for parking, charging for parking pricing the use of infrastructure, provision of traffic and trip information, etc.;
5. **Education –** Measures to inform and educate drivers about traffic laws and regulations, appropriate driving behavior, maintenance requirements for vehicles, traffic safety, etc.;
6. **Management and regulation –** such as police reform, transit regulation, and land use planning; and
7. **Enforcement** of traffic laws and development regulations.

Three types of criteria were used to evaluate the attractiveness of policy measures for dealing with traffic congestion in the GCMA, namely: feasibility, effectiveness, and timeframe for realization/implementation. The feasibility criteria included a consideration of financial, political, and institutional feasibility. The effectiveness criteria included a consideration of traffic flow; trip reduction/mode shift; safety; equity; and significant other benefits not directly related to above criteria.

STAKEHOLDER DISCUSSION RESULTS

Screening and Evaluation of Categories of Policy Measures by Experts

Seven experts answered the discussion questions in Phase 2 to identify policy measures. For each category of policy measures a composite score was calculated for each category of policy. This composite score is simply the average of the scores of the seven respondents for the three feasibility and five effectiveness criteria. Based on their composite score, the categories of policy measures were assigned a rank. The category of policy measures viewed as most important by the local experts was Infrastructure Capacity and Design, followed by Traffic Operations and Control, Public Transit, Travel Demand Management, Education, and Management and Regulation. A brief explanation of the results for each category of policy measures as well as any comments provided by the local experts.

Infrastructure Capacity and Design. The policy measure with the highest ranking in this category is additions to transit capacity and design improvements. The local experts were of the opinion that improvements in roadway geometry, good maintenance of roads, and better bicycle and pedestrian facilities would be effective and provide a wide range of benefits. However, financial feasibility was a concern for all measures besides the minor roadway improvements. One expert was concerned that major increases in road capacity "will increase the passenger vehicle demand." Another expert noted that the type of transit infrastructure should be targeted to the community that it is intended to serve: "BRT can serve most of the internal zones; however, outside suburbs or new communities may need light rail or similar modes."

Traffic Operations and Control. The highest ranked traffic operations and control measure was better use of street space. All experts supported the specific "use of street space" measures, namely, discipline measures, service lanes along primary and local roads where possible, and time-of-day access/delivery controls. The local experts also supported new traffic controls. Finally, the perception of that implementing measures based on ITS was expensive was worth noting.

Public Transit. The two measures included in this category were: expansion of transit service and improved operations and maintenance. Of the two, the expansion of transit services was deemed as being more attractive Increased service frequency was noted by four experts as a critical example of an important expansion of transit service.

Travel Demand Management (TDM). The highest average measure in this category was the digital and decentralized provision of government services. One expert commented that "using e-services as well as giving more delegation to local authority will solve a lot of problems: one of them is the attraction of living in Cairo." Other measures included in this category are pricing and employer/worksite-based TDM. One of experts warned that "parking and fuel pricing should consider different income levels but not by direct subsidy." Another felt that employer/worksite-based TDM strategies such as carpool/ridesharing info and alternative work options would have limited effectiveness due to trip-chaining constraints: "the private car is used for more than one trip or purpose such as giving rides to children to school and doing other services in which public transport is not suitable."

Education. Education, along with management and regulation as well as enforcement, while ranked as effective, was scored slightly lower than the previous category of measures. Driver education and training programs were identified as critical by all of the experts.

Management and Regulation. Several of the policy measures included in this category was identified by the experts as being critical. These measures included: Reform of the traffic police, land use planning, reforming the process by which development permits are granted, and traffic mitigation.

Enforcement. All respondents identified enforcement of traffic laws as a very important policy measure in dealing with traffic congestion in the GCMA.

Evaluation of Importance of Criteria using Expert Judgment

The ranking of the importance of each evaluation criteria was used as the weight given to the criteria (see Section 8.0) in the analysis for assessing the overall importance of the policy measure. Based on the expert responses, the evaluation criteria were ranked by order of importance.

The feasibility criteria were ranked in order of importance as:

1. Financial;
2. Political; and
3. Institutional.

The effectiveness criteria were ranked in order of importance as:

1. Traffic flow;
2. Safety;
3. Trip reduction/mode shift;
4. Equity; and
5. Other.

STAKEHOLDER INTERVIEWS

Introduction

In addition to the discussion questions, we contacted and conducted telephone and in person interviews with the following individuals:

- Ms. Azza Reda and budget staff, Egypt Ministry of Finance;
- Eng. Samy Abozeid;
- Brigadier Safwat Kamel, Manager of Research and Planning Unit, Ministry of Interior; and
- Professors Moustafa Sabry and Hatem Abdellatif, Ain Shams University.

The interviewees were briefed on the results of Phase 1 and the objectives of Phase 2. These experts provided data, information and previous studies that were used in this study. Each interview covered the same topics as the discussion questions. In addition, the interviews focused on local knowledge about the organization and governance of the various agencies involved in transport in the GCMA, the policies that are possible under Egyptian law, the legislative changes that could facilitate implementation of suggested policy measures, and the available funding and financing mechanisms.

Experts Assessment of Policy Measures

The interviewees indicated that the objectives and tasks of the work in Phase 2, with the focus on solutions are consistent with ongoing efforts to introduce low-cost solutions to mitigate road congestion in the GCMA. Some of those policy measures strategies are explicitly considered in the master plan for the GCMA. The interviewees approved of the policy measures being considered in Phase 2, and suggested the measures that were, in their view, the most important measures.

One interviewee was of the view that the problem of congestion in the GCMA was less a result of high traffic volumes and more a consequence of the near absent law enforcement and policing. Were existing traffic rules and regulations were to be properly enforced, it could significantly reduce the magnitude of the congestion problem. This interviewee suggested several possible solutions:

- Improved training and compensation for law enforcement personnel, including study trips to familiarize these personnel with international best practices;
- Greater use of automated technologies and ITS for traffic management as well as enforcement of traffic rules and regulations;
- Stricter enforcement of the traffic rules and regulations and better compensation/training of traffic police personnel to limit the corruption and bribery around acquiring driver's licenses and avoiding traffic violations; and
- Organizational reforms to the traffic police agency, including a dedicated source of funds to finance the training, development, and compensation of traffic police personnel.

Other policy measures identified by the interviewees included:

- Accelerating the expansion of the metro network beyond the current two lines.
- Improving access to government buildings along major road corridors (e.g., Salah Salem Road). For example, the access and egress movements of large buses carrying government employees causes major disruptions to flow of traffic along Salah Salem road during peak periods, causing serious traffic congestion. In addition, parking management around government buildings needs to be improved.
- Limiting the problem of unauthorized parking and jaywalking around large government and other buildings can help to reduce congestion and improve safety.

- Finding network solutions at specific points in the road network could relieve traffic congestion. For example, converting the parallel Salah Salem and Autostrad roads into one-way roads and connecting them with lateral roads could improve traffic flow along these two major corridors.
- Reforming the Ministry of Interior to improve their ability to manage traffic congestion, road accidents and other incidents on the roads.
- Regulating and controlling the micro and minibuses along major arterials in the GCMA.
- Improving driver education/training programs.
- Reforming parking policies and enforcement.
- Replacing U-turns with regular intersections.
- Signalizing uncontrolled intersections.
- Incorporating transit-oriented design into community redevelopment, such as places for minibuses to stop or pull over in urban core.
- Improving the reliability and comfort of bus services.
- Increasing the use of the river for freight and passenger transport.

Organization and Governance

The planning, maintenance and operation of the transport system in the GCMA is highly fragmented. It involves numerous agencies and different levels of government, often with overlapping and ill defined tasks and responsibilities and ambiguous authority. The lack of effective governance compounds the problem of traffic congestion making it very difficult to effectively and efficiently deal with this problem.

In the domain of public transport, The Egyptian Ministry of Transport is responsible for realizing and operating the metro lines. The Governate has the responsibility for the bus lines, with several operators active within the Governate: the Greater Cairo Bus Company, the Cairo Transit Authority (for trams), and private operators of mini buses. The Governate is funded by the central government and distributes these funds as subsidies. However, the Governate has no dedicated and/or independent source of funding for its activities. Neither does the Governate have any authority to implement its own services, nor does it have much control over private operators over whom it exercises its limited control through levying license fees.

For urban roads, the Route Authority, an agency under the Governate, maintains and constructs the system. The ring road, however, is under the authority of the Ministry of Transport. The Ministry of Tourism has developed some intercity routes, and the Ministry of Defense maintains an intercity highway for public use. The Ministry of Housing built a tunnel since it had the needed financing.

Traffic studies are conducted by the Traffic Authority, housed within the Governate.

The Ministry of Interior handles enforcement and some elements of traffic management. However, there are separate police departments for general policing, traffic, bus, and rail.

The interviewees also pointed out that that weak coordination among all the different entities involved in the development, operation and maintenance of transport infrastructure and services seriously hinders successful and efficient planning, programming, and implementation of comprehensive transportation solutions. As a result, a "Committee of the Wise" was recently created to identify local traffic problems, discuss tactical solutions, and implement the best – and often lowest-cost – solutions. This committee includes representatives from the:

- Route Authority;
- Cairo Transit Authority;
- Traffic Authority;
- Traffic police; and
- Academics and local experts.

Funding and Finance

The collection of revenues is largely done by the Central government with no local taxes. Increasing the taxes on fuels also seems very unlikely in the short term as this is a politically sensitive action that would affect a large number of the less well off population in the GCMA. However, Egypt currently is studying ways to reduce the fuel subsidy, and recently attempts have actually been made to implement the reduction of the fuel subsidy for industry. The removal of the fuel subsidy is seen as a good measure by several of the interviewees.

Property taxes had been in place for hundreds of years, but the previous government removed them. A new property tax has been proposed, but this is still on hold. This proposed property tax would allow Governates to keep up to 25 percent of locally generated property tax revenues. The Minister would be able to increase that percentage if necessary, and the assessed value of property would be revised in line with inflation.

Currently, while corporate and individual income taxes are levied, there is no VAT or the infrastructure necessary to administer a VAT. The Egyptian government, however, is considering the implementation of a VAT and is discussion this with the IMF.

Licensing and vehicle registration fees go directly to the Governate. The Central Maritime Agency administers a cargo tax. Collected tolls go to the General Agency for Highways and Bridges and Road Transport (GAHBRT), with 90 percent of these funds going back into maintenance of roads. Truck weight violation fines primarily go to roadway maintenance, with a small proportion of these revenues being used to pay the salary and bonuses of the police force.

Finally, a new law now makes it possible to create public-private partnerships and this opens up new possibilities to attract private investment to the transport sector. Finally, foreign aid also helps fund the transportation system.

Based on the interviews, one of the pressing problems facing the transport sector in the GCMA is the lack of an adequate, dedicated, and stable source of funds to finance development, improvement, operational and maintenance activities in the GCMA. This lack of funds also is clearly hampering effort to deal with the problems of congestion.

8.0 Evaluation of Congestion Reduction Strategies

APPROACH FOR IDENTIFYING POLICY MEASURES

A key objective of the work in Phase 2 was the identification and analysis of policy measures to address congestion and to make recommendations to reduce congestion and its adverse effects in the GCMA. There are several different categories of policy measures that can be taken to combat congestion. A comprehensive list of more than 50 policy measures was developed by reviewing best practices worldwide. This list was combined with policy measures suggested by local experts in Phase 1

Section 7.0 described the discussion with local experts to *qualitatively* evaluate the policy measures. This section describes the quantitative assessment of selected policy measures for their effect on direct and indirect benefits from reducing congestion. The selection of policy measures for assessing quantitatively was based on:

- Including the types of projects that already were being implemented or being proposed for implementation in the GCMA.
- Responses provided by local experts to the discussion questions and interviews, along with feedback from the workshop held in April 2012. The expert input identified policy measures thought by local experts to be most relevant for implementation in the GCMA.
- The ability to quantify the effects of policy measures based on the available. Policy measures whose effects could not be quantified using available data were dropped from further consideration. For example, police reform was determined to be too difficult to evaluate quantitatively since there are no data on the direct impacts such reform might have on traffic congestion in the GCMA.

It would have been impractical to quantify the more than 50 individual policy measures that were identified. Some of the individual policy measures contained in the initial list and suggested through stakeholder outreach were combined to simplify their evaluation. For example, various transit operations measures (bus priority, schedule control, etc.) were combined into a single group. In the end, the quantitative evaluation included 16 policy measure in seven categories:

1. Major additions to road capacity;
2. Major transit investment;

3. Transit operations and nonmotorized travel;
4. Travel demand management;
5. Intelligent transportation systems;
6. Pricing; and
7. Access management.

Some policy measures are sufficiently closely related to other policy measures for which data was not available. For example, advanced corridor management improves traffic flow along a given corridor. Other policy measures with roughly the same effects, such as improved enforcement of traffic laws, should provide roughly similar benefits. Thus, we believe that the benefits of these 16 policy measures are representative of the potential benefits of a comprehensive set of policy measures to reduce congestion. A more precise comparison of the benefits of individual policy measures would require a much more detailed analysis of each corridor that is well beyond the scope of this study. Other potentially attractive policy measures for reducing congestion in the GCMA, such as low-emission vehicles or fuel and emissions standards, that are not directly related to reducing *congestion* costs were not included in the list of policy measures considered as part of this study. Nevertheless, the policy measures are generally consistent with efforts to reduce CO_2 and health impacts from other emissions and many can provide substantial reductions to these environmental costs. Where possible, it is recommended that strategies be implemented in the most environmentally sustainable way to reduce emissions even more, such as by implementing bus improvements using low-emission vehicles.

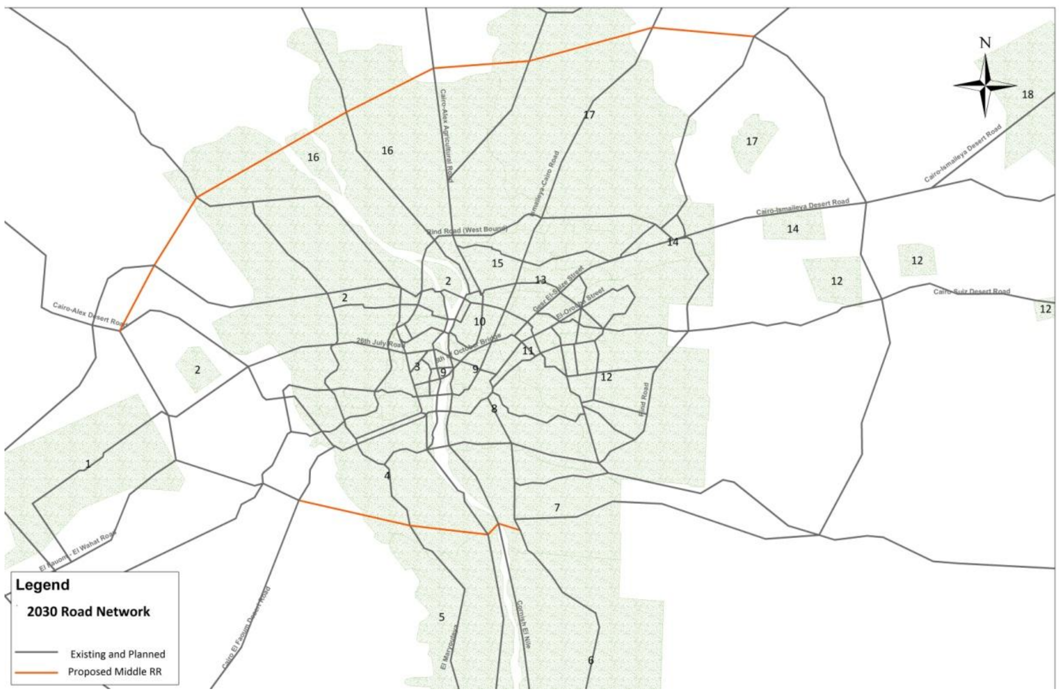
The remainder of this subsection describes the specific policy measures evaluated in each category and how each of these policy measures can reduce congestion.

Category 1: Investing in Additions to Road Capacity

This category includes two policy measures: 1) new facilities; and 2) new lanes (road widening). These policy measures have the effect of increasing road capacity. The new road tested in this analysis was a new ring road, something that could be constructed outside of the dense urban core of the city, considering right-of-way availability and construction costs. This was tested by adding new links representing this road to the model network. In addition to new roads, new lanes/widening was tested on the existing ring road, again considering practical right-of-way requirements. These proposed projects for testing are shown in Figure 8.1.

Roadway investments have a direct effect on reducing congestion by increasing capacity relative to demand on existing roadways. However, over time they can lead to increased vehicle travel due to induced demand, more dispersed urban growth, and make nonmotorized travel less safe or convenient in the case of road widening. Therefore, over time their benefits from reducing congestion may decline. It should be noted that most of the effects of roadway investments on induced demand, urban growth, and nonmotorized travel are not captured in the GCMA travel model. Finally, to avoid the denudation of the beneficial effects of investments in road capacity,, investments in roads should be combined with other policy measures such as, for example, congestion pricing or other forms of pricing to manage demand and ensure that road capacity is preserved for high-value uses.

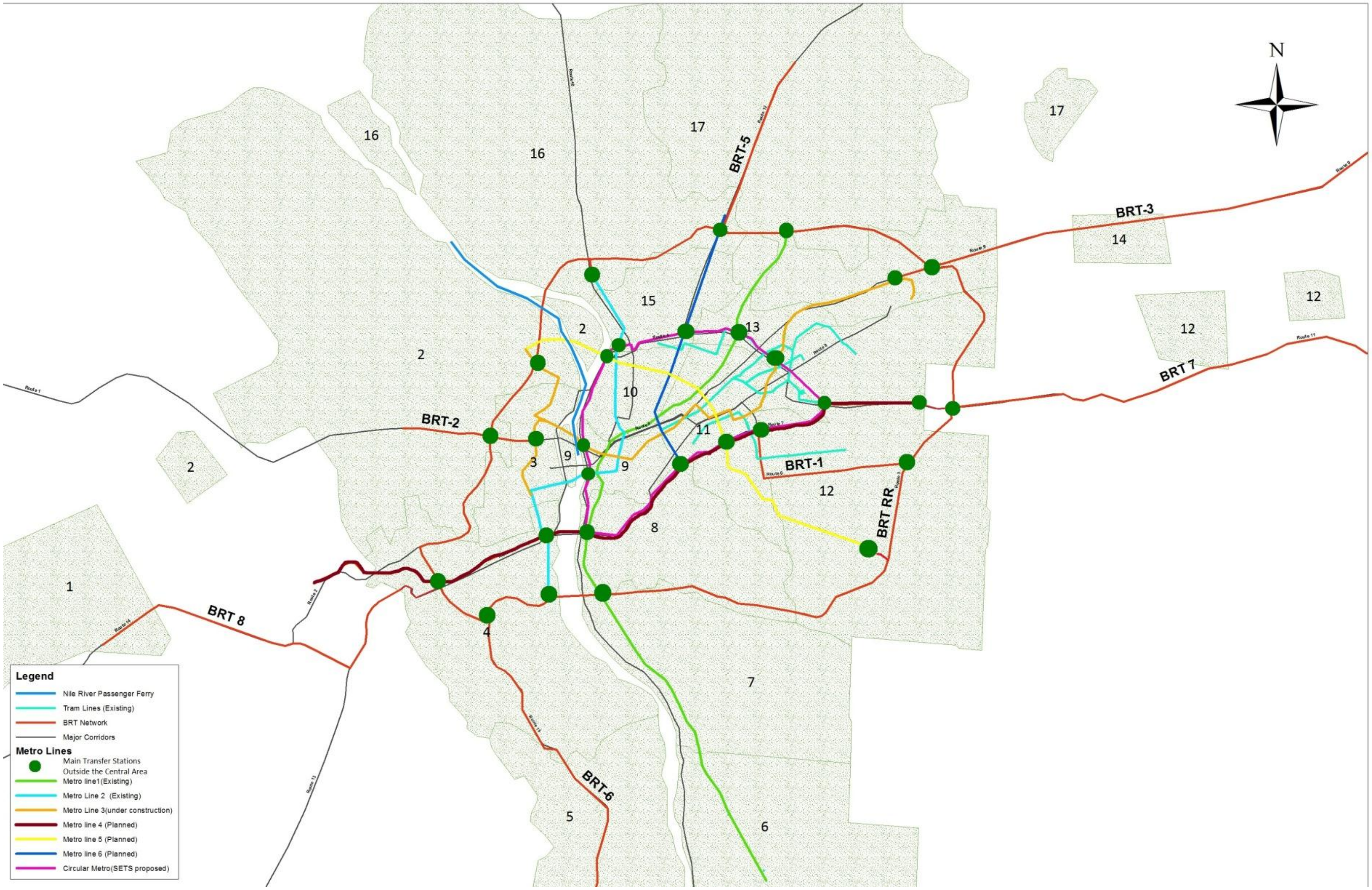
Figure 8.1 Investing in Road Capacity



Category 2: Investing in Improving and Expanding Transit

This category includes three policy measure: 1) a new circular metro line; 2) new radial metro lines; and 3) bus rapid transit (BRT) lines that provide connections between the metro systems along major corridors. The radial metro lines tested included Lines 4, 5 and 6; several BRT lines were tested in conjunction with transit operations improvements (described later), and lines are illustrated in Figure 8.2. While this study examines impacts purely from congestion improvements, it is recommended that low- or no-emission vehicles be considered for any BRT fleet purchases to further reduce $CO2$ and other emissions impacts.

Figure 8.2 Existing, Planned, and Proposed Major Transit Investments



Investments in improving and expanding the metro and BRT network and service offer people an alternative to private vehicle travel, or travel by public transit vehicles (for example, micro/mini buses), thereby reducing traffic and congestion on surface streets. A metro is well suited for very high-demand corridors (more than 30,000 trips/hour), whereas BRT can provide premium transit service in lower-density corridors (up to 30,000 trips/hour) at a significantly lower cost than a metro. BRT projects along surface streets also can be realized with other forms of traffic control (such as access management and ITS) to improve traffic flow on arterials, as is assumed in this study. It is further assumed that BRT includes traffic signal priority, frequent service, and dedicated lanes and stations. Finally, providing good pedestrian access to transit stations, and increasing development around stations, also are important for maximizing the benefits of investments in transit.

Category 3: Transit Operations and Nonmotorized Travel

This category includes two sets of policy measures: 1) operational improvements in transit; and 2) improvement and development of nonmotorized infrastructure. Both these policy measures make it easier and more comfortable for users and potential users to use transit. The improvement and development of nonmotorized infrastructure is an essential part of getting more people to use transit by providing the "last-mile" connectivity. If the "last-mile" connectivity is not good or safe, potential transit users are likely to avoid using transit.

Operational improvements in Transit can include: Priority for buses at traffic signals, higher capacity vehicles, increased frequency of service, higher standards for the state of good repair, improved control of schedules to increase reliability of bus services, and potentially fare integration among different operators. All of these improvements are directed towards making transit service more attractive to users and potential users (for example, car drivers or other users of private transport) and increasing ridership. While this study examines impacts purely from congestion improvements, it is recommended that low- or no-emission vehicles be considered for any improvements in the bus fleet to further reduce CO_2 and other emissions impacts.

Improvements in nonmotorized travel can include: new infrastructure for bicycling and bicycles (including facilities for bicycle parking), pedestrian facilities, and information and publicity campaigns to support nonmotorized travel,, a pedestrian and bicycle friendly traffic code, and stricter enforcement of traffic laws, etc. These actions are designed to stimulate people to walk and use bicycles as much as they can, while at the same time making it easier, safer, convenient and comfortable to get from point A to B by walking or cycling.

Category 4: Travel Demand Management

This category includes three distinct sets of policy measures: 1) Work/office TDM; 2) Government services; and 3) TDM at new projects.

Work/office TDM is aimed at targeting a large group of users of road capacity during peak periods, namely the people who commute from home to work and back. Anything that can be done to induce these people to do their commute using transit, or shared public or private transport falls in the category of these policy measures. The measures in this category can include, for example, carpool/ridesharing information and alternative work schedule options. These policy measures are aimed at helping commuters find alternatives to the private car to get to and from work. These types of measures are quite common in the United States and Europe, but not as common in Egypt. Carpooling, ridesharing, or similar ride-matching systems, can help and facilitate other commuters find other commuters living near them and with whom they can potentially share a ride. Other possibilities are to reorganize work schedule so that the work week is compressed requiring fewer commuting trips, or to offer the possibility of telecommuting. While these possibilities may not be for everyone, they are most well suited for professional jobs which do not require employees to be constantly present at the office, they can help to alleviate congestion problems.

Government services are a big generator of trips and congestion – people needing to use government services have to physically travel to the point of service. In the GCMA, government offices are concentrated in certain areas of central Cairo. Anyone wanting to use these services must physically travel to these government offices. Currently, a the large number of people, not just from within the GCMA, but from all over Egypt travel to these offices causing lots of congestion. One interesting proposal to relieve congestion, at least in the areas where these government buildings are located, is to decentralize the provision of these government services to locations closer to where the people live, and away from the one central location. Furthermore, providing, where possible, these services digitally will significantly reduce the need to physically travel to these offices.

TDM for new developments, including requirements for traffic mitigation in new development, and enforcement through permitting. One of the most effective ways of reducing vehicle trips is to design projects right from the start in such a way that they encourage access by other transport modes and to integrate them into the transit system. For example, the number of parking places in new developments can be limited and made more expensive by charging for it (rather than providing it for free). In order to stimulate use of transit, features such as convenient pedestrian connections to surrounding streets, entrances adjacent to bus stops, and secure bicycle parking facilities, and connection to transit services all encourage use of alternative transport modes and transit.

Additionally, mixed-use buildings can reduce the need for off-site trips. Finally, developers can be required to implement traffic improvements on adjacent streets (particularly the access roads and arterials). Guidelines or requirements for TDM and traffic mitigation can be established for new development and enforced by linking these improvements to the granting of permits – an approach that is becoming increasingly common in the United States and Europe.

Category 5: Intelligent Transportation Systems and Operations

This category includes two policy measures: 1) advanced corridor management focused on specific corridors; and 2) traveler information systems applied to the entire metro area. ITS policy measures are directed at increasing the efficiency with which available/existing road capacity can be utilized by streamlining and improving traffic flows. However, they do require varying degrees of investment in hardware and software infrastructure, such as a traffic control center, monitoring equipment, and traffic signal controller upgrades.

Advanced corridor management is a term that includes a number of IT'S/operations activities to improve traffic flow within a travel corridor. These activities may include incident management (detecting and responding to incidents), traffic signal interconnection and coordination, adaptive signal control, real-time traveler information within the corridor (e.g., roadway and metro travel times between points A and B), and variable speed limits. Subsets of these policy measures also could be implemented individually or in combination, with somewhat lower benefits than a comprehensive package of policy measures.

Traveler information systems include the expanded provision of real-time information throughout the GCMA. Methods for disseminating this information may include telephone hotlines, highway advisory radio, variable message signs, web-based information, trip planning software, and real-time transit information disseminated via message signs and/or mobile devices. Traveler information may help reduce congestion in multiple ways: by helping travelers avoid particularly congested times or locations; by showing comparative times for transit versus automobile; and by giving transit users greater certainty over how long their trip will take.

Category 6: Pricing

This category includes two policy measures: 1) reducing or eliminating fuel subsidies; and 2) increasing the cost of travel in the central area via cordon fees, parking fees, or both. Both policy measures are directed at increasing the cost of private vehicle use, thereby providing travelers an incentive to use public transit or nonmotorized modes of travel. They also result in revenues to government, which can be reinvested in other transportation improvements to achieve greater public benefits.

Reducing or eliminating fuel subsidies – Fuel currently is heavily subsidized in Egypt: approximately half the price. One measure available to government can to reduce congestion is to lower or eliminate fuel subsidies. More expensive fuel would make driving more expensive and it would other transport modes more attractive, and it also would make more fuel efficient vehicles more attractive than what they currently are. The savings resulting from eliminating fuel subsidies could further be used to improve and expand transit and other transportation system improvements to reduce congestion. The transit and transport system infrastructure improvements along with less congestion would offset the negative impacts of increased costs to consumers. Finally, overall economic efficiency would be increased, since subsidies distort the market and mean that the true cost of fuel use and travel is not reflected in the decisions that consumers make.

Increasing the cost of travel in the central area – A few major cities, including London, Singapore, Stockholm, and cities in Norway, have implemented pricing schemes whereby vehicles must have a paid permit to be able to drive in the central area of the city during peak period. The result has been less congestion and better air quality in the central areas of these cities. While implementing a charging/pricing scheme does require significant investments in payment, monitoring, and enforcement technology, the scheme also yields revenues which can more than offset these up-front investments.

Category 7: Access Management

This final category (evaluated as a single policy measure) includes median closures, turn restrictions, control of access/egress to major buildings such as government buildings, and establishment of service lanes along primary and local roads. The objective is to increase the efficiency and safety of traffic flow by channelizing movements and separating turning and low-speed traffic from the general traffic flows. This policy measure is suitable for major roadway corridors and can be applied in conjunction with ITS measures to improve traffic flow without adding additional road capacity. The ability to implement specific access management policy measures will vary by corridor, depending upon the specific situation on the ground in each corridor.

Table 8.1 next page provides additional details on the approach used to model and test policy measures for GCMA.

Table 8.1 Approach to Modeling Policy measures

Policy measure	Elements of Policy Measure	Method for Peak-Period Impact	Geographic Scope	Justification
Major Highway Capacity				
New facilities	New Ring Road	Modeled using GCMA travel model – adding new roadway links	Areas currently with available ROW where growth expected to occur	
New lanes/road widening	Additional Capacity to Existing Ring Road	Modeled using GCMA travel model – increasing capacity of existing links	Major corridors with available ROW	
Major Transit Investment				
Metro expansion – circular	Circular metro line	Base vehicle trip reduction on ridership estimates back-calculated from service levels using existing load factors	Zones to be served by transit	Assume expansion attracts riders at same loading as current services
Metro expansion – radial	Three proposed radial metro lines	Base vehicle trip reduction on ridership estimates back-calculated from service levels using existing load factors	Zones to be served by transit	Assume expansion attracts riders at same loading as current services
BRT network	BRT lines adding connectivity to metro system	Assume 10% of vehicle trips starting and ending in corridor captured by BRT. Assume any traffic capacity lost is offset by access management (i.e., no change in traffic capacity in corridors – do not apply access management policy measure benefit).	Several major corridors not served by Metro	Professional judgment based on observed data on BRT ridership in other cities
Nile river passenger ferry		Base vehicle trip reduction on assumed ferry passenger service along 23 km from central GCMA to the north. Assume service consisting of 30 passenger boats 15-minute peak headway, with prior mode shares based on existing average mode shares. Check by comparing estimated passenger volume against existing trips in ferry travel shed	Zones to be served by ferry (travel shed)	

Policy measure	Elements of Policy Measure	Method for Peak-Period Impact	Geographic Scope	Justification
Transit Operations and Nonmotorized Travel				
Transit operations	Bus priority operations Higher capacity vehicles Increased frequency State of good repair Improved schedule control	15% increase in number of existing bus pax-trips (removed from vehicle-trips based on existing average mode share)	Trip reductions proportional to level of bus service or current ridership	Judgment of effects of comprehensive transit service improvement, based on limited evidence from literature
Nonmotorized Travel	Bicycle facilities Pedestrian facilities Active travel campaign	10% of vehicle trips < 5 miles or 5% of all vehicle-trips starting or ending in corridor	Trip reductions applied to trips throughout GCMA based on length	Assumes that most mode-shifting comes from bike improvements, since pedestrian trips are usually short. Bike mode shares in European cities with good bike infrastructure are in the range of 10-20%; most trips are under 5 miles
Travel Demand Management				
Worksite TDM	Carpool/ridesharing info Alternative work options	5% reduction in vehicle work trips with destinations in major corridors	Trip reductions applied to work trips	Conservative judgment for areawide TDM initiatives, based on TDM literature from U.S. and Europe
Government Services	Decentralize government service provision Expand government e-services	Not quantified		
New Project TDM	Development mitigation Permitting enforcement	5% of vehicle-trips generated by new development destinations in some major corridors (additional to worksite TDM)	Proportional to amount of new development	Conservative judgment based on TDM literature from U.S. and Europe. Assumes that TDM for new developments includes parking supply management and pricing, pedestrian design, bike facilities, transit access, information on travel options
Intelligent Transportation Systems and Operations				
Advanced corridor management	Incident management, traffic signal coordination/ interconnection, adaptive control, real-time information, variable speed limits	Increase arterial capacity by 15% (signal coordination). Reduce calculated travel time reliability (hours of nonrecurring delay) by 15%. Reduce applied crash rate (per VKT) by 5% (all crash categories)	Major Arterial Corridors	Arterial capacity increase due to signal coordination based on methodology from U.S. IDAS model. Reduction in hours of nonrecurring delay based on combined impact of incident management and traveler information improvements. Safety improvements due to variable speed limit improvements based on literature review

Policy measure	Elements of Policy Measure	Method for Peak-Period Impact	Geographic Scope	Justification
Traveler information systems	Telephone hotline, highway advisory radio, variable message signs, web-based traveler information, real-time transit arrival information, trip planning software	Reduce calculated travel time reliability (hours of nonrecurring delay) by 5%. Factor this impact by the percent coverage of the roadway network by the traveler information system	Regionwide	Based on data in U.S. IDAS model
Pricing				
Reduce/eliminate fuel subsidies	Fuel to be sold to consumers at or near market prices	Apply elasticity of VKT with respect to fuel price of -0.3 to all travel	Regionwide	Elasticity of -0.3 consistent with long-run elasticity's in literature – see Litman (http://www.vtpi.org/tdm/tdm11.htm#_Toc161022580)
Central area pricing (cordon pricing and/or parking fees)	Pricing of most congested central area applied to congested/ daytime times (e.g., 12 hours 7:00 a.m.-7:00 p.m.), with revenue reinvested in transit	1. Define area to be priced (CBD) 2. Reduce vehicle trip-ends in this area by 10%	Central Area	10% is a conservative reduction based on 10-15% VKT reduction in priced area for other cities (London, Norway, Singapore, New York – modeled)
Access Management				
Access management and service lanes	Median closures, turn restrictions, access/ egress to major buildings such as government buildings, service lanes along primary and local roads	Increase arterial capacity by 25% and reduce crash rate by 25%	Major Arterial Corridors	Access management will have similar effects to advanced corridor management. The numbers here are based on Table 2-5 of the Access Management Manual (TRB, 2003). Benefits of at least 30% are cited in most cases, so 25% is conservative considering whether opportunities in Egypt may be limited.

ANALYSIS OF POLICY MEASURES

Each of the above categories of policy measures was analyzed using a combination of quantitative and qualitative approaches. The assessment of policy measures involved the following steps:

- Estimating travel and congestion in a baseline scenario in 2010 and 2030.
- Estimating the effect of the policy measure on annual vehicle travel to the year 2030. For the policy measures for which this was not possible, we used estimates of the effectiveness of the policy measure based on experience in other parts of the world.
- Translating the reduction in vehicle travel into reduction in congestion on the road network.
- Translating the reduction in congestion into other direct and indirect benefits (for example, reduced emissions and lower vehicle operating costs).
- Applying the weights based on the feasibility and effectiveness criteria to each policy measure to come up with the overall relative (to other policy measures that were considered) attractiveness of each policy measure.
- Estimating the cost of each policy measure to include both capital and operating costs. The operating costs were for a 20 year period.

Effectiveness was quantified using the GCMA travel demand model as a starting point. However, since the model does not include a transit network or a mode choice component, it could only directly be used to quantify the impacts of highway capacity improvements. Other policy measures were evaluated using off-model assumptions (e.g., assumed transit ridership based on observation in existing corridors, or estimates of TDM benefits from other studies). These off-model assumptions were applied to specific travel markets as determined from the model.

The quantitative assessment was conducted at a sketch-level, given that an assessment needed to be made of the benefits to all of the GCMA with very limited data and modeling resources. The results, therefore, should be considered order-of-magnitude estimates to show the size of benefits that might be achieved. A more precise estimate of any policy measure would require detailed local data collection and analysis that is well beyond the scope of the current study.

Order-of-magnitude cost estimates (including capital and operational costs) also were developed, using local or comparable measures in other cities, for each policy measure. The purpose of these estimates was to create a basis for comparing the relative cost-effectiveness of each policy measure in reducing congestion and providing benefits like better air quality, improved safety, and economic benefits. Cost effectiveness is calculated as the net present value of 20 years of estimated benefits, assuming an annual percent reduction in congestion costs compared to the baseline, divided by the net present value of 20 years of steady operating costs plus total up front capital implementation cost. Some of these operating costs may be offset by revenues, but potential revenues such as fares or tolls are not included in the cost-effectiveness analysis.

In the following pages, Table 8.2 shows cost estimates for implementing each of the policy measures, Table 8.3 underlines the relative synergies between policy packages and Table 8.4 provides an evaluation of the different policy packages.

Table 8.2 Estimated Costs of Policy Measures

Policy Measure	Capital and Operating Cost Estimate	Source of Cost Estimates	Supporting Data
Major Highway Capacity			
New facilities	$4.0M (24M LE) per mile * X miles (multilane arterials) $10.0M (60M LE) per mile * X miles (expressways)	Combination of World Bank and U.S. costs per mile	**World Bank** ROCKS Database (8): ($2000) New 2L Highway: $1.7M/mile New 4L Highway: $3.5M/mile New 6L Highway: $4.3M/mile New 4L Expressway: $3.0M/mile **U.S. (1, 17)**: Urban freeways – $10-50+M/mile; arterials – $5-10M/mile
New lanes/road widening	$1.0M (6.0M LE) per mile * X miles	Combination of Cairo projects and ranges from World Bank and U.S. data	**World Bank** ROCKS Database (8): ($2000) Partial widening: $215k/mile Partial Widening and Reconstruction: $405k/mile Widening: $1.4M/mile Widening and Reconstruction: $2.0M/mile **U.S. (1, 17)**: $1.0M-5.0M/lane-mile (urban) **Cairo Projects:** Mediterranean Coastal International Highway: $387k/mile [18] Alexandria to Delta Region Highway: $411k/mile [18] Cairo-Alexandria-Matrouh Highway Project: $1.5M/mile upgrade to freeway standards [19]
Major Transit Investment			
Metro expansion – circular	$110M (660M LE) per mile * X miles Assume operating costs fully recovered	Existing/planned projects in Cairo	**Cairo Estimates (3):** $112.6M/mile for metro improvements $49.9M/mile for Supertram Line #1 ($2002) $21M/mile for Line #1 (at-grade, upgrade existing) $219M/mile for Line #2 $137M/mile for Line #3 $125M/mile for Line #4 **World Bank (6):** $24-48M/mile at-grade new-build system ($2000) $48-120M/mile elevated new-build system $96-290M/mile underground new-build system **Flyvberg et al. (7):** $80-240M/mile ($2002) **Santiago Metro Expansion (9):** $64M/mile for Line 2 Extension $80M/mile for Line 5 $49M/mile for Lines 4 and 4A **Seoul, Korea (10):** $130-$160M/mi for metro lines in general. $172M/mi est. for northeastern metro line

Policy Measure	Capital and Operating Cost Estimate	Source of Cost Estimates	Supporting Data
Metro expansion – radial	$110M (660M LE) per mile * X miles Assume operating costs fully recovered	Existing/planned projects in Cairo	see above
BRT network	$5M (30M LE) per mile * X miles (capital) Assume operating costs fully recovered	Existing/planned projects in Cairo BRT in other developing cities	**Cairo Estimates (3):** $4.6M/mile for "West Wing" corridor ($2002) **Bogota (4):** $9.42M/mile for BRT Phase I ($2003) **ITDP (5):** $1-3M for a BRT Plan $1.6-12.9M/mile for capital costs $0/year for operational subsidies ($2007) **U.S. GAO (10):** $15M/mi ($2001) **Bus Operating Ratio (12):** Revenues should cover costs such that operating ratio (total revenue/operating costs) – 1.05-1.08.
Nile river passenger ferry	$10M (60M LE) per vessel Assume operating costs fully recovered		**U.S. (20):** New high-speed vessel: $19M; refurbish used vessel: $10M
Transit Operations and Nonmotorized Travel			
Transit operations	$300M (1,800M LE) citywide public cost	Ballpark figure based on integrated transport systems in Santiago and Bogota	**Transantiago Public Transportation Modernization Plan (9)**: $30 million for support systems (fare collection, control, and user information); **Urban Transport Integrated Plan for Santiago (PTUS 2000-2010) (9)**: Total public cost = $250M ($2000), with additional private investment of $700M, without including Metro investments. **Bogota (15):** $300M contract to establish and operate automatic fare collection (AFC) and bus management system (BMS) in Bogota (18 months for 40 BRT stations and 12,000 buses)
Nonmotorized Travel	$160M (800M LE) citywide cost over 20 years	$400k/mi for bike facilities and programs * 200 mi (300 km) = $80M; double to account for ped improvements	**Bogota (11)**: New bicycle facilities = $800k/mi **Bogota (13):** $400k/mile for first phase of bicycle master plan (200 km = $80M) **Bogota (14)**: $2M/year for maintenance of 152 miles of the CicoRuta. **U.S. (2)**: $100-200/capita for 20-year citywide program of ped improvements in U.S. cities; ~$200/capita for bicycle improvements $220K/mile for bike facilities
Travel Demand Management			
Worksite TDM	$50M (300M LE) citywide cost over 20 years	$2.5M (15M LE) per year	**U.S. (2)**: ~$2/capita annual for employer outreach and rideshare **U.S. (16)**: Typically $1-10M annual budgets for TDM program implementation in larger cities
Government Services	0 or net savings	Assume that efficiencies will pay for themselves	N/A – no literature available
New Project TDM	$5M (30M LE) citywide cost over 20 years	Assume $250K (1.5M LE) annual for staffing to cover permit review and enforcement	Professional judgment

Policy Measure	Capital and Operating Cost Estimate	Source of Cost Estimates	Supporting Data
Intelligent Transportation Systems and Operations			
Advanced corridor management	$1M (6M LE) per mile * miles affected (capital + operating cost over 20 years)	U.S. costs per mile	$5-10M cap for regional TMC, + $0.5-1.5M annual op costs (1) $100K cap + $50K annual op/maint per mile (2)
Traveler information systems	$2.5M (12.5M LE) citywide cost over 20 years	U.S. costs for citywide system	$0.5M cap + $0.1M op for surveillance/info systems only (1) $100K cap + $10K annual op/maint per mile (2)
Pricing			
Reduce/eliminate fuel subsidies	$0 capital investment cost Net revenue for public sector and net social cost savings	Public sector cost: Increased revenue based on size of subsidy eliminated. Net social cost: Savings due to improved economic efficiency	N/A
Central area pricing (cordon pricing and/or parking fees)	$200-500M (1.2-3.0B LE) capital investment for cordon pricing Net savings after 2-3 years considering operating revenue	Public sector cost: operating revenues offset initial investment in 2-3 years Net social cost: Assume efficiency benefits from congestion reduction offset capital + operating costs	London, Stockholm – $400-500M investment + $170M/yr operations (40% of revenue) (1) NYC (Manhattan) – $224M capital + $229M/yr ops (35% of revenue (1)
Access Management			
Access management and service lanes	$500K (3M LE) per mile * X miles	Assume 25% of road widening cost	Wide variations, $10,000 – > $1 million per mile (1)

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EVALUATION RESULTS

Table 8.3 shows the relative synergies between the different policy packages: green represents good synergies, yellow is neutral, and red indicates that the strategies may be working toward contrary ends. For example, access management, central area pricing, and enforcement all help to improve transit operations, so these policy packages are considered synergistic. Alternatively, major investments in new highways tend to have contrary goals and outcomes to investments in pedestrian and bicycle facilities to encourage fewer auto trips. The relationships in this table help to guide the evaluation of combined packages and, ultimately, the development of logical implementation plans for the GCMA. Using these relationships, two sets of combined policy packages were tested for their cumulative impacts on congestion in 2030.

Table 8.4 shows the evaluation results for each of the policy packages, incorporating both quantitative and qualitative analysis. This table includes modeled policy packages for infrastructure and operations policy measure, as well as high-level policy packages. For each policy package, its contribution to direct cost reduction and indirect cost reduction are shown, along with institutional feasibility; local acceptance; implementation cost (order of magnitude capital and operating); cost-effectiveness, defined as total direct and indirect cost reduction divided by implementation cost; and overall implementation timeframe (based on when project can be operational; however, some strategies require immediate actions even though full implementation will be in the long term).

Metro system build-out, transit operations improvements along with BRT, and reducing fuel subsidies by at least 50 percent have the highest relative impact on congestion costs. Other high-impact policy packages include the access management package, which also includes all operational spot improvements and service roads, as well as individual metro lines.

Through the stakeholder outreach, financial feasibility was identified as the most important feasibility criterion. This is a practical concern, since without the up-front capital for a project, even the most cost-effective project cannot be implemented. TDM, access management, and traveler information systems projects all have high cost-effectiveness as well as low implementation cost. Reducing the fuel subsidy is a measure with no financial implementation cost that has a drastic impact on reducing congestion.

Among effectiveness criteria traffic flow was identified as most important by stakeholders. Using reduction in demand and reliability costs as an indicator of traffic flow, the reduction of fuel subsidies, construction of a circular metro line, and improvement of transit operations and BRT provide the largest impacts. Safety was ranked as the second most important criterion: transit operations and nonmotorized transport packages make the largest reduction in safety costs due to congestion.

The data in Table 8.3 and Table 8.4 are displayed graphically in Figure 8.4.

Figure 8.3 Impact of policy measures on CO_2 Emissions

Policy measures and CO_2 emissions

The high-impact policies detailed in this section of the report also have the greatest impact on CO_2 and other emissions cost reductions. For example, reducing fuel subsidies is expected to reduce CO_2 costs by nearly 30 percent, while transit operations improvements are expected to reduce CO_2 costs by nearly 15 percent. Access management reduces CO_2 costs by about 10 percent. Except for road expansion measures, all of the measures that reduce congestion will reduce CO_2 emissions. There are also measures that could reduce CO2 emissions without major impacts on congestion such as the use of clean buses and clean energy for mass transit; however these measures were not tested as part of the study since its main focus is congestion.

Table 8.3 Relative Synergies Between Policy Packages

	New Highway	Road Widening	Metro – Circle Line	Metro – Radial Lines	Nile River Ferry	Transit Operations/ BRT	NMT	Worksite TDM	New Project TDM	Advanced Corridor Management	Traveler Information Systems	Reduced Fuel Subsidies	Central Area Pricing	Access Management	Education	Management and Reg.	Enforcement
New Highway	Grey																
Road Widening	Green	Grey															
Metro – Circle Line	Red	Red	Grey														
Metro – Radial Lines	Red	Red	Green	Grey													
Nile River Ferry	Red	Red	Green	Green	Grey												
Transit Operations/BRT	Red	Yellow	Green	Green	Green	Grey											
NMT	Red	Red	Green	Green	Green	Green	Grey										
Worksite TDM	Red	Red	Green	Green	Green	Green	Green	Grey									
New Project TDM	Red	Red	Green	Green	Green	Green	Green	Green	Grey								
Advanced Corridor Management	Green	Green	Yellow	Yellow	Yellow	Green	Green	Green	Green	Grey							
Traveler Information Systems	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Grey						
Reduced Fuel Subsidies	Red	Red	Green	Green	Green	Green	Green	Green	Green	Yellow	Yellow	Grey					
Central Area Pricing	Red	Red	Green	Green	Green	Green	Green	Green	Green	Yellow	Yellow	Green	Grey				
Access Management	Green	Green	Yellow	Yellow	Yellow	Green	Green	Green	Green	Green	Yellow	Yellow	Yellow	Grey			
Education	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Green	Yellow	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Grey		
Management and Reg.	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Grey	
Enforcement	Green	Green	Yellow	Yellow	Yellow	Green	Green	Yellow	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Grey

Table 8.4 provides the results of evaluating the policy measures. Columns 1, 2 and 3 give the name of the policy measure, its description and how it was defined for purposes of this evaluation, respectively. Columns 4 and 5 give the estimates of the reduction in direct and indirect costs, with column 6 showing the total percent reduction. These estimates are estimates of the annual reduction in direct and indirect costs relative to the direct and indirect costs in the baseline scenario. In order to estimate the reduction in direct and indirect costs because of a given policy measure we first estimated the direct and indirect costs in 2010 for a baseline scenario. We then estimated the direct and indirect costs for the baseline scenario in 2030. Then we redid the analysis to estimate the direct and indirect costs when the policy measure is fully implemented (we assumed that the policy measure would be completely implemented in 2010 itself). The difference in the direct and indirect costs between the baseline scenario and the scenario including the policy measure is the estimate of the reduction in direct and indirect costs due to implementing the policy measure.

Columns 7 and 8 give our assessment of the institutional feasibility and the degree of support/acceptance (among the local population) for the policy measure. The assessment of institutional feasibility represents our judgment of the degree to which the relevant institutions are capable and competent to implement the policy measure. Thus, for example, while the relevant authorities and organizations are capable and competent to implement the more technical and operational measure, they are less able to properly implement the "soft" measures such as enforcement of traffic rules and regulations. The degree of local support/acceptance for policy measures is high for new infrastructure and facilities, but is less when it involves changes to traffic behavior via enforcement, pricing or any other means.

Through the stakeholder outreach, financial feasibility was identified as the most important feasibility criterion. This is a practical concern, since without the up-front capital for a project, even the most cost-effective project cannot be implemented. TDM, access management, and traveler information systems projects all have high cost-effectiveness as well as low implementation cost. Reducing the fuel subsidy is a measure with no financial implementation cost that has a drastic impact on reducing congestion.

Among effectiveness criteria traffic flow was identified as most important by stakeholders. Using reduction in demand and reliability costs as an indicator of traffic flow, the reduction of fuel subsidies, construction of a circular metro line, and improvement of transit operations and BRT provide the largest impacts. Safety was ranked as the second most important criterion: transit operations and non-motorized transport packages make the largest reduction in safety costs due to congestion.

Column 9 provides the costs of implementing the policy measure in its entirety. Thus, for example, the cost of implementing the policy measure "New Highways," i.e., the new ring road is almost 3.2 Billion Egyptian

Pounds. For the policy measures where it was not possible to develop a sensible estimate of the costs we have indicated whether in our assessment the costs are small or large. The cost shown are the net costs over a 20-year timeframe, including one-time capital costs and 20 years of annual operating costs (costs are not discounted).

Column 10 provides the cost effectiveness ratio. This ratio was calculated by adding up the discounted (we assumed a discount rate of 4%) benefits to 2030 and dividing these by the estimated costs. It is assumed that all capital costs are incurred in 2010; operating costs were discounted over 20 years. The final column gives our assessment of the time it would take to implement the policy measure.

Table 8.4 Evaluation of Policy Packages

Policy Measure Packages	Description	Location	Reduction in Direct Costs (Percent)	Reduction in Indirect Costs (Percent)	Total Reduction in Costs (Percent)	Institutional Feasibility	Local Acceptance	Capital Implementation Cost (Billions LE)	Cost-Effectiveness Ratio	Timeframe
New Highway	New highway construction	Tested on new ring road (Figure 8.1)	3.3%	2.0%	2.9%			3.18	10	Long
Road Widening	Added lanes to existing roads	Tested by adding one lane to existing ring road (Figure 8.1)	1.9%	0.4%	1.4%			1.30	9	Long
Metro – Circle Line	Circle Metro Line	See Figure 8.2	13.5%	13.8%	13.6%			16.16	6	Long
Metro – Radial Line	Planned Lines 4, 5, and 6 (results reflect each line independently)	See Figure 8.2	10.6%	7.9%	9.6%			13.57	5	Long
Metro – Combined System	Circle Metro Line + Planned Lines 4, 5, and 6 (combined)	See Figure 8.2	37.6%	37.7%	37.6%			56.88	7	Long
Nile River Ferry	Ferry route from CBD to the north	See Figure 8.2	0.3%	0.7 %	0,4%			1.78	0.2	Mid
Transit Operations/BRT	Several BRT lines plus transit operational improvements to support BRT and other bus service.	See Figure 8.2. Transit operations applied across major corridors.	17.8%	32.4%	23.1%			5.94	35	Near/Mid
NMT	Bicycle facilities; Pedestrian facilities; Active travel campaign	Other Routes	1.3%	4.1%	2.3%			0.95	22	Near/Mid
Worksite TDM	Carpool/ridesharing info Alternative work options	Major Corridors	0.6%	0.6%	0.7%			0.30	24	Near
New Project TDM	Development mitigation Permitting enforcement	Regionwide	5.2%	6.0%	5.5%			0.03	1,819	Near
Advanced Corridor Management	Incident management, traffic signal coordination/interconnection, adaptive control, real-time information, variable speed limits, etc., along major corridors	Major Corridors	4.8%	5.0%	4.9%			1.47	32	Mid
Traveler Information Systems	511, highway advisory radio, variable message signs, web-based traveler information, real-time transit arrival information, trip planning software, etc.	Regionwide	1.4%	1.8%	1.6%			0.01	1,123	Mid
Reduced Fuel Subsidies	50% increase in fuel price to consumers	Regionwide	14.4%	23.0%	17.5%			No implementation cost and revenue positive	N/A	Near
Central Area Pricing	Pricing of most congested central area applied to congested/daytime times, with revenue reinvested in transit	Cairo CBD	0.6%	0.7%	0.7%			Low implementation cost and revenue positive	2,695	Mid
Access Management	Median closures, turn restrictions, access/egress to major buildings such as government buildings, etc.	Major Corridors	9.4%	7.0%	8.5%			0.73	112	Near/Mid
Education	Media campaign; Driver education and training programs; Active travel	Regionwide	N/A	N/A	N/A			Low	High	Near

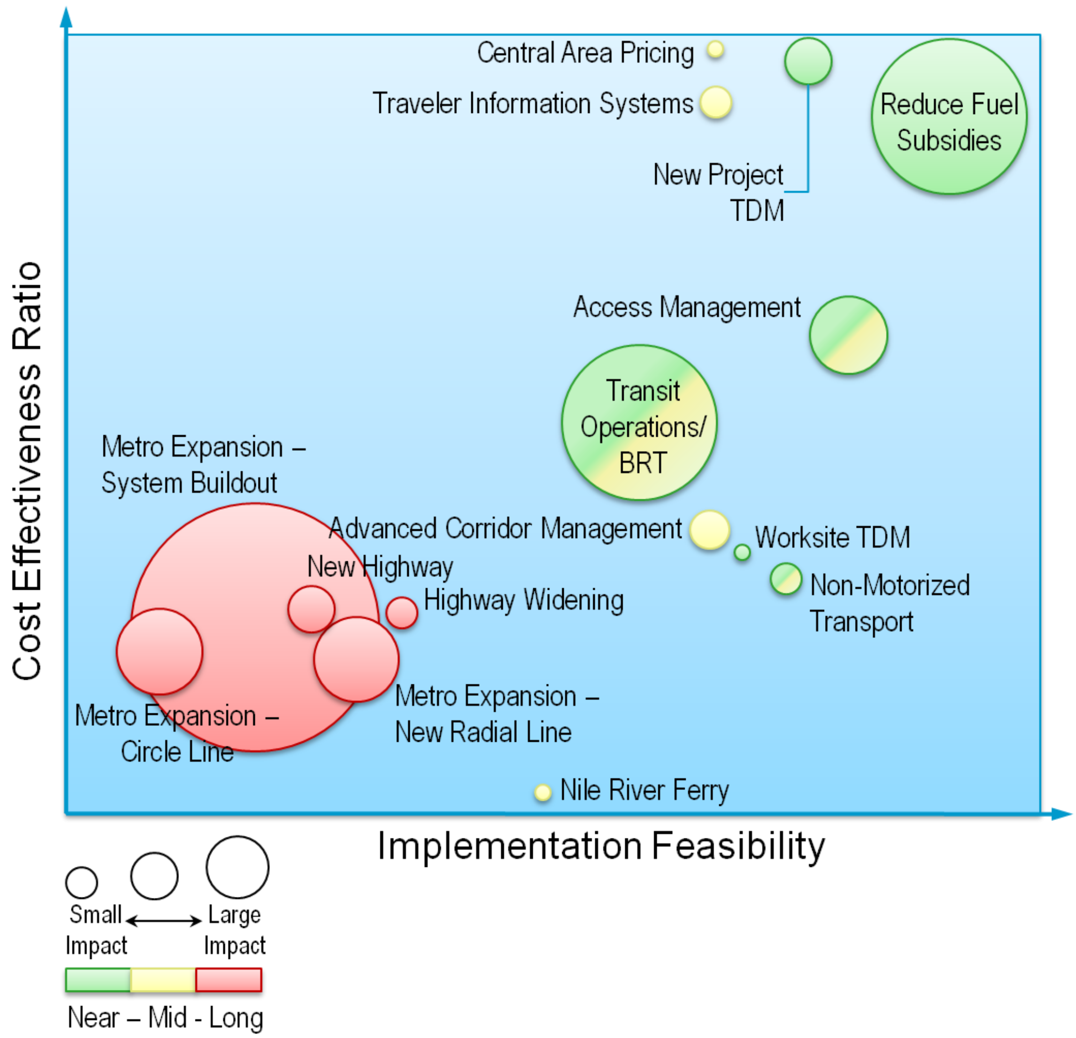
Policy Measure Packages	Description	Location	Reduction in Direct Costs (Percent)	Reduction in Indirect Costs (Percent)	Total Reduction in Costs (Percent)	Institutional Feasibility	Local Acceptance	Capital Implementation Cost (Billions LE)	Cost-Effectiveness Ratio	Timeframe
Management and Reg.	Traffic police reform; Regulation of paratransit; Vehicle safety inspection; Regional oversight of the transport sector; Land use planning; Development permitting and traffic mitigation	Regionwide	Impacts most regionwide policy measures	Impacts most regionwide policy measures	Impacts most regionwide policy measures			Low	High	Near
Enforcement	Enforcement of traffic laws; Driver licensing and violations; Requirements for developments	Regionwide	N/A	N/A	N/A			Low	High	Near
Combined Packages										
Highway Capacity and Operations	Add highway capacity through expansion, access management, operations, and ITS	See above packages	22.6%	17.3%	20.7%	See above packages	See above packages	6.70	31	Near through long
Mode Shift and Demand Management	Reduce demand for trips through TDM and pricing and move travelers by nonhighway modes	See above packages	37.6%	46.0%	40.6%	See above packages	See above packages	38.73	10	Near through long

Figure 8.4. graphically compares the policy options to each other and displays several dimensions of each policy package:

- The magnitude of the impact on direct and indirect congestion costs is indicated by the size of the circle;
- The likely phasing is shown by color: green is near (1 to 5 years), yellow is mid (5 to 10 years), and red is long (more than 10 years);
- The height of the circle along the vertical axis denotes the cost-effectiveness, (measured as the impacts divided by capital implementation costs), so that the higher the circle, the more cost-effective is the measure; and
- The distance along the horizontal axis denotes the feasibility of implementing the policy measure, so that the further along the horizontal axis the higher the feasibility of the measure getting implemented.

From the combination of these dimensions emerges the relative priority of the policy package. The larger the policy package and the closer to the upper right side of the graph it is, the better it is for quick and effective implementation. For example, the policy option to reduce the fuel subsidy can be implemented relatively quickly and easily – with the exception of potential political difficulties – and has a large impact on reducing congestion costs, and it is a very cost effective way to address traffic congestion. By contrast, building new metro lines take a long time to implement, are relatively difficult to implement (because of managing the disruptions that will occur due to the construction works), are not as cost-effective as reducing the fuel subsidy, but they have a very large impact on reducing traffic congestion. Access management, transit operations and BRT, and new project TDM are all packages that emerge as higher priority and potential "quick wins."

Figure 8.4 Comparison of Policy Packages



Section 9.0 synthesizes this information into logical sets of policy packages and an implementation plan.

9.0Implementation

INTRODUCTION

The traffic congestion problem in the GCMA is a complicated and large problem. No single policy measure will be adequate for addressing all the traffic problems in the GCMA. What are needed are combinations of policy measures, and packages, implemented simultaneously, to address different aspects of the problem.

In this section, we recommend policy packages for implementation in the GCMA. The success of the these policy packages in addressing the congestion problem in the GCMA will, however, also depend on how a number of other factors such as, for example, adequate training for traffic police, driver training, enforcement of laws, adequate and stable financing. Thus, in addition to the policy packages we also discuss the need to introduce some broader measures that can potentially have a large effect on the functioning of the transport system, but fall outside the domain of the transport sector itself.

RECOMMENDATIONS

We have grouped the recommendations for addressing congestion into short- and mid/long-term recommendations. The recommendations for addressing congestion in the short term are measures that can be implemented relatively quickly and inexpensively and whose benefits can be quickly realized. The mid/long-term measures are measures that require incurring significant expense, and longer times are needed to implement and realize their benefits. Several recommendations are horizontal and overarching and apply universally to all policy measures. In general, with the exception of transit and additions to infrastructure capacity, most measures that are being recommended are relatively inexpensive and can be quickly realized.

These measures are also displayed in Table 9.1, organized by policy measure package. Each package is in turn classified according to the primary timeframe in which the bulk of the measures can be implemented and benefits realized, though within each package there are individual actions that can be taken immediately, measures that should be implemented in 1-5 years, and other actions that will need to occur after 5 years. Some packages have interdependencies with other packages, including considerations for phasing and timing.

Quick Wins (One to Five Years)

All the policy packages, with the exception of Public Transit, include at least some policy measures that can be implemented relatively quickly and inexpensively, and yet provide significant benefits in terms of reduced congestion. The management of the transport system in the GCMA can be significantly improved. In the short term, the actions to improve the management of the system include:

- Developing a Transport Master Plan, to be revised every three years, that sets objectives and priorities for the transport system in the GCMA.
- Developing and implementing a data and information collection system providing traffic volumes on the road network, number of users of the transit system (the metro lines and the train system), and the number of users of the micro/mini buses. While this action is not something that will directly lead to the reduction of congestion, it must be recognized that good data and information (i.e., situational awareness) for the basis for being able to manage the existing and planned transport network *road and transit), for making improvements and additions to the infrastructure, and for improving and expanding transport services in the GCMA.
- Developing and installing an asset management system (at least for monitoring and managing major assets within the GCMA). Again, while this may not seem to be an action that can reduce congestion, it is focused on collection of information about the quality of the assets, which in turn affects the ability to use the infrastructure.

In terms of Regulation, enforcement needs to be significantly improved, particularly:

- Addressing the encroachment of public right-of-way. Encroachment of the public right-of-way reduces effective capacity of the network. This encroachment on the "other" roads, many of which have limited capacity, is a significant problem in areas of the GCMA.
- Observing of traffic laws (observing traffic lights, illegal parking and randomly stopping). Traffic rules and regulations are generally poorly observed in the GCMA. This situation clearly needs to be improved.
- Licensing requirements for drivers need to be made more stringent and enforced to ensure knowledge of traffic rules and regulations and driving behavior.
- Licensing and permit requirements for drivers of mini/micro buses to make sure that drivers understand the traffic rules and regulations, as well as the rules for operating micro/mini buses in the GCMA.
- Observance of capacity/occupancy limits of vehicles need to be better enforced.
- Road worthiness certification of vehicles needs to carried out more frequently and enforced more stringently to make sure that vehicle breakdowns become less common.

Similarly, there needs to be focus on Education to raise awareness about:

- Traffic laws, driving etiquette, and maintenance requirements of vehicles;
- Driving behavior; and
- Behavior of pedestrians on roads so that they do not randomly cross streets and/or interfere with traffic.

Another set of policy measure that can be quickly and inexpensively implemented are in the category Traffic Operations and Control. The policy measures to consider implementing include:

- Controlling access of pedestrians to major corridors (so that pedestrians cannot randomly cross streets;
- Providing over bridges at strategic locations and zebra crossings at all intersections;
- Limiting the number of entry and exit points for traffic entering and exiting major corridors;
- Installing traffic cameras at intersections to monitor and enforce observance of traffic rules and regulations;
- Installing traffic signals at intersections;
- Developing and implementing high-occupancy lanes for vehicles with five occupants or more, during peak periods, on the major corridors; and
- Developing and implementing traffic management plans for large events.

Another of the major causes of congestion is the U-turns at signalized intersections or through median openings is one of the major causes of congestion in the GCMA. This can be relatively easily fixed by changing some design features of the current road network. Thus, we would recommend:

- Closing all median openings on major corridors;
- Minimizing the number of left turns: left turns should only be possible at intersections where traffic lights protect the left turn; and
- Physically separating turning lanes.

Also given that congestion if often caused by vehicle breakdowns and accidents, removing disabled vehicles or vehicles involved in accidents should be a priority. To be able to quickly and effectively remove disabled vehicles, the following is recommended:

- Developing and implementing an Incident Management System for the major corridors to remove disabled vehicles and vehicles involved in accidents as quickly as possible;

- Providing an emergency lane on all highways and major corridors; and
- Pre-positioning towing vehicles, during peak periods, at strategic locations along major corridors for the specific purpose of removing disabled vehicles.

Another big cause of congestion in the GCMA is illegal parking and the random stopping of micro/mini buses to pick-up and drop-off passengers. In many areas within the GCMA, the demand for parking clearly exceeds the available supply of street parking in the GCMA. There also is no organized supply of parking in the GCMA. Similarly, the pick-up and drop-off points for micro/mini buses are not clearly marked, or these are located at inconvenient points along the routes of the buses. Thus, we recommend:

- Building parking garages across the GCMA in locations with a high concentration of offices buildings and/or shops;
- Enforcement of the use of existing residential parking for parking purposes only;
- Building parking bays for micro and mini buses picking up and dropping off passengers along major corridors; and
- Developing safe routes for pedestrians walking to bus stops and metro stations.

The above policy measures and packages include measures aimed at improving the efficiency of capacity utilization of existing road infrastructure. Improving the efficiency of capacity utilization is, however, only one side of the coin, and beyond a certain point, either demand will have to be managed and/or supply of capacity will have to be increased. The additions to increase capacity cannot easily be realized in the short term and are discussed in the next section. Here, we discuss measures to manage demand for transport in the GCMA. Travel demand measures include:

- Developing and implementing a commuter program with businesses/offices in the GCMA to provide alternatives to the private car such as ride-sharing programs, provide shuttle buses to ferry workers to their point of work, staggering working hours, and stimulating telecommuting;
- Introducing paid parking throughout the GCMA;
- Restricting/limiting motorized vehicles access to certain parts of the city to residents, shopkeepers and businesses;
- Developing and implementing a charging scheme for access to certain areas of the GCMA during peak hours; and
- Elimination of the fuel subsidy.

So far we have suggested measures that improve efficiency and restrict demand. Given the size of the GCMA and the transportation needs of those living and conducting business in the GCMA, the above measures by themselves will not, however, be adequate for dealing with traffic congestion in the GCMA. Measures need to be taken to increase the capacity of the transportation system in the GCMA. In the short term, there are some measures that can be taken to significantly increase the capacity of the transit system in the GCMA. These measures include:

- Reorganize the system of mini/micro buses so that there each vehicle is assigned to a specific route, with specific departure and arrival times for their hours of operation;
- Equip vehicles with GPS tracking devices to ensure compliance with route, speed and stopping rules; and
- Develop and implement Bus Rapid Transit (BRT) system for major corridors in the GCMA.

The Longer Term (Five Years and Longer)

In the middle and long term, there are essentially four recommendations, namely:

- Making transit more attractive by improving the frequency and reliability of transit operations and increasing the capacity and coverage of the transit system;
- Strategically increasing road network capacity;
- Integrating land use and transportation planning; and
- Increasing the use of technology to optimize use of existing capacity.

The GCMA clearly has a pressing need for improving and expanding the transit system. In terms of making the transit system more convenient and easier to use we would recommend:

- Introduction of a single, common, electronic ticket for all forms of transit within the GCMA, including for micro/mini buses;
- Provision of travel and trip information (arrival and departure times of buses on the BRT system, and metro;
- Providing safe routes for pedestrians to reach BRT and Metro stations;
- Expanding the BRT system to cover larger parts of the GCMA (beyond just the major corridors);
- Providing good links between the BRT and Metro system;
- Providing pick-up and drop-off points at BRT and Metro stations;
- Developing a metro circle line; and
- Developing radial metro lines.

Given the volume of traffic on the roads in the GCMA expanding road capacity is important. The ability to increase road capacity, however, is limited in many parts of the GCMA, and it also is not entirely desirable. Thus, the increases to road capacity should be done strategically. We would recommend the following two actions with regards to increasing road capacity:

- Developing a second ring road to circle around the GCMA; and
- Widening existing roads where necessary and possible.

The integration of transport and land use planning is an important step towards reducing congestion in the GCMA in the long run. Going forward, the authorities in the GCMA need to, at a minimum, pay attention and ensure the following:

- All new development takes place along a transportation corridor;
- Is connected to the transit system; and
- Provides safe and convenient access for nonmotorized transport to transit stations.

Finally, we would propose the use of advanced technology for monitoring and managing the capacity of corridors and parking in the city. What we are proposing is the introduction of technology that would allow communication real-time traffic management by:

- Traffic signal interconnection and coordination;
- Adaptive signal control;
- Real-time traveler information within the corridor (e.g., roadway and metro travel times between points A and B); and
- Variable speed limits.

HORIZONTAL MEASURES

The policy packages and measures in the previous section were all focused on either improving the efficiency of the transport system and infrastructure, restricting demand, or increasing supply. What we are proposing in this section are measures that are necessary for the eventual long term and continued success of these measures. The measures being proposed in this section include:

- Capacity building;
- Changes in governance; and
- Ensuring an adequate and steady form of funding for the transport system in the GCMA.

Capacity Building

Ensuring that the transport infrastructure and services necessary to meet the demand of millions of people is a difficult and complicated exercise. The policy packages and measures we have proposed in the previous section will require new types of skills, and more people with these skills if the necessary changes are going to be successfully brought about and continued over time.

Examples of areas in which additional capacity will be needed include more and better trained people for, for example:

- Traffic policing and enforcement;
- Procurement and contracting;
- Deployment and use of ITS;
- Transport planning;
- Project and program management;
- Financial and risk management; and
- Training and education activities and campaigns.

Governance and Organization

The current governance of the transport system is fragmented across geographic areas as well as across modes. One major change that we are recommending is the creation of a single organization responsible for the transport system (covering all transport modes) across the entire GCMA. This organization would be responsible for developing and implementing strategy, managing the provision of transportation services (taxis, buses, metro, light rail, and river transportation), responsible for charging/pricing schemes, maintaining and developing the infrastructure.

Financial Reform

The long-term development of the transport system in the GCMA will depend on the availability of an adequate and stable source of financing for the development, operation and maintenance of the system. The reforms that we are proposing are of two types, namely:

- To the current system of taxation of fuel and vehicles, and
- For the use of revenues raised from the transport sector.

We already have recommended reducing and ultimately completely removing the subsidy on fuels. Here what we would like to propose a system of taxation that goes significantly further than just reducing and eliminating the fuel subsidy. We propose the replacement of all taxes on fuels and vehicles by a distance-based charge, to be implemented in all of Egypt, differentiated by type of fuel used (benzene or diesel), size of the engine, weight of the vehicle, the area in which the vehicle is driven and the time of day when the vehicle is used. Such a distance-based charge is fair in that it taxes the distances driven and not the ownership of a vehicle, it is based on the user pays principle, it allows for the possibility of internalizing the externalities, is efficient, and provides a clear source of financing for the transport system.

In terms of the use of revenues collected from use and operation of the transport infrastructure, these revenues should be legally required to be invested back in the transport system. What is important is that there is a stable flow of funding for the operational and maintenance activities, and not only for development of new infrastructure, in the transport sector.

Table 9.1 Timeline of High-Priority Strategies

Policy Measure Packages	Examples of Strategies	Immediate Actions	One to Five-Year Actions	5+ Year Actions	Interdependent Policies
Immediate/Near Term					
Regulation/Enforcement	Traffic police reform; Regulation of paratransit; Vehicle safety inspection; Regional oversight of the transport sector; Land use planning; Development permitting and traffic mitigation; Enforcement of traffic laws; Driver licensing and violations; Requirements for developments.	• Address the encroachment of public right of way • Observe traffic laws (observing traffic lights, illegal parking and randomly stopping) • Increase and enforce licensing requirements for drivers • Enforce licensing and permit requirements for drivers of mini/micro buses and link to increased education • Enforce capacity/occupancy limits of vehicles • Increase frequency of, and better enforce, road worthiness certification of vehicles	• Integrate with advanced corridor management systems to use technology to aid enforcement		Links closely with education; Critical first step for successful implementation of all other strategies. Capacity building critical
Education	Media campaign; Driver education and training programs; Active travel.	• Implement media campaigns and education/training programs for drivers focusing on: – traffic laws – driving etiquette/behavior – maintenance requirements of vehicles • Implement media campaigns and education/training programs for all citizens focusing on behavior of pedestrians on roads so that they do not randomly cross streets and/or interfere with traffic	• Integrate campaigns throughout elementary and secondary educational system.		Links closely with regulation/enforcement; Critical first step for successful implementation of all other strategies.
Access Management	Median closures; Turn restrictions; Access/egress controlled to major buildings such as government buildings.	• Close all median openings on major corridors, in particular to restrict u-turns (see Appendix C for problematic u-turn locations along the sample corridors). Send survey teams to verify most problematic locations. • Minimize the number of left turns: left turns should only be possible at intersections where traffic lights protect the left turn. Send survey teams to verify most problematic locations. • Physically separate turning lanes where left turns are permitted and, where possible, for right turns. • Limit the number of entry and exit points for traffic entering and exiting major corridors • Control access of pedestrians to major corridors (so that pedestrians cannot randomly cross streets • Provide zebra crossings at intersections with high pedestrian traffic, fatalities, and injuries	• Continue to identify additional locations for improvement. • Develop standards for all future roadways or improvements to existing roadways. • Provide pedestrian over bridges at strategic locations • Provide zebra crossings at all intersections	• Continue to identify additional locations for improvement.	Develop in concert with advanced corridor management strategies; access management strategies may be implemented first. Enforcement necessary for controlling pedestrian/vehicle interactions.
Worksite TDM	Carpool/ridesharing info; Alternative work options.	• Develop and implement a commuter program with businesses/offices in the GCMA to provide alternatives to the private car such as ride-sharing programs, provide shuttle buses to ferry workers to their point of work, staggering working hours, and stimulating tele-commuting	• Introduce paid parking throughout the GCMA in areas of highest demand and lowest supply • Restrict/limit motorized vehicles access to certain parts of the city to residents, shopkeepers and businesses. These should be highly multimodal areas (e.g., high pedestrian traffic) and limited roadway capacity.		Integrates with measures that improve non-auto alternatives.

Policy Measure Packages	Examples of Strategies	Immediate Actions	One to Five-Year Actions	5+ Year Actions	Interdependent Policies
New Project TDM	Development mitigation; Permitting enforcement.	• Develop TDM plans/regulations for new development • Ensure enforcement mechanisms in place			Overlaps with planning and enforcement
Reduced Fuel Subsidies	Reduced and eventually eliminated fuel subsidy for consumer	• Begin phased reduction of fuel subsidy for consumers	• Eliminate fuel subsidy		Begin improvement of transit operations, construction of BRT, planning for metro system, and NMT improvements in parallel to provide equitable alternative to increased cost of driving
Near/Mid Term					
Advanced Corridor Management	Incident management; Traffic signal coordination/interconnection; Adaptive control; Real-time information; Variable speed limits.	• Install traffic signals at intersections • Pre-positioning towing vehicles, during peak periods, at strategic locations along major corridors for the specific purpose of removing disabled vehicles • Begin investigating potential technology providers and types of IT systems, and identify funding sources	• Install traffic cameras at intersections to monitor and enforce observance of traffic rules and regulations • Develop and implement traffic management plans for large events • Develop and implement high occupancy lanes, with automated enforcement, for vehicles with five occupants or more, during peak periods, on the major corridors • Develop and implement an Incident Management System for the major corridors to remove disabled vehicles and vehicles involved in accidents as quickly as possible • Implement traffic signal interconnection and coordination along major corridors • Implement adaptive signal control along major corridors	• Providing an emergency lane on all highways and major corridors; include as a design standard for new facilities. • Implement variable speed limits along major corridors • Develop plan/standards for ongoing implementation of advanced corridor management/ITS	Develop in concert with or after access management strategies. Aids enforcement; HOV lanes require enforcement for successful implementation
Transit Operations/ BRT	Several BRT lines plus transit operational improvements to support BRT and other bus service.	• Reorganize the system of mini/micro buses so that there each vehicle is assigned to a specific route, with specific departure and arrival times for their hours of operation • Develop transit system strategic plan, prioritizing corridors/routes and identifying modes and phasing	• Building parking bays for micro and mini buses picking up and dropping off passengers along major corridors • Equip vehicles with GPS tracking devices to ensure compliance with route, speed and stopping rules • Develop and implement Bus Rapid Transit (BRT) lines along highest priority corridors with available ROW • Make transit more attractive by improving the frequency and reliability of transit operations and increasing the capacity and coverage of the transit system • Provide safe routes for pedestrians to reach BRT and Metro stations • Provide good links between the BRT and Metro system • Provide pick-up and drop-off points at BRT and Metro stations	• Develop and implement complete Bus Rapid Transit (BRT) system for major and other corridors in the GCMA • Provision of travel and trip information (arrival and departure times of buses on the BRT system and metro) • Introduce a single, common, electronic ticket for all forms of transit within the GCMA, including for micro/mini buses •	Strong planning, capacity building, and reorganization of transportation agencies required for successful long-term implementation. Complements NMT and metro improvements. Leverage IT infrastructure from traveler information systems and advanced corridor management, which should be implemented first.

Policy Measure Packages	Examples of Strategies	Immediate Actions	One to Five-Year Actions	5+ Year Actions	Interdependent Policies
NMT	Bicycle facilities; Pedestrian facilities; Active travel campaign.	• Provide zebra crossings at key intersections with high pedestrian traffic, fatalities, or injuries	• Develop safe routes for pedestrians walking to bus stops and metro stations • Provide over bridges at strategic locations • Provide zebra crossings at all intersections		Complements transit operations/BRT and metro improvements.
Central Area Pricing	Pricing of most congested central area applied to congested/daytime times, with revenue reinvested in transit.		• Develop and implement a charging scheme for access to certain areas of the GCMA during peak hours		Complements transit operations/BRT and NMT improvements, which should begin to occur as an equitable alternative to driving first. Can occur prior to completion of additional metro lines.
Traveler Information Systems	511; highway advisory radio; variable message signs; web-based traveler information; real-time transit arrival information; trip planning software.		• Real-time traveler information within the corridor (e.g., roadway and metro travel times between points A and B)		Leverage advanced corridor management technology
Parking (not included in quantitative evaluation)	Increased parking supply; Parking enforcement; Paid parking, permitting.	• Enforce the use of existing residential parking for parking purposes only	• Introduce paid parking throughout the GCMA in areas of highest demand and lowest supply	• Build parking garages across the GCMA in locations with a high concentration of offices buildings and/or shops	Restrictions or increased costs of parking should be balanced with equitable improvements in other modes; Can be implemented in concert with TDM strategies.
Mid/Long Term					
New Highway	New highway construction: 2nd ring road	• Begin system and feasibility studies through foreign technical assistance	• Investigate funding sources • Prepare ROW preservation plan	• Design, engineering, and construction	Access management and advanced corridor management plans should be in place to optimize and maintain new capacity
Road Widening	Added lanes to existing roads where necessary and possible	• Begin system and feasibility studies through foreign technical assistance	• Investigate funding sources • Prepare ROW preservation plan	• Design, engineering, and construction	Access management and advanced corridor management plans should be in place to optimize and maintain new capacity
Metro – Radial Lines	Planned Lines 4, 5, and 6	• Begin/continue system and feasibility studies through foreign technical assistance	• Investigate funding sources	• Design, engineering, and construction	Transit Operations/BRT improvements should be complete to provide connecting/feeder service to metro. NMT strategies should be complete to provide easy access/egress to stations.
Metro – Circle Line	Circle Metro Line.	• Begin system and feasibility studies through foreign technical assistance	• Investigate funding sources	• Design, engineering, and construction	Transit Operations/BRT improvements should be complete to provide connecting/feeder service to metro. NMT strategies should be complete to provide easy

Policy Measure Packages	Examples of Strategies	Immediate Actions	One to Five-Year Actions	5+ Year Actions	Interdependent Policies
					access/egress to stations.
HORIZONTAL					
Planning	Long range and strategic plans; Data collection; Monitoring.	• Develop a Transport Master Plan, to be revised every three years, that sets objectives and priorities for the transport system in the GCMA. • Plan/develop a data and information collection system providing traffic volumes on the road network, number of users of the transit system, and the number of users of the micro/mini buses. • Plan/develop an asset management system.	• Implement a data and information collection system, considering traveler information system and advanced corridor information requirements • Install an asset management system.	• Integrate land use and transportation planning	Should begin immediately and guide all policy measures
Capacity Building	Training	• Traffic policing and enforcement • Procurement and contracting • Deployment and use of ITS • Transport planning • Project and program management • Financial and risk management • Training and education activities and campaigns	• Ongoing capacity building	• Ongoing capacity building	Should begin immediately and help all policy measures, particularly planning, enforcement, and education.
Governance and Org.	Agency reorganization and creation; Changes in powers and duties.	• Develop governance/organizational plan	• Implement plan		Should be redesigned in concert with master/strategic plan development and financial strategies.
Financial	Taxes; Fees; ODA; Other revenues.	• Develop financial plan	• Implement plan. Consider replacing fuel and vehicle fees with distance-based fees. • Continue to seek ODA.		Should be considered in concert with governance/organization and master/strategic plan development.

10.0 APPENDIX A

List of Major Corridors and Local Routes

Major Corridors Sample

No.	Name	O/D (Direction 1)	Main Streets	Road Class	Length (km)	% Length	Total Length (km)
1	26th of July/ 15th May Travel Corridor	- Cairo-Alex Desert Road/ El-Esaaf	26th July Street	3	0.56	3	19.35
			15th of May Bridge	3	2.5	13	
			26th of July corridor	2	15	78	
			Cairo-Alex Desert Road	1	1.29	7	
2	Ring Road North	Cairo-Suiz Desert Road Interchange/ El-Wahaat Road	Ring Road	2	61	100	61
3	Ring Road South	Cairo-Suez Desert Road Interchange/ Cairo Alex Desert Road	Ring Road	2	41	100	41
4	El Corniche-East/ El-Matareya Square	El-Matareya Sqr/ Maadi Corniche	El-Kablat Str.	4	2	9	22.5
			Terat Al-Ismaileya Road	4	3.5	16	
			Said Salem Str.	4	1.5	7	
			Kornish El-Nile Road(East)	4	15.5	69	
5	Rod El Farag/ El-Remaya	Roud El-Farag-Bridge/ Remaya Sqr	Roud El-Farag Bridge	4	1.3	7	17.8
			Kornish El-Nile Road(West)	4	2.4	13	
			Gamal Abdel Naser(El-Nile)Str.	4	2.9	16	
			El-Giza (Sharl De Gol) str.	4	2.2	12	
			Morad Str.	4	0.6	3	
			El-Giza Bridge	4	0.5	3	
			El-Ahram Str.	4	7.9	44	
6	Cairo-Suez Desert Road/El-Qallaa	Mobarak Academy for Security (5th District)/ El-Qalaa	Ahmad El-Zomor Str. (El Methaq Str.)	4	6.6	30	21.72
			Zaker Hussein Str.	4	1	5	
			El-Tayaran Str.	4	4.4	20	
			El-tayaran Tunnel	4	1.12	5	
			Salah Salem	4	8.6	40	
7	Autostrad/ Giza Square	Autostrad-Thawra Intersection/Giza Sqr	El-Nasr Road/Autostrad	4	12.1	70	17.2
			Salah Salem	4	3.2	19	
			Hassan El-Anwar Str.	4	0.8	5	
			El Rawda	4	0.4	2	
			Abbas Bridge	4	0.4	2	
			Al-Ahram Str.	4	0.3	2	
8	El-Orouba/	Cairo Int Airport/	El-Orouba Str.	4	11.6	54	21.5

9	6th of October Bridge	ElBatal Ahmed AbdElaziz	6th of October Bridge	3	9.9	46	20
	Cairo-Ismaillia Desert Road/El-Qubba	Obour City/ El-Qubba Bridge	Cairo-ismaileya Desert Road	1	6	30	
			Gesr El-Suize Str.	4	14	70	
10	Cario-Alex Agr Road El-Qubba	Upstream RingRoad Interchange/El-Qubba Bridge	Cairo-Alex Agricultural Road(Quesna-Qalyoub Road)	1	5.8	25	23.5
			Ahmed Helmy Str.	4	8	34	
			Ahmed Badawy Str.	4	0.7	3	
			Shoubra Str.	4	1	4	
			El-Galaa Str.	4	1	4	
			Ramsis Str.	4	5.5	23	
			El-Khaleefa El-Ma'moon Str.	4	1.5	6	
11	Cairo-Suez Desert Road/Ebn-ElHakam Square	Cairo-Suiz Desert Road (Rehab Entrance)/ Ibn El-Hakam Sqr.	Cairo-Suiz Desert Road	1	15	71	21
			El-Thawra Str.	4	2.1	10	
			El-Nozha Str.	4	1.3	6	
			Abo Bakr Al-Sedeeq Str.	4	2.1	10	
			Ibn El-Hakam Str.	4	0.5	2	

Road Class	Code
Inter-Urban Primary Highway	1
Regional Primary Highway	2
Urban Expressway	3
Urban Primary Street	4

Local Routes Sample				
Route	**Road Class**	**Total Length (km)**	**Main Features**	**Location in GCMA**
Route 1 Section 1: Tomanbay Street	Urban Secondary Arterial	2.32	Typical residential area, including commercial, business, activities within heavily populated area	East Cairo
Route 1 Section 2: Gesr Al Sweis	Urban Primary Street	1.58		
Route 2 Section 1: El Kasr El Aini St.	Collector	1.32	Governmental Ministries, Hospital, Commercial Activities	Central Cairo Area
Route 2 Section 2: Nubar St.	Collector	1.58		
Route 3: Section 1: El Gomhoreya St.	Collector	3.3	Commercial, business, Islamic Heritage and Tourist Sp ot	Central Cairo Area
Route 3: Section 2: Al Azhar St. till Abd El-Aziz Street	Urban Secondary Arterial			
Route 4: Section 1: Ahmed Said St.	Urban Secondary Arterial	0.86/1.34	Typical residential area close to CBD	Central Cairo Area
Route 4: Section 2: El Giash St. , Al Sakakini St.	Collector			
Route 5: Section 1: Gameat El Qahera St	Urban Secondary Arterial	1.89	Cairo University, commercial and business activities	West Cairo
Route 5: Section 2: El-Doqqy St.	Urban Secondary Arterial	1.76		
Route 6: El Malek Faisal St	Urban Secondary Arterial	7.6	High-density residential, with industrial activities and warehouses at the lower level. A number of hotels are located towards its end (near Giza pyramids).	Giza, West Cairo
Route 7: Section 1: Mostafa El Nahas St.	Urban Secondary Arterial	5/3.80	Located in mixed use area, including residential, offices, commercial and retail facilities. A tramline passes through Mostafa El Nahas Street	Nasr City, East Cairo
Route 7: Section 2: Makram Obaid St., Abass Akkad St.	Collector			
Route 8 Street No. 9 in Al Mokatam	Urban Secondary Arterial	5.8	Mainly residential area, with offices and commercial activities at the lower levels. Has 2 main characteristics: varied topography (some steep slopes) and being a link between the CBD area (Salah Salem Road) and	Giza, West Cairo

			the Ring Road	

11.0 APPENDIX B

Traffic Counts on Other Routes
Floating Car Survey Schedule
Traffic Volumes on Major Corridors
Temporal Distribution of Traffic Volumes
Estimation Procedures for Speeds and Buffer Index

B.1 Traffic Counts on Other Routes

Classified Traffic Counts

Date: Monday 13 June 2011
Location No: L3-1
Road Name: El Gomhoreya St.
Direction: To Opera Squar

By: Ahmed Mostafa, Moman Zain and Osama Radwan






Time From - To	Private Car	Taxi	Microbus and Minibus	Big Bus	Small Truck	Heavy Truck	Total
5:00 - 5:15	5	7	4	2	1	0	19
5:15 - 5:30	8	6	4	2	2	2	24
5:30 - 5:45	11	10	5	4	5	3	38
5:45 - 6:00	20	16	8	6	3	2	55
5:00 - 6:00	***44***	***39***	***21***	***14***	***11***	***7***	**136**
7:00 - 7.15	64	83	37	7	14	0	205
7:15 - 7:30	97	76	36	10	7	0	226
7:30 - 7:45	106	99	44	14	14	1	278
7:45 - 8:00	171	101	52	20	20	0	364
7:00 - 8:00	***438***	***359***	***169***	***51***	***55***	***1***	**1,073**
8:00 - 8:15	***158***	***120***	***63***	***22***	***20***	***0***	383
8:15 - 8:30	190	132	55	13	16	1	407
8:30 - 8:45	170	122	44	16	22	1	375
8:45 - 9:00	164	136	40	7	21	0	368
8:00 - 9:00	***682***	***510***	***202***	***58***	***79***	***2***	**1,533**
9:00 - 9:15	163	147	33	9	19	1	372
9:15 - 9:30	138	148	33	8	20	0	347
9:30 - 9:45	160	136	48	10	26	0	380
9:45 - 10:00	140	150	30	11	25	1	357
9:00 - 10:00	***601***	***581***	***144***	***38***	***90***	***2***	**1,456**
10:00 - 10:15	168	159	62	6	25	1	421
10.15 - 10.30	165	107	55	10	50	0	387
10.30 - 10.45	150	130	44	9	41	0	374
10.45 - 11.00	137	127	41	8	42	0	355
10:00 - 11:00	***620***	***523***	***202***	***33***	***158***	***1***	**1,537**
3:00 - 3:15	84	48	27	6	31	1	197
3:15 - 3:30	93	35	18	6	53	2	207
3:30 - 3:45	102	41	32	8	38	2	223
3:45 - 4:00	92	53	22	9	37	0	213
3:00 - 4:00	***371***	***177***	***99***	***29***	***159***	***5***	**840**
4:00 - 4:15	80	25	26	5	46	1	183
4:15 - 4:30	101	54	17	9	35	0	216
4:30 - 4:45	118	63	26	7	38	1	253
4:45 - 5:00	110	65	13	8	45	0	241
4:00 - 5:00	***409***	***207***	***82***	***29***	***164***	***2***	**893**
5:00 - 5:15	104	75	24	11	32	0	246
5:15 - 5:30	69	45	14	7	27	0	162
5:30 - 5:45	136	63	21	6	27	0	253
5:45 - 6:00	139	80	22	8	36	1	286
5:00 - 6:00	***448***	***263***	***81***	***32***	***122***	***1***	**947**
6:00 - 6:15	136	96	23	6	51	0	312
6:15 - 6:30	92	62	22	3	52	0	231
6:30 - 6:45	146	104	26	9	30	0	315
6:45 - 7:00	120	97	22	5	31	0	275
6:00 - 7:00	***494***	***359***	***93***	***23***	***164***	***0***	**1,133**

Date: Monday 13 June 2011
Location No: L3-2
Road Name: 26 of July St.
Direction: To Ramses St.

By: Ahmed El Kabani, Ahmed Zaki and Hosian Nadi

Time From - To	Private Car	Taxi	Microbus and Minibus	Big Bus	Small Truck	Heavy Truck	Total
5:00 - 5:15	9	7	3	2	2	3	26
5:15 - 5:30	12	7	2	4	2	2	29
5:30 - 5:45	25	18	8	10	7	3	71
5:45 - 6:00	47	9	9	9	8	4	86
5:00 - 6:00	***93***	***41***	***22***	***25***	***19***	***12***	**212**
7:00 - 7.15	92	74	9	13	9	3	200
7:15 - 7:30	142	63	10	12	10	0	237
7:30 - 7:45	207	102	14	34	11	0	368
7:45 - 8:00	317	115	28	28	10	0	498
7:00 - 8:00	***758***	***354***	***61***	***87***	***40***	***3***	**1,303**
8:00 - 8:15	***353***	***132***	***16***	***24***	***10***	***0***	535
8:15 - 8:30	360	129	6	23	12	0	530
8:30 - 8:45	334	160	8	20	10	0	532
8:45 - 9:00	313	150	10	17	10	0	500
8:00 - 9:00	***1,360***	***571***	***40***	***84***	***42***	***0***	**2,097**
9:00 - 9:15	336	157	8	10	12	1	524
9:15 - 9:30	300	174	6	20	14	1	515
9:30 - 9:45	293	161	9	13	10	0	486
9:45 - 10:00	286	122	8	10	7	0	433
9:00 - 10:00	***1,215***	***614***	***31***	***53***	***43***	***2***	**1,958**
10:00 - 10:15	291	147	3	16	18	1	476
10.15 - 10.30	233	145	9	10	15	0	412
10.30 - 10.45	226	137	13	17	11	0	404
10.45 - 11.00	199	140	5	30	18	0	392
10:00 - 11:00	***949***	***569***	***30***	***73***	***62***	***1***	**1,684**
3:00 - 3:15	194	62	13	25	23	0	317
3:15 - 3:30	175	61	18	6	25	0	285
3:30 - 3:45	129	67	15	7	32	0	250
3:45 - 4:00	131	70	9	6	14	1	231
3:00 - 4:00	***629***	***260***	***55***	***44***	***94***	***1***	**1,083**
4:00 - 4:15	162	56	16	8	22	0	264
4:15 - 4:30	180	68	16	4	23	0	291
4:30 - 4:45	154	70	10	4	21	0	259
4:45 - 5:00	156	93	17	1	26	1	294
4:00 - 5:00	***652***	***287***	***59***	***17***	***92***	***1***	**1,108**
5:00 - 5:15	183	91	13	8	28	0	323
5:15 - 5:30	171	64	12	7	20	1	275
5:30 - 5:45	187	86	7	6	16	1	303
5:45 - 6:00	171	109	14	8	21	0	323
5:00 - 6:00	***712***	***350***	***46***	***29***	***85***	***2***	**1,224**
6:00 - 6:15	168	106	12	8	29	1	324
6:15 - 6:30	174	103	17	8	32	1	335
6:30 - 6:45	192	157	11	6	14	0	380
6:45 - 7:00	204	154	7	6	10	0	381
6:00 - 7:00	***738***	***520***	***47***	***28***	***85***	***2***	**1,420**

Date: Wednesday 15 June 2011
Location No: L 6-1 By: Mohamed Ibrahim, Mohamed Marzouk and Mohamed Abd El Hamid Ghalii
Road Name: Fisal St. near to Giza
Direction: Giza to Pyramid

Time From - To	Private Car	Taxi	Microbus and Minibus	Big Bus	Small Truck	Heavy Truck	Total
5:00 - 5:15	6	5	3	2	1	0	17
5:15 - 5:30	9	6	4	2	2	2	25
5:30 - 5:45	13	8	7	3	6	3	40
5:45 - 6:00	19	14	7	5	4	2	51
5:00 - 6:00	***47***	***33***	***21***	***12***	***13***	***7***	**133**
7:00 - 7.15	38	37	62	5	10	0	152
7:15 - 7:30	68	51	79	10	7	0	215
7:30 - 7:45	42	55	86	6	19	1	209
7:45 - 8:00	74	78	81	9	13	0	255
7:00 - 8:00	***222***	***221***	***308***	***30***	***49***	***1***	**831**
8:00 - 8:15	***59***	***76***	***79***	***11***	***20***	***1***	246
8:15 - 8:30	75	55	83	3	7	0	223
8:30 - 8:45	80	57	57	2	4	0	200
8:45 - 9:00	65	64	81	5	10	0	225
8:00 - 9:00	***279***	***252***	***300***	***21***	***41***	***1***	**894**
9:00 - 9:15	82	70	74	2	9	0	237
9:15 - 9:30	88	63	79	3	12	2	247
9:30 - 9:45	106	102	72	2	13	0	295
9:45 - 10:00	77	69	70	1	20	0	237
9:00 - 10:00	***353***	***304***	***295***	***8***	***54***	***2***	**1,016**
10:00 - 10:15	75	87	83	0	15	1	261
10.15 - 10.30	77	97	82	2	21	0	279
10.30 - 10.45	81	112	91	1	14	0	299
10.45 - 11.00	107	103	86	0	16	0	312
10:00 - 11:00	***340***	***399***	***342***	***3***	***66***	***1***	**1,151**
3:00 - 3:15	165	94	85	4	10	0	358
3:15 - 3:30	140	70	59	11	21	1	302
3:30 - 3:45	100	81	65	6	17	1	270
3:45 - 4:00	157	63	75	13	16	0	324
3:00 - 4:00	***562***	***308***	***284***	***34***	***64***	***2***	**1,254**
4:00 - 4:15	97	57	72	8	12	1	247
4:15 - 4:30	125	52	74	10	15	0	276
4:30 - 4:45	171	59	77	5	18	0	330
4:45 - 5:00	162	72	90	9	19	0	352
4:00 - 5:00	***555***	***240***	***313***	***32***	***64***	***1***	**1,205**
5:00 - 5:15	155	72	76	3	15	0	321
5:15 - 5:30	137	68	69	8	17	0	299
5:30 - 5:45	133	62	67	3	14	0	279
5:45 - 6:00	128	48	54	3	11	0	244
5:00 - 6:00	***553***	***250***	***266***	***17***	***57***	***0***	**1,143**
6:00 - 6:15	141	81	72	2	18	0	314
6:15 - 6:30	117	64	56	4	12	0	253
6:30 - 6:45	113	87	60	1	15	0	276
6:45 - 7:00	110	76	57	1	14	0	258
6:00 - 7:00	***481***	***308***	***245***	***8***	***59***	***0***	**1,101**

Date: Wednesday 15 June 2011
Location No: L 6-1 By: Islam Abd El Aziz, Mohamed Abd El Aziz and Hazm El Akad
Road Name: Fisal St. near to Giza
Direction: Pyramid to Giza






Time From - To	Private Car	Taxi	Microbus and Minibus	Big Bus	Small Truck	Heavy Truck	Total
5:00 - 5:15	4	7	10	2	2	0	25
5:15 - 5:30	14	5	11	2	2	3	37
5:30 - 5:45	12	6	8	4	4	4	38
5:45 - 6:00	14	7	6	6	2	5	40
5:00 - 6:00	***44***	***25***	***35***	***14***	***10***	***12***	**140**
7:00 - 7.15	339	75	124	15	6	0	559
7:15 - 7:30	227	56	120	13	9	11	436
7:30 - 7:45	167	64	99	8	6	0	344
7:45 - 8:00	157	59	87	9	6	0	318
7:00 - 8:00	***890***	***254***	***430***	***45***	***27***	***11***	**1,657**
8:00 - 8:15	***79***	***41***	***36***	***3***	***2***	***0***	161
8:15 - 8:30	100	39	38	2	5	0	184
8:30 - 8:45	102	51	31	1	2	1	188
8:45 - 9:00	153	56	59	1	6	0	275
8:00 - 9:00	***434***	***187***	***164***	***7***	***15***	***1***	**808**
9:00 - 9:15	164	83	58	3	8	0	316
9:15 - 9:30	189	62	68	1	13	0	333
9:30 - 9:45	178	69	47	2	8	1	305
9:45 - 10:00	242	73	72	0	17	2	406
9:00 - 10:00	***773***	***287***	***245***	***6***	***46***	***3***	**1,360**
10:00 - 10:15	231	95	77	1	18	0	422
10.15 - 10.30	195	90	78	1	16	0	380
10.30 - 10.45	174	76	80	2	21	0	353
10.45 - 11.00	225	101	67	2	13	2	410
10:00 - 11:00	***825***	***362***	***302***	***6***	***68***	***2***	**1,565**
3:00 - 3:15	163	76	72	3	22	1	337
3:15 - 3:30	144	62	69	2	23	0	300
3:30 - 3:45	202	100	109	8	29	0	448
3:45 - 4:00	186	63	105	6	17	0	377
3:00 - 4:00	***695***	***301***	***355***	***19***	***91***	***1***	**1,462**
4:00 - 4:15	216	82	99	2	22	0	421
4:15 - 4:30	139	69	101	1	15	0	325
4:30 - 4:45	203	63	104	0	25	0	395
4:45 - 5:00	150	66	101	0	21	0	338
4:00 - 5:00	***708***	***280***	***405***	***3***	***83***	***0***	**1,479**
5:00 - 5:15	156	74	94	5	20	1	350
5:15 - 5:30	188	71	91	2	22	2	376
5:30 - 5:45	186	69	98	1	24	0	378
5:45 - 6:00	209	73	89	4	26	0	401
5:00 - 6:00	***739***	***287***	***372***	***12***	***92***	***3***	**1,505**
6:00 - 6:15	199	85	106	3	21	0	414
6:15 - 6:30	167	80	98	3	11	0	359
6:30 - 6:45	200	92	100	3	11	0	406
6:45 - 7:00	189	77	97	2	13	0	378
6:00 - 7:00	***755***	***334***	***401***	***11***	***56***	***0***	**1,557**

Date: Wednesday 15 June 2011
Location No: L 6-2
By: Mahmoud Marzouk, Ahmed M. El Kabanii and Ahmed Ibrahim Usaf
Road Name: Fisal St. near to Pyriamd
Direction: Pyriamd to Giza

Time From - To	Private Car	Taxi	Microbus and Minibus	Big Bus	Small Truck	Heavy Truck	Total
5:00 - 5:15	3	3	5	3	2	2	18
5:15 - 5:30	5	3	3	3	3	1	18
5:30 - 5:45	6	4	6	4	1	4	25
5:45 - 6:00	5	4	5	5	4	1	24
5:00 - 6:00	***19***	***14***	***19***	***15***	***10***	***8***	**85**
7:00 - 7.15	32	38	43	44	11	2	170
7:15 - 7:30	26	33	48	12	9	2	130
7:30 - 7:45	29	47	64	12	6	0	158
7:45 - 8:00	26	38	45	14	3	2	128
7:00 - 8:00	***113***	***156***	***200***	***82***	***29***	***6***	**586**
8:00 - 8:15	***28***	***26***	***55***	***9***	***8***	***5***	131
8:15 - 8:30	31	30	62	6	8	1	138
8:30 - 8:45	32	37	56	15	11	3	154
8:45 - 9:00	36	21	61	4	17	1	140
8:00 - 9:00	***127***	***114***	***234***	***34***	***44***	***10***	**563**
9:00 - 9:15	43	36	56	13	20	2	170
9:15 - 9:30	73	54	63	14	14	1	219
9:30 - 9:45	77	39	76	16	18	1	227
9:45 - 10:00	84	42	70	14	19	2	231
9:00 - 10:00	***277***	***171***	***265***	***57***	***71***	***6***	**847**
10:00 - 10:15	96	66	74	10	19	3	268
10.15 - 10.30	83	57	79	15	21	6	261
10.30 - 10.45	64	73	88	9	26	2	262
10.45 - 11.00	83	40	67	15	17	3	225
10:00 - 11:00	***326***	***236***	***308***	***49***	***83***	***14***	**1,016**
3:00 - 3:15	66	25	34	9	15	0	149
3:15 - 3:30	86	28	51	15	26	3	209
3:30 - 3:45	88	24	61	9	29	0	211
3:45 - 4:00	72	28	66	20	27	0	213
3:00 - 4:00	***312***	***105***	***212***	***53***	***97***	***3***	**782**
4:00 - 4:15	105	33	61	17	28	3	247
4:15 - 4:30	84	42	62	21	21	4	234
4:30 - 4:45	59	25	55	17	18	6	180
4:45 - 5:00	62	41	67	19	22	4	215
4:00 - 5:00	***310***	***141***	***245***	***74***	***89***	***17***	**876**
5:00 - 5:15	92	46	75	21	25	1	260
5:15 - 5:30	77	34	67	22	23	5	228
5:30 - 5:45	74	45	80	12	29	0	240
5:45 - 6:00	123	33	77	19	32	5	289
5:00 - 6:00	***366***	***158***	***299***	***74***	***109***	***11***	**1,017**
6:00 - 6:15	129	51	86	12	38	12	328
6:15 - 6:30	95	55	77	15	34	1	277
6:30 - 6:45	106	33	56	16	28	3	242
6:45 - 7:00	72	38	64	12	32	2	220
6:00 - 7:00	***402***	***177***	***283***	***55***	***132***	***18***	**1,067**

Date: Wednesday 15 June 2011
Location No: L 6-2 By: Ahmed Mostafa, Osama Radwan and Husain Nadii
Road Name: Fisal St. near to Pyriamd
Direction: Giza to Pyriamd

Time From - To	Private Car	Taxi	Microbus and Minibus	Big Bus	Small Truck	Heavy Truck	Total
5:00 - 5:15	15	6	3	5	0	2	31
5:15 - 5:30	17	8	5	5	1	3	39
5:30 - 5:45	19	5	7	7	5	1	44
5:45 - 6:00	22	12	9	12	3	1	59
5:00 - 6:00	***73***	***31***	***24***	***29***	***9***	***7***	**173**
7:00 - 7.15	192	48	92	70	18	7	427
7:15 - 7:30	157	44	89	56	24	9	379
7:30 - 7:45	169	47	72	34	14	1	337
7:45 - 8:00	161	49	76	30	17	13	346
7:00 - 8:00	***679***	***188***	***329***	***190***	***73***	***30***	**1,489**
8:00 - 8:15	***137***	***39***	***82***	***34***	***35***	***7***	334
8:15 - 8:30	229	57	80	19	15	9	409
8:30 - 8:45	187	48	62	20	18	11	346
8:45 - 9:00	163	40	67	18	21	9	318
8:00 - 9:00	***716***	***184***	***291***	***91***	***89***	***36***	**1,407**
9:00 - 9:15	151	47	68	20	19	5	310
9:15 - 9:30	187	59	73	19	34	9	381
9:30 - 9:45	215	46	45	14	20	8	348
9:45 - 10:00	141	55	57	11	29	6	299
9:00 - 10:00	***694***	***207***	***243***	***64***	***102***	***28***	**1,338**
10:00 - 10:15	120	61	63	14	34	9	301
10.15 - 10.30	111	51	72	8	19	16	277
10.30 - 10.45	140	50	57	8	28	3	286
10.45 - 11.00	158	47	69	15	26	6	321
10:00 - 11:00	***529***	***209***	***261***	***45***	***107***	***34***	**1,185**
3:00 - 3:15	72	31	35	8	12	2	160
3:15 - 3:30	88	20	36	15	22	3	184
3:30 - 3:45	109	31	69	21	31	4	265
3:45 - 4:00	86	42	40	16	34	4	222
3:00 - 4:00	***355***	***124***	***180***	***60***	***99***	***13***	**831**
4:00 - 4:15	110	41	63	21	42	1	278
4:15 - 4:30	89	28	46	17	25	2	207
4:30 - 4:45	75	24	40	7	16	3	165
4:45 - 5:00	116	42	60	21	29	0	268
4:00 - 5:00	***390***	***135***	***209***	***66***	***112***	***6***	**918**
5:00 - 5:15	101	32	62	13	27	2	237
5:15 - 5:30	92	27	59	11	20	2	211
5:30 - 5:45	84	37	74	11	22	5	233
5:45 - 6:00	84	39	52	12	22	3	212
5:00 - 6:00	***361***	***135***	***247***	***47***	***91***	***12***	**893**
6:00 - 6:15	75	46	61	17	27	4	230
6:15 - 6:30	61	32	66	8	26	1	194
6:30 - 6:45	73	26	51	11	15	2	178
6:45 - 7:00	66	33	58	12	23	1	193
6:00 - 7:00	***275***	***137***	***236***	***48***	***91***	***8***	**795**

Date: Wednesday 8 June 2011
Location No: L7-1 By: Mohamed Abd El Hamid Ghali, and Hazm El akad
Road Name: Abbas El Akad St.
Direction: From El Nasr Road to Mostafa El Nahas

Time From - To	Private Car	Taxi	Microbus and Minibus	Big Bus	Small Truck	Heavy Truck	Total
5:00 - 5:15	13	8	6	0	0	0	27
5:15 - 5:30	18	11	9	1	2	0	41
5:30 - 5:45	27	9	8	3	1	2	50
5:45 - 6:00	44	13	12	1	3	1	74
5:00 - 6:00	***102***	***41***	***35***	***5***	***6***	***3***	**192**
7:00 - 7.15	153	101	42	3	5	1	305
7:15 - 7:30	213	116	62	8	7	1	407
7:30 - 7:45	322	122	41	6	6	0	497
7:45 - 8:00	357	136	55	4	8	0	560
7:00 - 8:00	***1,045***	***475***	***200***	***21***	***26***	***2***	**1,769**
8:00 - 8:15	***340***	***114***	***60***	***2***	***4***	***1***	521
8:15 - 8:30	315	123	49	1	4	0	492
8:30 - 8:45	357	152	39	2	7	1	558
8:45 - 9:00	321	144	51	5	6	0	527
8:00 - 9:00	***1,333***	***533***	***199***	***10***	***21***	***2***	**2,098**
9:00 - 9:15	337	126	42	1	8	0	514
9:15 - 9:30	374	160	66	1	5	0	606
9:30 - 9:45	271	144	49	2	7	0	473
9:45 - 10:00	292	163	48	0	14	2	519
9:00 - 10:00	***1,274***	***593***	***205***	***4***	***34***	***2***	**2,112**
10:00 - 10:15	326	134	51	0	7	0	518
10.15 - 10.30	317	134	49	2	15	0	517
10.30 - 10.45	329	131	47	1	11	0	519
10.45 - 11.00	267	94	39	1	9	0	410
10:00 - 11:00	***1,239***	***493***	***186***	***4***	***42***	***0***	**1,964**
3:00 - 3:15	256	107	31	0	13	1	408
3:15 - 3:30	279	107	27	0	11	0	424
3:30 - 3:45	307	111	28	1	9	0	456
3:45 - 4:00	352	128	43	2	14	0	539
3:00 - 4:00	***1,194***	***453***	***129***	***3***	***47***	***1***	**1,827**
4:00 - 4:15	274	94	41	1	8	0	418
4:15 - 4:30	294	92	23	1	9	1	420
4:30 - 4:45	358	109	35	0	15	0	517
4:45 - 5:00	285	102	27	1	17	0	432
4:00 - 5:00	***1,211***	***397***	***126***	***3***	***49***	***1***	**1,787**
5:00 - 5:15	333	122	26	0	7	0	488
5:15 - 5:30	316	101	27	0	12	0	456
5:30 - 5:45	277	86	33	1	13	1	411
5:45 - 6:00	270	104	40	0	6	0	420
5:00 - 6:00	***1,196***	***413***	***126***	***1***	***38***	***1***	**1,775**
6:00 - 6:15	288	99	17	1	4	0	409
6:15 - 6:30	349	114	21	0	3	0	487
6:30 - 6:45	370	126	24	0	11	0	531
6:45 - 7:00	354	113	19	0	5	1	492
6:00 - 7:00	***1,361***	***452***	***81***	***1***	***23***	***1***	**1,919**

Date: Wednesday 8 June 2011
Location No: L7-1 By: Ahmed Sobhi, Ahmed Mostafa and Housian Abd El Ghani
Road Name: Abbas El Akad St.
Direction: From Mostafa El Nahas to El Nasr Road

Time From - To	Private Car	Taxi	Microbus and Minibus	Big Bus	Small Truck	Heavy Truck	Total
5:00 - 5:15	8	9	3	1	0	0	21
5:15 - 5:30	11	7	3	3	2	2	28
5:30 - 5:45	23	10	3	2	0	0	38
5:45 - 6:00	27	12	5	4	2	3	53
5:00 - 6:00	***69***	***38***	***14***	***10***	***4***	***5***	**140**
7:00 - 7.15	111	69	26	11	3	0	220
7:15 - 7:30	137	87	21	15	3	0	263
7:30 - 7:45	225	96	27	12	10	0	370
7:45 - 8:00	374	100	31	8	7	0	520
7:00 - 8:00	***847***	***352***	***105***	***46***	***23***	***0***	**1,373**
8:00 - 8:15	***358***	***95***	***31***	***9***	***14***	***0***	507
8:15 - 8:30	354	82	24	3	11	0	474
8:30 - 8:45	379	120	19	10	6	0	534
8:45 - 9:00	400	121	22	6	7	0	556
8:00 - 9:00	***1,491***	***418***	***96***	***28***	***38***	***0***	**2,071**
9:00 - 9:15	355	98	33	4	6	0	496
9:15 - 9:30	348	106	25	5	16	0	500
9:30 - 9:45	302	115	22	5	10	0	454
9:45 - 10:00	290	133	22	8	13	0	466
9:00 - 10:00	***1,295***	***452***	***102***	***22***	***45***	***0***	**1,916**
10:00 - 10:15	309	125	28	5	17	2	486
10.15 - 10.30	306	126	25	6	13	1	477
10.30 - 10.45	244	110	24	5	13	1	397
10.45 - 11.00	230	95	22	3	12	0	362
10:00 - 11:00	***1,089***	***456***	***99***	***19***	***55***	***4***	**1,722**
3:00 - 3:15	261	135	25	4	27	2	454
3:15 - 3:30	257	107	24	5	13	0	406
3:30 - 3:45	292	86	26	7	25	0	436
3:45 - 4:00	348	102	26	8	21	1	506
3:00 - 4:00	***1,158***	***430***	***101***	***24***	***86***	***3***	**1,802**
4:00 - 4:15	357	120	26	11	17	0	531
4:15 - 4:30	264	115	27	5	17	0	428
4:30 - 4:45	300	142	27	4	20	0	493
4:45 - 5:00	307	102	24	6	12	0	451
4:00 - 5:00	***1,228***	***479***	***104***	***26***	***66***	***0***	**1,903**
5:00 - 5:15	335	128	15	2	21	0	501
5:15 - 5:30	365	104	22	3	7	0	501
5:30 - 5:45	330	100	18	2	21	0	471
5:45 - 6:00	374	126	17	2	14	0	533
5:00 - 6:00	***1,404***	***458***	***72***	***9***	***63***	***0***	**2,006**
6:00 - 6:15	309	112	20	4	14	0	459
6:15 - 6:30	326	138	12	3	19	0	498
6:30 - 6:45	328	98	17	2	17	0	462
6:45 - 7:00	272	134	15	2	7	0	430
6:00 - 7:00	***1,235***	***482***	***64***	***11***	***57***	***0***	**1,849**

Date: Wednesday 8 June 2011
Location No: L7-2 By:Mohamed Marzouk, Mohamed Ibrahim and Mahmoud Marzouk
Road Name: Makram Abiad St.
Direction: From El Nasr road to Mostafa El Nahas






Time From - To	Private Car	Taxi	Microbus and Minibus	Big Bus	Small Truck	Heavy Truck	Total
5:00 - 5:15	7	5	3	0	0	0	15
5:15 - 5:30	11	7	2	1	0	0	21
5:30 - 5:45	12	9	4	3	4	2	34
5:45 - 6:00	22	8	5	1	4	1	41
5:00 - 6:00	***52***	***29***	***14***	***5***	***8***	***3***	**111**
7:00 - 7.15	81	60	32	11	8	0	192
7:15 - 7:30	101	53	43	3	11	3	214
7:30 - 7:45	128	81	40	1	7	2	259
7:45 - 8:00	188	74	54	3	11	2	332
7:00 - 8:00	***498***	***268***	***169***	***18***	***37***	***7***	**997**
8:00 - 8:15	***208***	***96***	***46***	***4***	***14***	***1***	369
8:15 - 8:30	189	78	43	0	16	0	326
8:30 - 8:45	252	86	40	1	17	0	396
8:45 - 9:00	211	77	45	1	12	1	347
8:00 - 9:00	***860***	***337***	***174***	***6***	***59***	***2***	**1,438**
9:00 - 9:15	222	111	39	1	17	0	390
9:15 - 9:30	234	79	36	1	16	0	366
9:30 - 9:45	226	95	33	1	12	0	367
9:45 - 10:00	209	101	38	1	14	0	363
9:00 - 10:00	***891***	***386***	***146***	***4***	***59***	***0***	**1,486**
10:00 - 10:15	219	87	28	1	9	0	344
10.15 - 10.30	207	47	35	0	13	0	302
10.30 - 10.45	224	84	31	2	17	0	358
10.45 - 11.00	208	72	29	0	10	0	319
10:00 - 11:00	***858***	***290***	***123***	***3***	***49***	***0***	**1,323**
3:00 - 3:15	261	54	28	0	6	0	349
3:15 - 3:30	286	85	30	2	12	0	415
3:30 - 3:45	279	74	24	1	13	1	392
3:45 - 4:00	293	58	28	3	17	0	399
3:00 - 4:00	***1,119***	***271***	***110***	***6***	***48***	***1***	**1,555**
4:00 - 4:15	316	63	20	1	16	0	416
4:15 - 4:30	321	53	27	2	9	0	412
4:30 - 4:45	382	72	28	2	16	0	500
4:45 - 5:00	334	71	29	0	7	0	441
4:00 - 5:00	***1,353***	***259***	***104***	***5***	***48***	***0***	**1,769**
5:00 - 5:15	304	76	22	1	12	0	415
5:15 - 5:30	294	70	23	0	15	0	402
5:30 - 5:45	329	66	21	1	8	0	425
5:45 - 6:00	288	74	17	0	10	0	389
5:00 - 6:00	***1,215***	***286***	***83***	***2***	***45***	***0***	**1,631**
6:00 - 6:15	311	64	26	1	7	0	409
6:15 - 6:30	290	72	25	0	6	0	393
6:30 - 6:45	303	76	28	0	6	0	413
6:45 - 7:00	387	81	27	3	5	0	503
6:00 - 7:00	***1,291***	***293***	***106***	***4***	***24***	***0***	**1,718**

Date: Wednesday 8 June 2011
Location No: L7-2 By:Mohamed Abd El Aziz, Islam Mohamed and Ahmed Ibrahim
Road Name: Makram Abiad St.
Direction: From Mostafa El Nahas to El Nasr road

Time From - To	Private Car	Taxi	Microbus and Minibus	Big Bus	Small Truck	Heavy Truck	Total
5:00 - 5:15	9	6	3	1	1	0	20
5:15 - 5:30	16	5	2	2	0	0	25
5:30 - 5:45	18	6	6	2	0	1	33
5:45 - 6:00	33	9	5	2	4	2	55
5:00 - 6:00	***76***	***26***	***16***	***7***	***5***	***3***	**133**
7:00 - 7.15	124	51	31	4	3	2	215
7:15 - 7:30	163	63	37	9	4	1	277
7:30 - 7:45	190	64	53	6	3	1	317
7:45 - 8:00	267	89	54	4	10	1	425
7:00 - 8:00	***744***	***267***	***175***	***23***	***20***	***5***	**1,234**
8:00 - 8:15	***278***	***108***	***50***	***2***	***18***	***0***	456
8:15 - 8:30	248	73	48	3	9	1	382
8:30 - 8:45	284	76	49	2	18	0	429
8:45 - 9:00	285	81	63	1	7	0	437
8:00 - 9:00	***1,095***	***338***	***210***	***8***	***52***	***1***	**1,704**
9:00 - 9:15	262	85	60	0	14	0	421
9:15 - 9:30	226	89	67	1	12	0	395
9:30 - 9:45	239	73	61	1	11	0	385
9:45 - 10:00	265	77	56	0	11	0	409
9:00 - 10:00	***992***	***324***	***244***	***2***	***48***	***0***	**1,610**
10:00 - 10:15	236	94	62	0	15	1	408
10.15 - 10.30	215	84	48	2	20	0	369
10.30 - 10.45	219	110	57	1	14	1	402
10.45 - 11.00	228	65	64	0	13	0	370
10:00 - 11:00	***898***	***353***	***231***	***3***	***62***	***2***	**1,549**
3:00 - 3:15	181	79	41	2	11	1	315
3:15 - 3:30	194	65	37	1	8	0	305
3:30 - 3:45	202	78	31	2	14	0	327
3:45 - 4:00	189	82	43	3	10	1	328
3:00 - 4:00	***766***	***304***	***152***	***8***	***43***	***2***	**1,275**
4:00 - 4:15	174	102	47	0	10	0	333
4:15 - 4:30	195	86	36	0	11	0	328
4:30 - 4:45	188	70	37	2	17	0	314
4:45 - 5:00	216	75	44	2	14	0	351
4:00 - 5:00	***773***	***333***	***164***	***4***	***52***	***0***	**1,326**
5:00 - 5:15	200	90	45	1	7	0	343
5:15 - 5:30	193	88	33	0	12	1	327
5:30 - 5:45	254	106	42	0	9	0	411
5:45 - 6:00	247	93	36	0	13	0	389
5:00 - 6:00	***894***	***377***	***156***	***1***	***41***	***1***	**1,470**
6:00 - 6:15	270	94	41	0	13	0	418
6:15 - 6:30	250	82	35	0	14	0	381
6:30 - 6:45	222	90	33	1	7	0	353
6:45 - 7:00	236	82	43	0	10	0	371
6:00 - 7:00	***978***	***348***	***152***	***1***	***44***	***0***	**1,523**

Non-Classified Traffic Counts

Date: Monday 13 June 2011 **Counted By:** Mohamed Abd El Aziz
Point No: Location 1-1
Name of Street: Tomanbay St.
Direction: One Way from West to East (Al Tagniad)

Time Per 15 Min	Volume per 15 min	Highest 15 Min	Time Per Hour	Volume per Hour	Flow Rate per Hour	PHF
5:00 - 5:15	9	16	5:00 - 6:00	50	64	0.781
5:15 - 5:30	12					
5:30 - 5:45	13					
5:45 - 6:00	16					
7:00 - 7.15	96	142	7.00 - 8.00	492	568	0.866
7:15 - 7:30	123					
7:30 - 7:45	131					
7:45 - 8:00	142					
8:00 - 8:15	139	154	8.00 - 9.00	572	616	0.929
8:15 - 8:30	154					
8:30 - 8:45	143					
8:45 - 9:00	136					
9:00 - 9:15	140	157	9.00 - 10.00	588	628	0.936
9:15 - 9:30	137					
9:30 - 9:45	154					
9:45 - 10;00	157					
10:00 - 10:15	191	191	10.00 - 11.00	721	764	0.944
10.15 - 10.30	189					
10.30 - 10.45	178					
10.45 - 11.00	163					
3.00 - 3.15	189	217	3.00 - 4.00	814	868	0.938
3.15 - 3.30	200					
3.30 - 3.45	208					
3.45 - 4.00	217					
4.00 - 4.15	177	217	4.00 - 5.00	776	868	0.894
4.15 - 4.30	217					
4.30 - 4.45	183					
4.45 - 5.00	199					
5.00 - 5.15	159	172	5.00 - 6.00	645	688	0.938
5.15 - 5.30	172					
5.30 - 5.45	166					
5.45 - 6.00	148					
6.00 - 6.15	196	213	6.00 - 700	777	852	0.912
6.15 - 6.30	190					
6.30 - 6.45	213					
6.45 - 7.00	178					

Date: Monday 13 June 2011 **Counted By:** Islam Mohamed Abd El Aziz
Point No: Location 1-2
Name of Street: Gesr El Suiz St.
Direction: From East (Alf Maskan) to West (Kobri El Kobah)

Time Per 15 Min	Volume per 15 min	Highest 15 Min	Time Per Hour	Volume per Hour	Flow Rate per Hour	PHF
5:00 - 5:15	59	133	5:00 - 6:00	408	532	0.767
5:15 - 5:30	111					
5:30 - 5:45	105					
5:45 - 6:00	133					
7:00 - 7.15	726	750	7.00 - 8.00	2,841	3,000	0.947
7:15 - 7:30	745					
7:30 - 7:45	620					
7:45 - 8:00	750					
8:00 - 8:15	844	1,014	8.00 - 9.00	3,774	4,056	0.930
8:15 - 8:30	984					
8:30 - 8:45	932					
8:45 - 9:00	1,014					
9:00 - 9:15	973	973	9.00 - 10.00	3,722	3,892	0.956
9:15 - 9:30	964					
9:30 - 9:45	934					
9:45 - 10;00	851					
10:00 - 10:15	887	958	10.00 - 11.00	3,590	3,832	0.937
10.15 - 10.30	946					
10.30 - 10.45	958					
10.45 - 11.00	799					
3.00 - 3.15	711	711	3.00 - 4.00	2,765	2,844	0.972
3.15 - 3.30	689					
3.30 - 3.45	664					
3.45 - 4.00	701					
4.00 - 4.15	808	875	4.00 - 5.00	3,225	3,500	0.921
4.15 - 4.30	773					
4.30 - 4.45	875					
4.45 - 5.00	769					
5.00 - 5.15	824	824	5.00 - 6.00	3,038	3,296	0.922
5.15 - 5.30	761					
5.30 - 5.45	800					
5.45 - 6.00	653					
6.00 - 6.15	883	883	6.00 - 700	3,297	3,532	0.933
6.15 - 6.30	779					
6.30 - 6.45	804					
6.45 - 7.00	831					

Date: Monday 13 June 2011 **Counted By:** Hazm Hosni El Akad
Point No: Location 2-1
Name of Street: El-Qasr El-Einy St
Direction: Oneway to Tahrir Squar

Time Per 15 Min	Volume per 15 min	Highest 15 Min	Time Per Hour	Volume per Hour	Flow Rate per Hour	PHF
5:00 - 5:15	63	115	5:00 - 6:00	354	460	0.770
5:15 - 5:30	99					
5:30 - 5:45	77					
5:45 - 6:00	115					
7:00 - 7.15	511	586	7.00 - 8.00	2,127	2,344	0.907
7:15 - 7:30	503					
7:30 - 7:45	527					
7:45 - 8:00	586					
8:00 - 8:15	654	865	8.00 - 9.00	3,084	3,460	0.891
8:15 - 8:30	782					
8:30 - 8:45	865					
8:45 - 9:00	783					
9:00 - 9:15	773	773	9.00 - 10.00	2,898	3,092	0.937
9:15 - 9:30	729					
9:30 - 9:45	712					
9:45 - 10;00	684					
10:00 - 10:15	739	814	10.00 - 11.00	3,105	3,256	0.954
10.15 - 10.30	754					
10.30 - 10.45	814					
10.45 - 11.00	798					
3.00 - 3.15	663	663	3.00 - 4.00	2,224	2,652	0.839
3.15 - 3.30	534					
3.30 - 3.45	582					
3.45 - 4.00	445					
4.00 - 4.15	424	483	4.00 - 5.00	1,776	1,932	0.919
4.15 - 4.30	411					
4.30 - 4.45	483					
4.45 - 5.00	458					
5.00 - 5.15	503	540	5.00 - 6.00	2,053	2,160	0.950
5.15 - 5.30	498					
5.30 - 5.45	540					
5.45 - 6.00	512					
6.00 - 6.15	632	674	6.00 - 700	2,543	2,696	0.943
6.15 - 6.30	598					
6.30 - 6.45	674					
6.45 - 7.00	639					

Date: Monday 13 June 2011 **Counted By:** Mohamed Marzok
Point No: Location 2-2
Name of Street: Nubar St.
Direction: Oneway from Rihan St. to Magls El Shab St.

Time Per 15 Min	Volume per 15 min	Highest 15 Min	Time Per Hour	Volume per Hour	Flow Rate per Hour	PHF
5:00 - 5:15	4	11	5:00 - 6:00	28	44	0.636
5:15 - 5:30	6					
5:30 - 5:45	7					
5:45 - 6:00	11					
7:00 - 7.15	74	98	7.00 - 8.00	310	392	0.791
7:15 - 7:30	56					
7:30 - 7:45	82					
7:45 - 8:00	98					
8:00 - 8:15	106	138	8.00 - 9.00	474	552	0.859
8:15 - 8:30	114					
8:30 - 8:45	138					
8:45 - 9:00	116					
9:00 - 9:15	121	122	9.00 - 10.00	453	488	0.928
9:15 - 9:30	107					
9:30 - 9:45	122					
9:45 - 10;00	103					
10:00 - 10:15	104	118	10.00 - 11.00	421	472	0.892
10.15 - 10.30	95					
10.30 - 10.45	118					
10.45 - 11.00	104					
3.00 - 3.15	84	91	3.00 - 4.00	334	364	0.918
3.15 - 3.30	70					
3.30 - 3.45	89					
3.45 - 4.00	91					
4.00 - 4.15	101	134	4.00 - 5.00	402	536	0.750
4.15 - 4.30	134					
4.30 - 4.45	90					
4.45 - 5.00	77					
5.00 - 5.15	104	106	5.00 - 6.00	408	424	0.962
5.15 - 5.30	102					
5.30 - 5.45	96					
5.45 - 6.00	106					
6.00 - 6.15	91	109	6.00 - 700	391	436	0.897
6.15 - 6.30	108					
6.30 - 6.45	83					
6.45 - 7.00	109					

Date: Monday 13 June 2011 **Counted By:** Mohamed Ibrahim
Point No: Location 4-1
Name of Street: Ramses St.
Direction: Oneway to Abasayah

Time Per 15 Min	Volume per 15 min	Highest 15 Min	Time Per Hour	Volume per Hour	Flow Rate per Hour	PHF
5:00 - 5:15	14	22	5:00 - 6:00	66	88	0.750
5:15 - 5:30	12					
5:30 - 5:45	22					
5:45 - 6:00	18					
7:00 - 7.15	235	235	7.00 - 8.00	835	940	0.888
7:15 - 7:30	200					
7:30 - 7:45	194					
7:45 - 8:00	206					
8:00 - 8:15	185	191	8.00 - 9.00	705	764	0.923
8:15 - 8:30	166					
8:30 - 8:45	163					
8:45 - 9:00	191					
9:00 - 9:15	177	197	9.00 - 10.00	738	788	0.937
9:15 - 9:30	183					
9:30 - 9:45	197					
9:45 - 10;00	181					
10:00 - 10:15	191	247	10.00 - 11.00	878	988	0.889
10.15 - 10.30	216					
10.30 - 10.45	247					
10.45 - 11.00	224					
3.00 - 3.15	155	228	3.00 - 4.00	764	912	0.838
3.15 - 3.30	197					
3.30 - 3.45	184					
3.45 - 4.00	228					
4.00 - 4.15	153	186	4.00 - 5.00	684	744	0.919
4.15 - 4.30	175					
4.30 - 4.45	186					
4.45 - 5.00	170					
5.00 - 5.15	155	212	5.00 - 6.00	725	848	0.855
5.15 - 5.30	212					
5.30 - 5.45	203					
5.45 - 6.00	155					
6.00 - 6.15	177	224	6.00 - 700	768	896	0.857
6.15 - 6.30	187					
6.30 - 6.45	180					
6.45 - 7.00	224					

Date: Monday 13 June 2011 **Counted By:** Mohamed Ghali
Point No: Location 4-2
Name of Street: El Gash St.
Direction: Oneway to Atabah

Time Per 15 Min	Volume per 15 min	Highest 15 Min	Time Per Hour	Volume per Hour	Flow Rate per Hour	PHF
5:00 - 5:15	13	23	5:00 - 6:00	68	92	0.739
5:15 - 5:30	15					
5:30 - 5:45	17					
5:45 - 6:00	23					
7:00 - 7.15	123	236	7.00 - 8.00	729	944	0.772
7:15 - 7:30	174					
7:30 - 7:45	196					
7:45 - 8:00	236					
8:00 - 8:15	274	349	8.00 - 9.00	1,225	1,396	0.878
8:15 - 8:30	280					
8:30 - 8:45	322					
8:45 - 9:00	349					
9:00 - 9:15	380	396	9.00 - 10.00	1,542	1,584	0.973
9:15 - 9:30	392					
9:30 - 9:45	374					
9:45 - 10;00	396					
10:00 - 10:15	384	429	10.00 - 11.00	1,626	1,716	0.948
10.15 - 10.30	401					
10.30 - 10.45	429					
10.45 - 11.00	412					
3.00 - 3.15	419	458	3.00 - 4.00	1,736	1,832	0.948
3.15 - 3.30	423					
3.30 - 3.45	458					
3.45 - 4.00	436					
4.00 - 4.15	454	461	4.00 - 5.00	1,784	1,844	0.967
4.15 - 4.30	439					
4.30 - 4.45	461					
4.45 - 5.00	430					
5.00 - 5.15	442	474	5.00 - 6.00	1,841	1,896	0.971
5.15 - 5.30	466					
5.30 - 5.45	459					
5.45 - 6.00	474					
6.00 - 6.15	491	491	6.00 - 700	1,865	1,964	0.950
6.15 - 6.30	436					
6.30 - 6.45	476					
6.45 - 7.00	462					

Date: Tuesday 14 June 2011 **Counted By:** Ahmed M. El Kabani
Point No: Location 5-1
Name of Street: Gameat El Qahera St.
Direction: From Giza to Dokii

Time Per 15 Min	Volume per 15 min	Highest 15 Min	Time Per Hour	Volume per Hour	Flow Rate per Hour	PHF
5:00 - 5:15	24	66	5:00 - 6:00	168	264	0.636
5:15 - 5:30	33					
5:30 - 5:45	45					
5:45 - 6:00	66					
7:00 - 7.15	385	648	7.00 - 8.00	2,107	2,592	0.813
7:15 - 7:30	497					
7:30 - 7:45	577					
7:45 - 8:00	648					
8:00 - 8:15	625	630	8.00 - 9.00	2,434	2,520	0.966
8:15 - 8:30	630					
8:30 - 8:45	610					
8:45 - 9:00	569					
9:00 - 9:15	563	630	9.00 - 10.00	2,305	2,520	0.915
9:15 - 9:30	607					
9:30 - 9:45	505					
9:45 - 10;00	630					
10:00 - 10:15	500	500	10.00 - 11.00	1,908	2,000	0.954
10.15 - 10.30	475					
10.30 - 10.45	493					
10.45 - 11.00	440					
3.00 - 3.15	382	431	3.00 - 4.00	1,463	1,724	0.849
3.15 - 3.30	317					
3.30 - 3.45	333					
3.45 - 4.00	431					
4.00 - 4.15	360	424	4.00 - 5.00	1,534	1,696	0.904
4.15 - 4.30	349					
4.30 - 4.45	401					
4.45 - 5.00	424					
5.00 - 5.15	377	476	5.00 - 6.00	1,688	1,904	0.887
5.15 - 5.30	424					
5.30 - 5.45	411					
5.45 - 6.00	476					
6.00 - 6.15	545	545	6.00 - 700	1,681	2,180	0.771
6.15 - 6.30	342					
6.30 - 6.45	414					
6.45 - 7.00	380					

Date: Tuesday 14 June 2011 **Counted By:** Husain Nadi
Point No: Location 5-1
Name of Stre Gameat El Qahera St.
Direction: From Dokii to Giza

Time Per 15 Min	Volume per 15 min	Highest 15 Min	Time Per Hour	Volume per Hour	Flow Rate per Hour	PHF
5:00 - 5:15	33	42	**5:00 - 6:00**	138	168	0.821
5:15 - 5:30	26					
5:30 - 5:45	37					
5:45 - 6:00	42					
7:00 - 7.15	308	366	**7.00 - 8.00**	1,256	1,464	0.858
7:15 - 7:30	238					
7:30 - 7:45	344					
7:45 - 8:00	366					
8:00 - 8:15	376	390	**8.00 - 9.00**	1,531	1,560	0.981
8:15 - 8:30	377					
8:30 - 8:45	388					
8:45 - 9:00	390					
9:00 - 9:15	470	550	**9.00 - 10.00**	1,907	2,200	0.867
9:15 - 9:30	388					
9:30 - 9:45	499					
9:45 - 10;00	550					
10:00 - 10:15	470	470	**10.00 - 11.00**	1,744	1,880	0.928
10.15 - 10.30	335					
10.30 - 10.45	444					
10.45 - 11.00	495					
3.00 - 3.15	242	262	**3.00 - 4.00**	854	1,048	0.815
3.15 - 3.30	150					
3.30 - 3.45	200					
3.45 - 4.00	262					
4.00 - 4.15	224	259	**4.00 - 5.00**	884	1,036	0.853
4.15 - 4.30	144					
4.30 - 4.45	259					
4.45 - 5.00	257					
5.00 - 5.15	337	338	**5.00 - 6.00**	1,185	1,352	0.876
5.15 - 5.30	338					
5.30 - 5.45	305					
5.45 - 6.00	205					
6.00 - 6.15	251	321	**6.00 - 700**	1,009	1,284	0.786
6.15 - 6.30	260					
6.30 - 6.45	321					
6.45 - 7.00	177					

Date: Tuesday 14 June 2011 **Counted By:** Mahmoud Marzok
Point No: Location 5-2
Name of Street: El-Doqy St.
Direction: From Dokii to Giza

Time Per 15 Min	Volume per 15 min	Highest 15 Min	Time Per Hour	Volume per Hour	Flow Rate per Hour	PHF
5:00 - 5:15	88	102	5:00 - 6:00	379	408	0.929
5:15 - 5:30	92					
5:30 - 5:45	97					
5:45 - 6:00	102					
7:00 - 7.15	657	957	7.00 - 8.00	2,969	3,828	0.776
7:15 - 7:30	661					
7:30 - 7:45	694					
7:45 - 8:00	957					
8:00 - 8:15	1,029	1,391	8.00 - 9.00	4,851	5,564	0.872
8:15 - 8:30	1,087					
8:30 - 8:45	1,344					
8:45 - 9:00	1,391					
9:00 - 9:15	1,232	1,232	9.00 - 10.00	4,646	4,928	0.943
9:15 - 9:30	1,208					
9:30 - 9:45	1,153					
9:45 - 10;00	1,053					
10:00 - 10:15	1,310	1,310	10.00 - 11.00	4,905	5,240	0.936
10.15 - 10.30	1,132					
10.30 - 10.45	1,288					
10.45 - 11.00	1,175					
3.00 - 3.15	995	1,158	3.00 - 4.00	3,669	4,632	0.792
3.15 - 3.30	1,158					
3.30 - 3.45	721					
3.45 - 4.00	795					
4.00 - 4.15	1,016	1,016	4.00 - 5.00	3,099	4,064	0.763
4.15 - 4.30	824					
4.30 - 4.45	641					
4.45 - 5.00	618					
5.00 - 5.15	625	669	5.00 - 6.00	2,452	2,676	0.916
5.15 - 5.30	598					
5.30 - 5.45	560					
5.45 - 6.00	669					
6.00 - 6.15	724	853	6.00 - 700	2,930	3,412	0.859
6.15 - 6.30	853					
6.30 - 6.45	727					
6.45 - 7.00	626					

Date: Tuesday 14 June 2011 **Counted By:** Ahmed Ibrahim
Point No: Location 5-2
Name of Stree El-Doqy St.
Direction: From Giza to Dokii

Time Per 15 Min	Volume per 15 min	Highest 15 Min	Time Per Hour	Volume per Hour	Flow Rate per Hour	PHF
5:00 - 5:15	53	99	5:00 - 6:00	291	396	0.735
5:15 - 5:30	48					
5:30 - 5:45	91					
5:45 - 6:00	99					
7:00 - 7.15	545	909	7.00 - 8.00	2,913	3,636	0.801
7:15 - 7:30	556					
7:30 - 7:45	903					
7:45 - 8:00	909					
8:00 - 8:15	1,076	1,128	8.00 - 9.00	4,407	4,512	0.977
8:15 - 8:30	1,095					
8:30 - 8:45	1,108					
8:45 - 9:00	1,128					
9:00 - 9:15	1,070	1,201	9.00 - 10.00	4,606	4,804	0.959
9:15 - 9:30	1,180					
9:30 - 9:45	1,155					
9:45 - 10;00	1,201					
10:00 - 10:15	1,153	1,212	10.00 - 11.00	4,663	4,848	0.962
10.15 - 10.30	1,144					
10.30 - 10.45	1,154					
10.45 - 11.00	1,212					
3.00 - 3.15	1,102	1,102	3.00 - 4.00	4,012	4,408	0.910
3.15 - 3.30	1,055					
3.30 - 3.45	1,001					
3.45 - 4.00	854					
4.00 - 4.15	932	1,024	4.00 - 5.00	3,531	4,096	0.862
4.15 - 4.30	1,024					
4.30 - 4.45	710					
4.45 - 5.00	865					
5.00 - 5.15	891	891	5.00 - 6.00	2,403	3,564	0.674
5.15 - 5.30	487					
5.30 - 5.45	445					
5.45 - 6.00	580					
6.00 - 6.15	675	681	6.00 - 700	2,617	2,724	0.961
6.15 - 6.30	612					
6.30 - 6.45	681					
6.45 - 7.00	649					

Date: Tuesday 14 June 2011 **Counted By:** Moman Zain
Point No: Location 8-1
Name of Street: Street No. 9 in Al Mokatam, near to Central Cairo
Direction: From Ring Road to Cairo

Time Per 15 Min	Volume per 15 min	Highest 15 Min	Time Per Hour	Volume per Hour	Flow Rate per Hour	PHF
5:00 - 5:15	11	18	5:00 - 6:00	56	72	0.778
5:15 - 5:30	12					
5:30 - 5:45	15					
5:45 - 6:00	18					
7:00 - 7.15	125	155	7.00 - 8.00	566	620	0.913
7:15 - 7:30	134					
7:30 - 7:45	155					
7:45 - 8:00	152					
8:00 - 8:15	166	175	8.00 - 9.00	661	700	0.944
8:15 - 8:30	157					
8:30 - 8:45	163					
8:45 - 9:00	175					
9:00 - 9:15	205	208	9.00 - 10.00	824	832	0.990
9:15 - 9:30	208					
9:30 - 9:45	204					
9:45 - 10;00	207					
10:00 - 10:15	201	204	10.00 - 11.00	800	816	0.980
10.15 - 10.30	196					
10.30 - 10.45	199					
10.45 - 11.00	204					
3.00 - 3.15	254	258	3.00 - 4.00	869	1,032	0.842
3.15 - 3.30	258					
3.30 - 3.45	191					
3.45 - 4.00	166					
4.00 - 4.15	155	240	4.00 - 5.00	843	960	0.878
4.15 - 4.30	240					
4.30 - 4.45	216					
4.45 - 5.00	232					
5.00 - 5.15	197	197	5.00 - 6.00	751	788	0.953
5.15 - 5.30	195					
5.30 - 5.45	168					
5.45 - 6.00	191					
6.00 - 6.15	236	236	6.00 - 700	837	944	0.887
6.15 - 6.30	187					
6.30 - 6.45	203					
6.45 - 7.00	211					

Date: Tuesday 14 June 2011 **Counted By:** Ahmed Mostafa
Point No: Location 8-1
Name of Stree Street No. 9 in Al Mokatam, near to Central Cairo
Direction: From Cairo to Ring Road

Time Per 15 Min	Volume per 15 min	Highest 15 Min	Time Per Hour	Volume per Hour	Flow Rate per Hour	PHF
5:00 - 5:15	11	18	5:00 - 6:00	50	72	0.694
5:15 - 5:30	9					
5:30 - 5:45	12					
5:45 - 6:00	18					
7:00 - 7.15	98	176	7.00 - 8.00	547	704	0.777
7:15 - 7:30	125					
7:30 - 7:45	148					
7:45 - 8:00	176					
8:00 - 8:15	196	206	8.00 - 9.00	788	824	0.956
8:15 - 8:30	192					
8:30 - 8:45	194					
8:45 - 9:00	206					
9:00 - 9:15	210	223	9.00 - 10.00	840	892	0.942
9:15 - 9:30	223					
9:30 - 9:45	211					
9:45 - 10;00	196					
10:00 - 10:15	201	208	10.00 - 11.00	809	832	0.972
10.15 - 10.30	198					
10.30 - 10.45	202					
10.45 - 11.00	208					
3.00 - 3.15	246	246	3.00 - 4.00	894	984	0.909
3.15 - 3.30	242					
3.30 - 3.45	200					
3.45 - 4.00	206					
4.00 - 4.15	200	218	4.00 - 5.00	808	872	0.927
4.15 - 4.30	218					
4.30 - 4.45	187					
4.45 - 5.00	203					
5.00 - 5.15	231	231	5.00 - 6.00	822	924	0.890
5.15 - 5.30	219					
5.30 - 5.45	164					
5.45 - 6.00	208					
6.00 - 6.15	251	251	6.00 - 700	924	1,004	0.920
6.15 - 6.30	222					
6.30 - 6.45	218					
6.45 - 7.00	233					

Date: Tuesday 14 June 2011 **Counted By:** Mohamed Marzok
Point No: Location 8-2
Name of Street: Street No. 9 in Al Mokatam, near to Ring Road
Direction: From Ring Road to Cairo

Time Per 15 Min	Volume per 15 min	Highest 15 Min	Time Per Hour	Volume per Hour	Flow Rate per Hour	PHF
5:00 - 5:15	18	45	5:00 - 6:00	107	180	0.594
5:15 - 5:30	16					
5:30 - 5:45	28					
5:45 - 6:00	45					
7:00 - 7.15	194	400	7.00 - 8.00	1,206	1,600	0.754
7:15 - 7:30	264					
7:30 - 7:45	348					
7:45 - 8:00	400					
8:00 - 8:15	428	459	8.00 - 9.00	1,727	1,836	0.941
8:15 - 8:30	402					
8:30 - 8:45	438					
8:45 - 9:00	459					
9:00 - 9:15	403	416	9.00 - 10.00	1,608	1,664	0.966
9:15 - 9:30	416					
9:30 - 9:45	390					
9:45 - 10;00	399					
10:00 - 10:15	358	383	10.00 - 11.00	1,451	1,532	0.947
10.15 - 10.30	369					
10.30 - 10.45	383					
10.45 - 11.00	341					
3.00 - 3.15	336	368	3.00 - 4.00	1,380	1,472	0.938
3.15 - 3.30	368					
3.30 - 3.45	352					
3.45 - 4.00	324					
4.00 - 4.15	382	390	4.00 - 5.00	1,442	1,560	0.924
4.15 - 4.30	390					
4.30 - 4.45	314					
4.45 - 5.00	356					
5.00 - 5.15	395	403	5.00 - 6.00	1,544	1,612	0.958
5.15 - 5.30	382					
5.30 - 5.45	364					
5.45 - 6.00	403					
6.00 - 6.15	381	400	6.00 - 700	1,527	1,600	0.954
6.15 - 6.30	400					
6.30 - 6.45	352					
6.45 - 7.00	394					

Date: Tuesday 14 June 2011 **Counted By:** Osama Radwan
Point No: Location 8-2
Name of Street: Street No. 9 in Al Mokatam, near to Ring Road
Direction: From Cairo to Ring Road

Time Per 15 Min	Volume per 15 min	Highest 15 Min	Time Per Hour	Volume per Hour	Flow Rate per Hour	PHF
5:00 - 5:15	7	29	5:00 - 6:00	66	116	0.569
5:15 - 5:30	14					
5:30 - 5:45	16					
5:45 - 6:00	29					
7:00 - 7.15	126	246	7.00 - 8.00	730	984	0.742
7:15 - 7:30	173					
7:30 - 7:45	185					
7:45 - 8:00	246					
8:00 - 8:15	285	306	8.00 - 9.00	1,151	1,224	0.940
8:15 - 8:30	290					
8:30 - 8:45	270					
8:45 - 9:00	306					
9:00 - 9:15	308	311	9.00 - 10.00	1,150	1,244	0.924
9:15 - 9:30	311					
9:30 - 9:45	277					
9:45 - 10;00	254					
10:00 - 10:15	264	336	10.00 - 11.00	1,196	1,344	0.890
10.15 - 10.30	275					
10.30 - 10.45	321					
10.45 - 11.00	336					
3.00 - 3.15	237	382	3.00 - 4.00	1,351	1,528	0.884
3.15 - 3.30	353					
3.30 - 3.45	379					
3.45 - 4.00	382					
4.00 - 4.15	366	366	4.00 - 5.00	1,382	1,464	0.944
4.15 - 4.30	351					
4.30 - 4.45	354					
4.45 - 5.00	311					
5.00 - 5.15	363	363	5.00 - 6.00	1,272	1,452	0.876
5.15 - 5.30	298					
5.30 - 5.45	309					
5.45 - 6.00	302					
6.00 - 6.15	340	359	6.00 - 700	1,406	1,436	0.979
6.15 - 6.30	359					
6.30 - 6.45	356					
6.45 - 7.00	351					

B.2 FLOATING CAR SURVEY SCHEDULE

Tables B.1 to B.3 below present the schedule of the FCS along the sample of routes including date, start and end times, and number of loops performed. It should be noted that since Routes 1, 2, 3 and 4 are operated for one-way traffic only, loops were repeated in the same direction and hence the so-called "return loops" do not apply.

Table B.1 FCS Schedule - AM

Route Description			Date	AM Period			
				Start Time	End Time	No. of Go Loops	No. of Return Loops
Route 1	One way	Tomanbey-Gasr El Suize	6-Jun	7:00	10:45	7	
Route 2	One way	El Kasr Al Aini-Nubar	7-Jun	7:00	10:37	5	
Route 3	One way	El Gomhoreya-Al Azhar	7-Jun	7:00	10:52	5	
Route 4	One way	El Giash-Ahmed Said	8-Jun	7:00	10:15	6	
Route 5	Two way	1.El Doqqi-Gameat El Qahera 2.Gameat El Qahera-El Doqqi	13-Jun	7:00	10:25	7	7
Route 6	Two way	1.El Malek Faisal (El Giza)-El Malek Faisal (El Haram) 2.El Malek Faisal (El Haram)-El Malek Faisal (El Giza)	13-Jun	7:00	10:59	5	5
Route 7	Two way	1.AbbasAkkad -akramAbiad 2.Makram Obaid-bbasAkkad	6-Jun	7:30	10:50	4	4
Route 8	Two way	1.Street No.9 (Salah Salem)-Street No. 9 (Ring Road) 2.Street No. 9 (Ring Road)-Street No.9 (Salah Salem)	8-Jun	7:00	10:48	6	6

Table B.2 FCS Schedule - PM

Route Description			Date	PM Period			
				Start Time	End Time	No. of Go Loops	No. of Return Loops
Route 1	One way	Tomanbey-Gasr El Suize	6-Jun	15:00	19:04	6	
Route 2	One way	El Kasr Al Aini-Nubar	7-Jun	15:10	18:49	5	
Route 3	One way	El Gomhoreya-Al Azhar	7-Jun	15:15	19:05	4	
Route 4	One way	El Giash-Ahmed Said	8-Jun	15:00	18:51	6	
Route 5	Two way	1.El Doqqi-Gameat El Qahera 2.Gameat El Qahera-El Doqqi	13-Jun	15:00	18:57	5	5
Route 6	Two way	1.El Malek Faisal (El Giza)-El Malek Faisal (El Haram) 2.El Malek Faisal (El Haram)-El Malek Faisal (El Giza)	13-Jun	15:00	18:59	3	3
Route 7	Two way	1.AbbasAkkad -MakramAbiad 2.Makram Obaid-AbbasAkkad	6-Jun	15:15	18:38	5	5
Route 8	Two way	1.Street No.9 (Salah Salem)-Street No. 9 (Ring Road) 2.Street No. 9 (Ring Road)-Street No.9 (Salah Salem)	8-Jun	15:00	19:01	6	6

Table B.3 FCS Schedule – Off-Peak

Route Description			Off-Peak Period			
			Start Time	End Time	No. of Go Loops	No. of Return Loops
Route 1	One way	Tomanbey-Gasr El Suize	5:30	5:37	1	
Route 2	One way	El Kasr Al Aini-Nubar	5:30	5:34	1	
Route 3	One way	El Gomhoreya-Al Azhar	5:50	5:56	1	
Route 4	One way	El Giash-Ahmed Said	5:25	5:29	1	
Route 5	Two way	1.El Doqqi-Gameat El Qahera 2.Gameat El Qahera-El Doqqi	5:50	6:04	1	1
Route 6	Two way	1.El Malek Faisal (El Giza)-El Malek Faisal (El Haram) 2.El Malek Faisal (El Haram)-El Malek Faisal (El Giza)	5:30	5:49	1	1
Route 7	Two way	1.AbbasAkkad –Makram Obaid 2.Makram Obaid-Abbas Akkad	5:10	5:35	1	1
Route 8	Two way	1.Street No.9 (Salah Salem)-Street No. 9 (Ring Road) 2.Street No. 9 (Ring Road)-Street No.9 (Salah Salem)	5:15	5:37	1	1

B.3 TRAFFIC VOLUMES ON MAJOR CORRIDORS

The following table indicates the traffic volumes on the main corridors in GCMA obtained from the following 2 sources:

- Traffic count survey conducted in July 2010 (Cairo Congestion Study Phase 1); and
- Traffic volumes as per JICA study dated 2005, projected to the year 2010.

The differences on some corridors are significant (Table B.4). The low volumes obtained during the CCS survey could be attributed to the summer period.

Table B.4 Differences in Traffic Volumes Based on Count Source

Corridor	Traffic count site	Direction	Total volume during peak hours (CCS traffic counts - July 2010)	Traffic count site	Direction	JICA study traffic flow (2010)	Difference (A)-(B)
1	P9	1	52,381	15 th May Bridge	1	43,920	8,461
		2	41,402		2	65,765	(24,363)
2	P1	1	25,070	Warraq Bridge	1	21,978	3,092
		2	24,787		2	16,755	8,032
3	P4	1	59,160	Moneeb Bridge	1	68,976	(9,816)
		2	65,283		2	95,255	(29,972)
4	P14	1	23,980	Kablat St.	1	8,255	15,725
		2	29,058		2	6,401	22,657
5	P7	1	22,036	Imbaba Bridge	1	6,177	15,859
		2	20,522		2	9,501	11,021
6	P13	1	30,582	Autostrade	1	10,128	20,454
		2	32,216		2	12,838	19,378
7	P8	1	13,108	Nasr Rd	1	89,004	(75,896)
		2	17,942		2	69,382	(51,440)
8	P11	1	34,684	6 October Bridge	1	140,548	(105,864)
		2	32,814		2	120,570	(87,756)
9	P2	1	44,957	Ismailia Desert Rd.	1	25,231	19,726
		2	22,349		2	29,762	(7,413)
10	P10	1	5,024	Alex. Agr. Rd	1	39,369	(34,345)
		2	4,891		2	31,464	(26,573)
11	P3	1	28,190	Suez Desert Rd.	1	17,530	10,660
		2	15,594		2	16,655	(1,061)

Another reason to consider JICA traffic volumes in the cost estimation is that they are based on manual classified traffic counts conducted on all corridors, while the CCS traffic survey includes manual classified counts on 2 corridors only (Salah Salem Street and Suez Desert Road).

B.4 TEMPORAL DISTRIBUTION OF TRAFFIC VOLUMES

Figure B.1 Traffic Volumes on Route 1 –Location L1-1

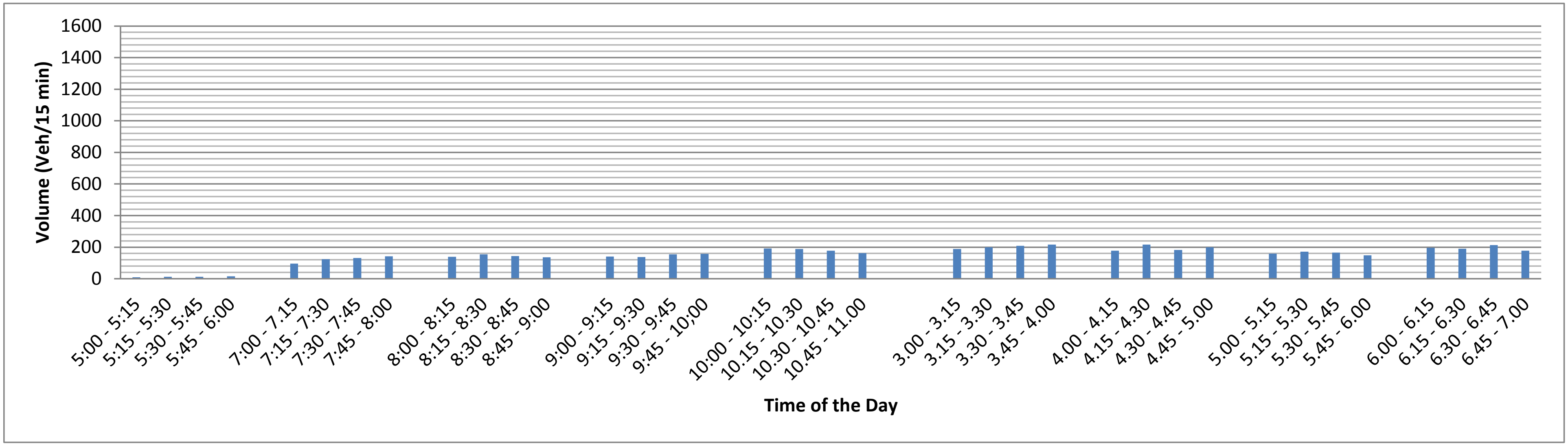


Figure B.2 Traffic Volumes on Route 1 –Location L1-2

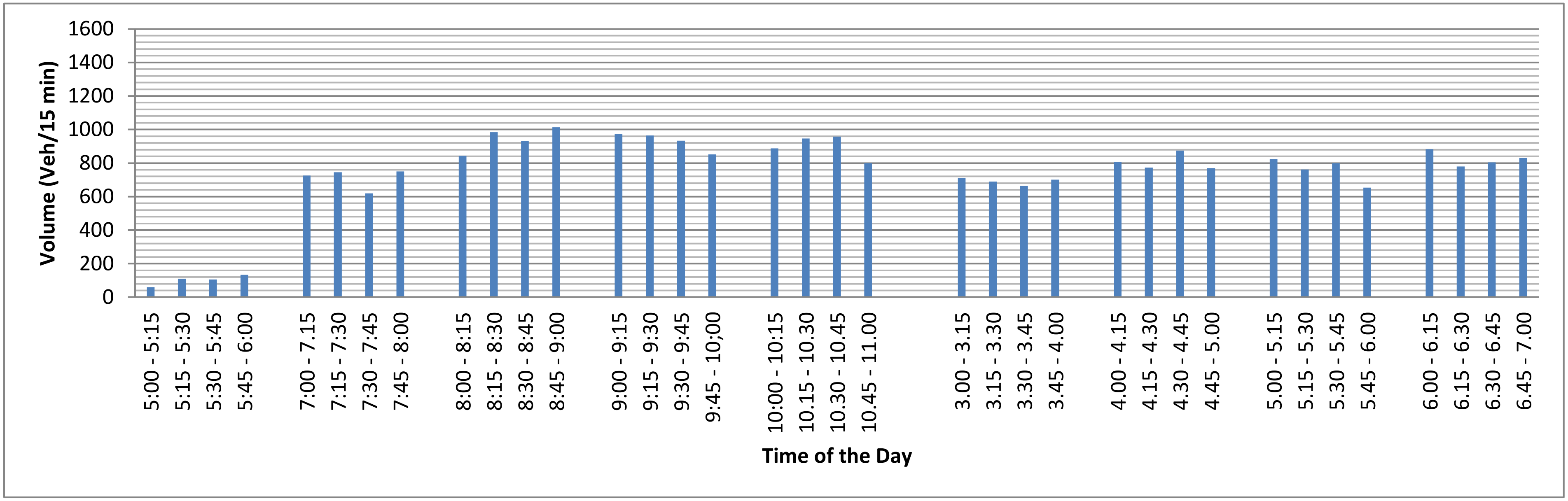


Figure B.3 Traffic Volumes on Route 2 –Location L2-1

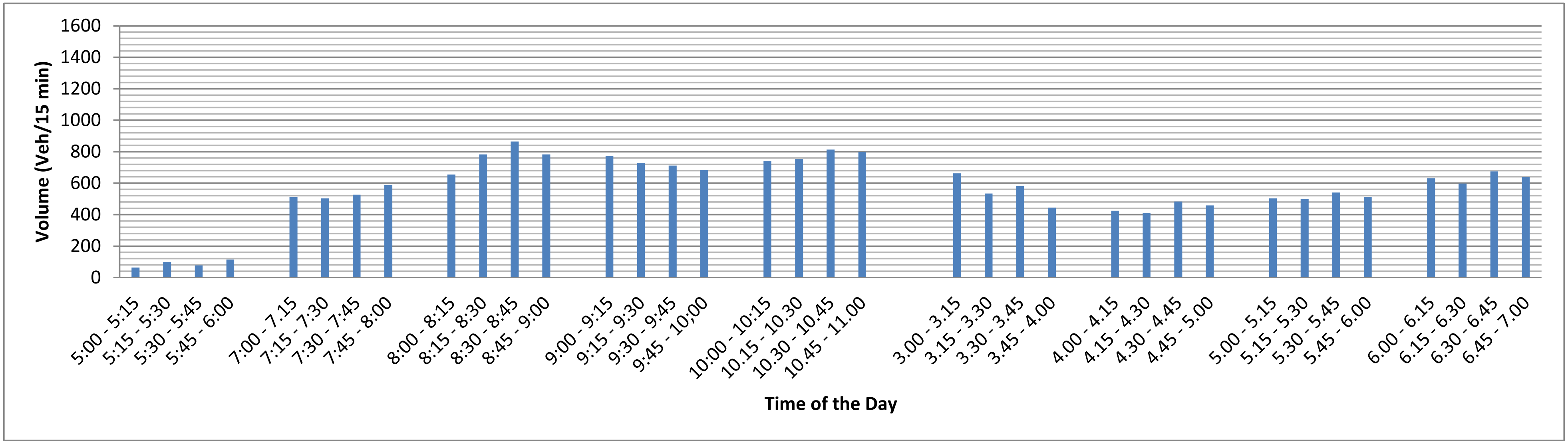


Figure B.4 Traffic Volumes on Route 2 –Location L2-2

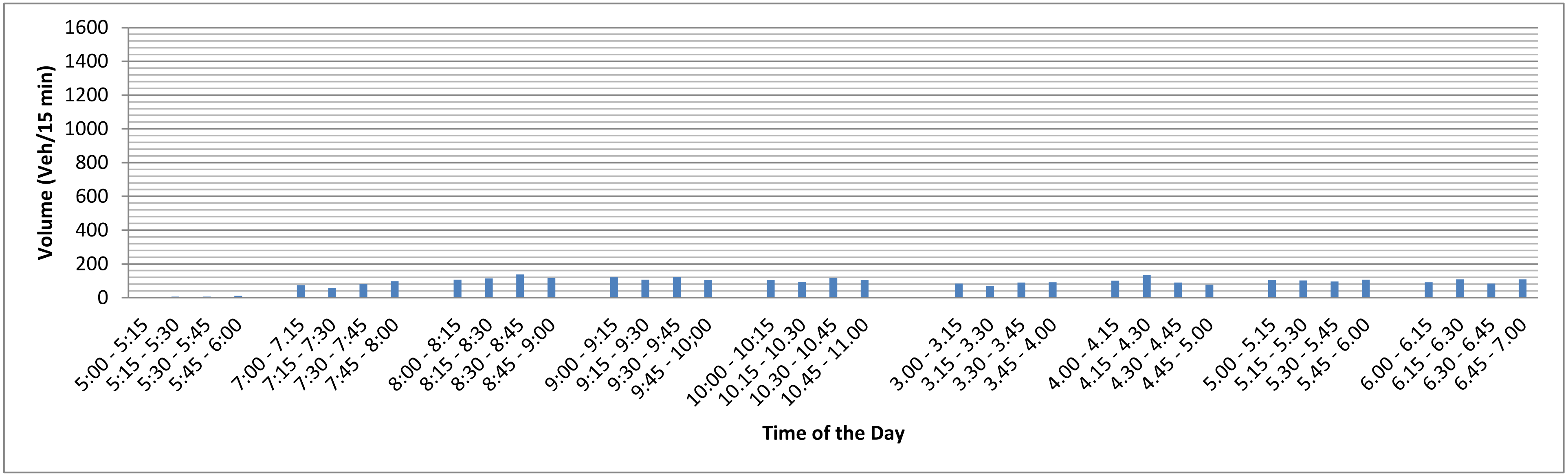


Figure B.5 Traffic Volumes on Route 3 –Location L3-1

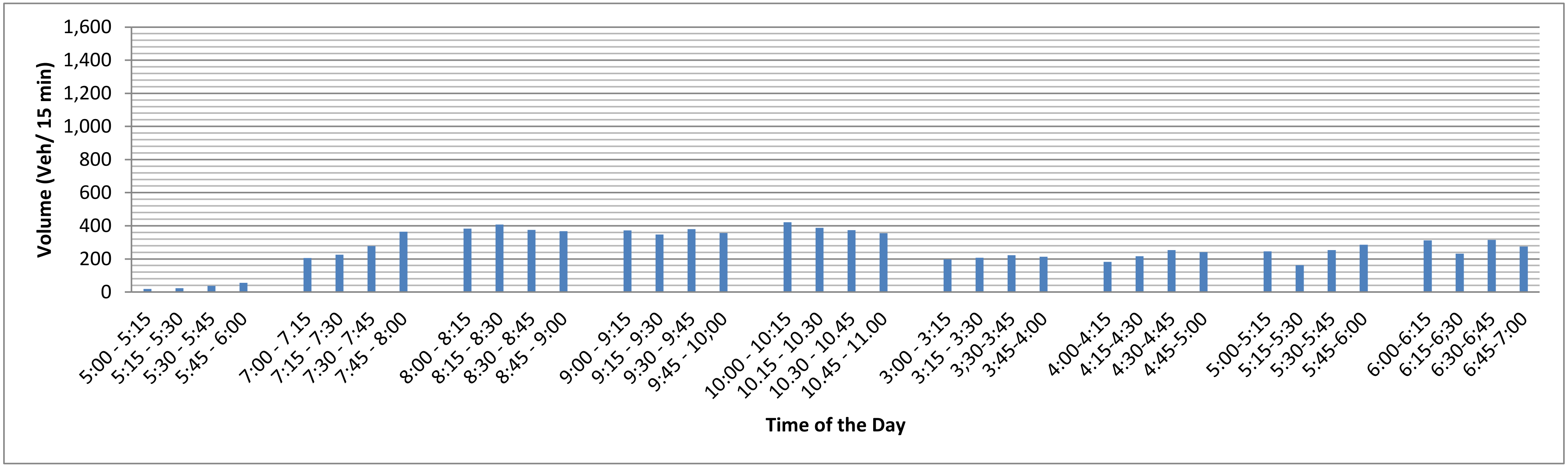


Figure B.6 Traffic Volumes on Route 3 –Location L3-2

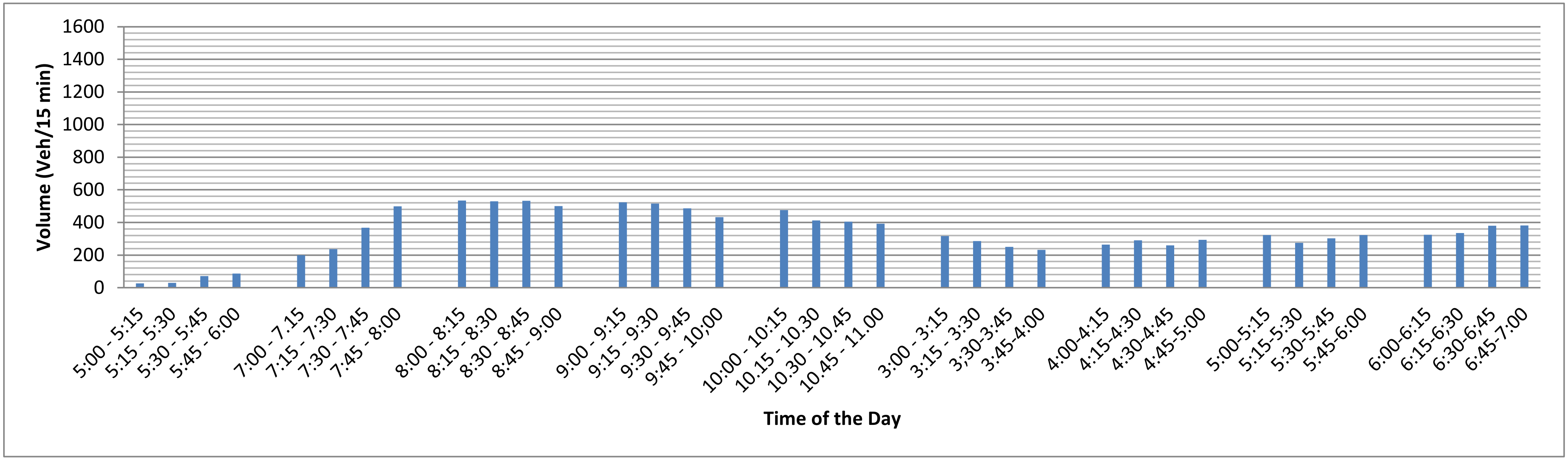


Figure B.7 Traffic Volumes on Route 4 –Location L4-1

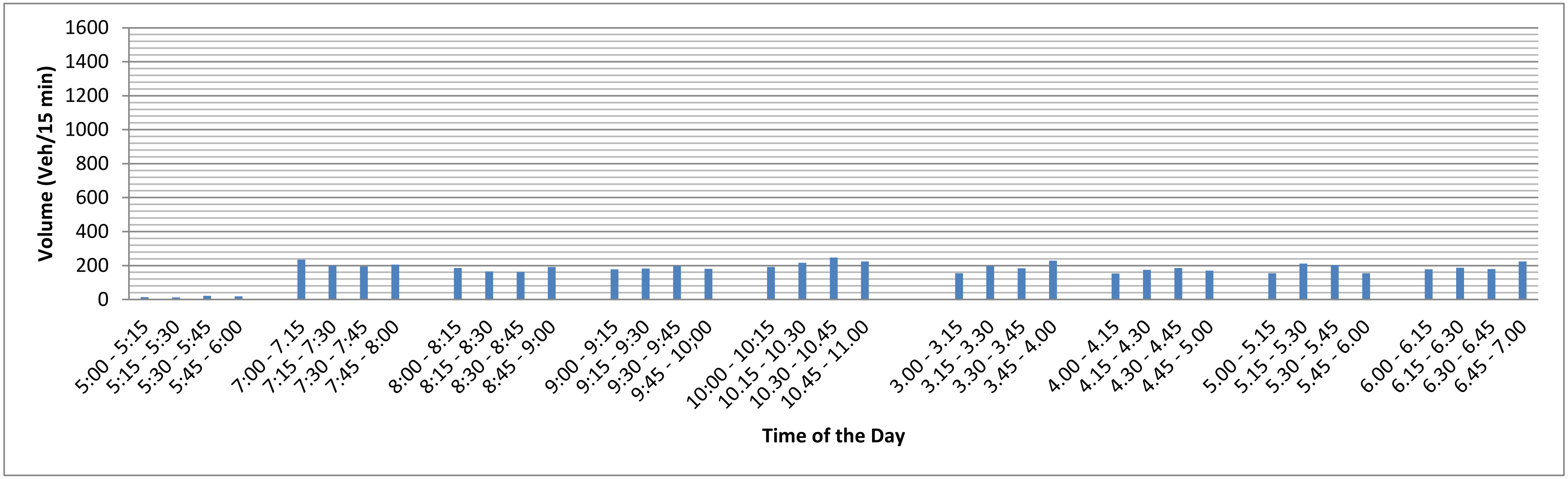


Figure B.8 Traffic Volumes on Route 4 –Location L4-2

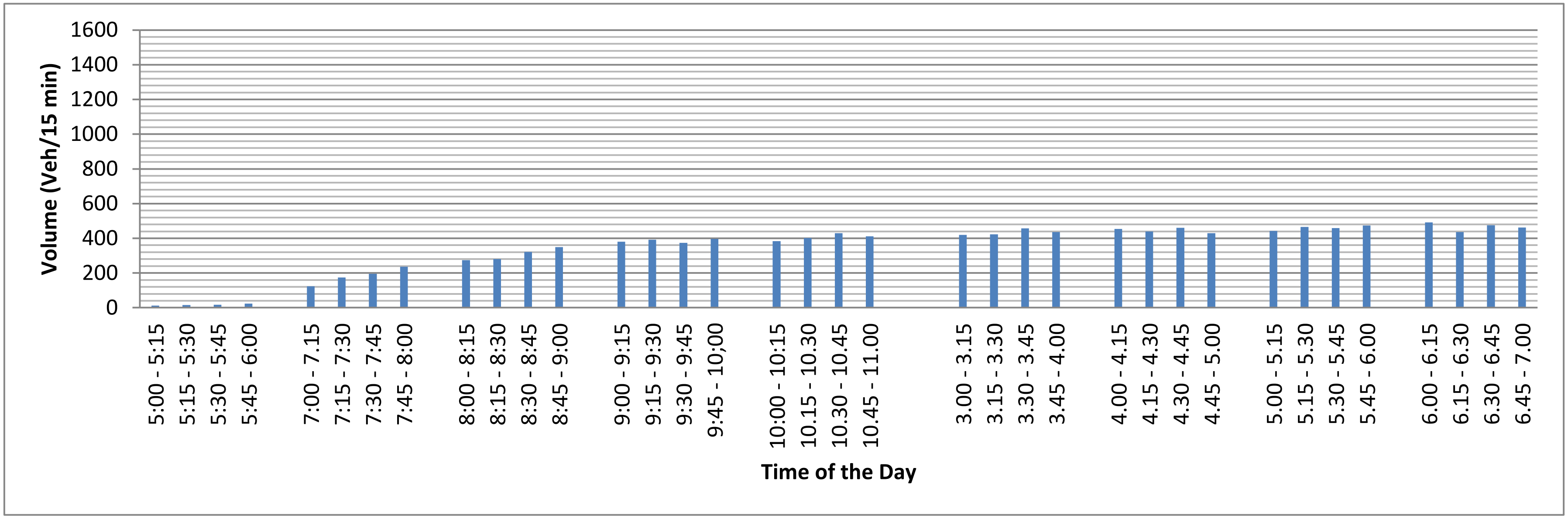


Figure B.9 Traffic Volumes on Route 5 –Location L5-1- Direction 1 (From Giza to Doqqi)

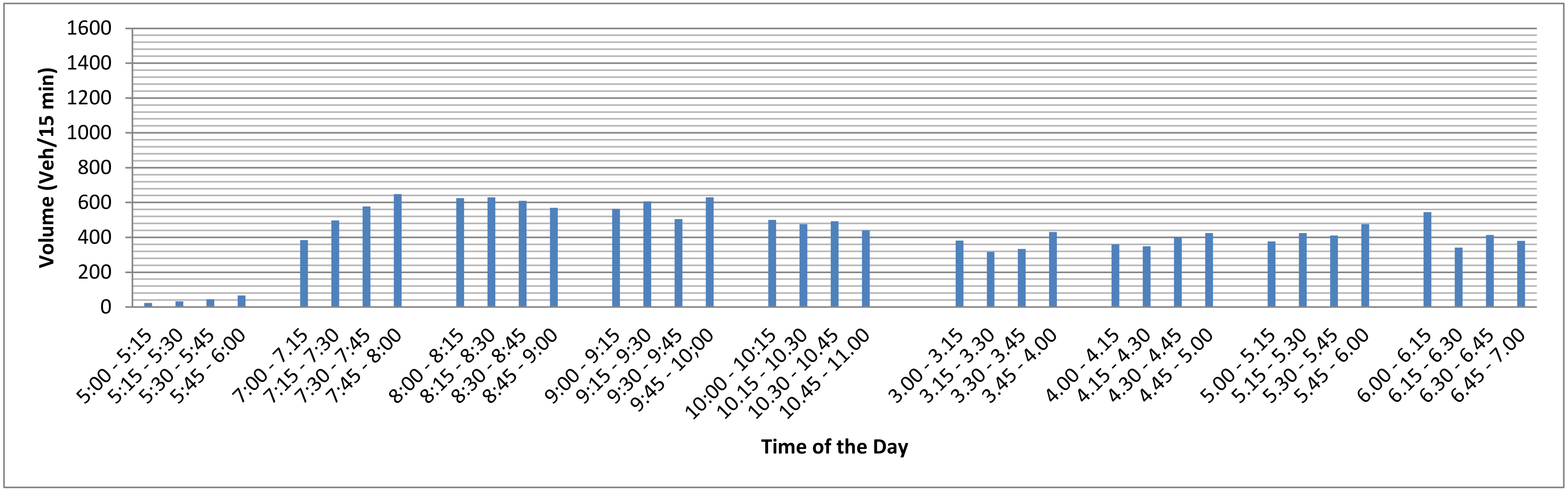


Figure B.10 Traffic Volumes on Route 5 –Location L5-1- Direction 2 (From Doqqi to Giza)

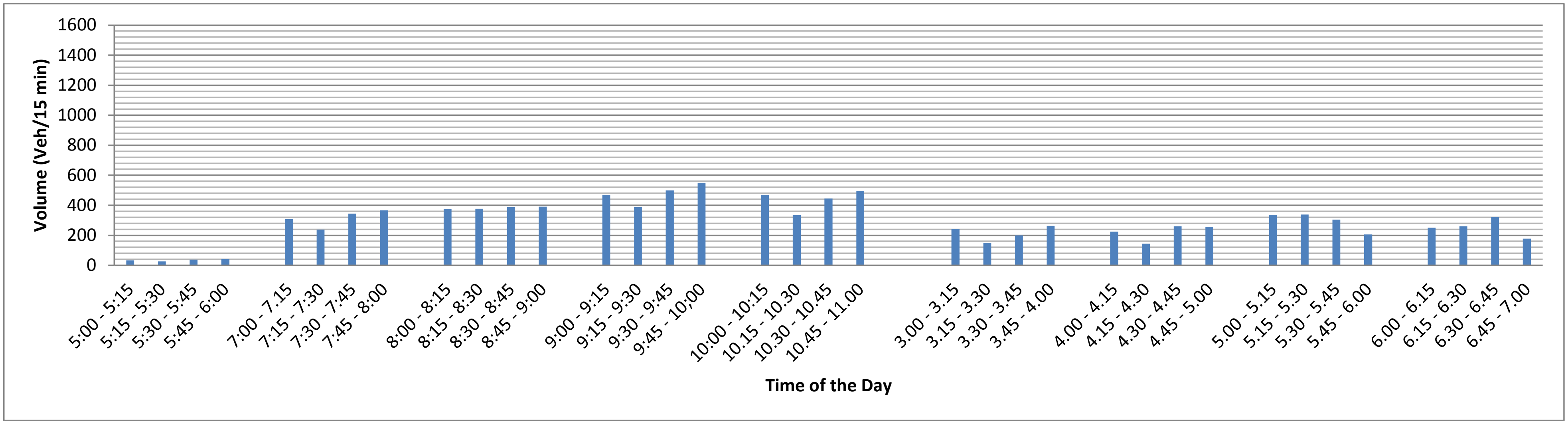


Figure B.11 Traffic Volumes on Route 5 –Location L5-2- Direction 1 (From Doqqi to Giza)

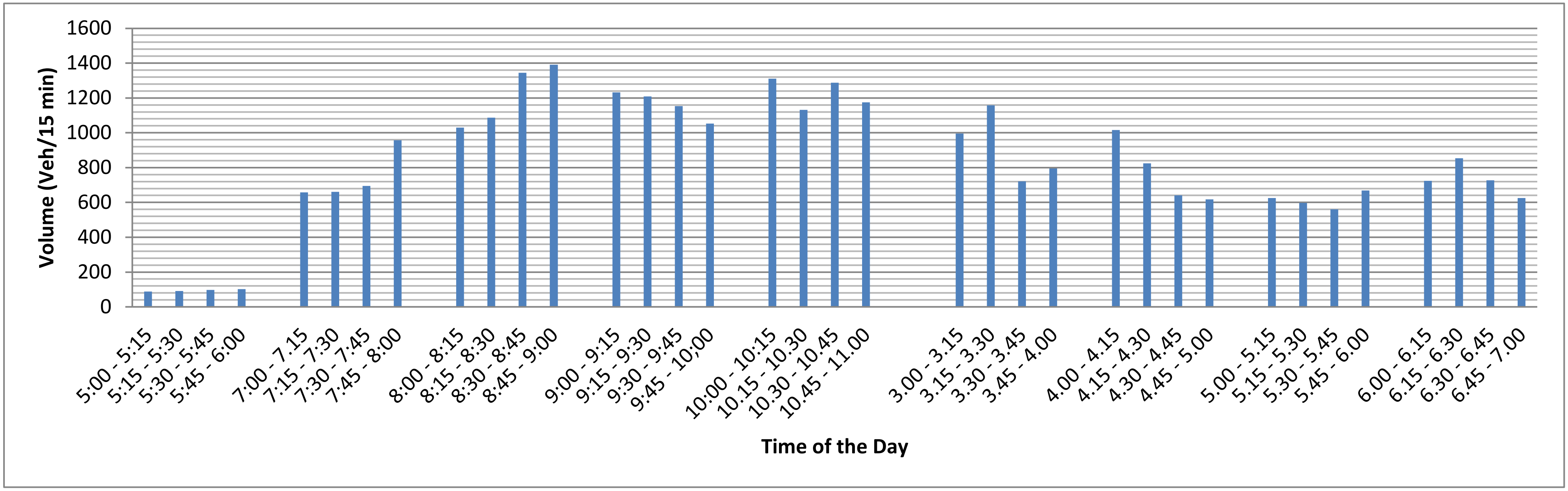


Figure B.12 Traffic Volumes on Route 5 –Location L5-2- Direction 2 (From Giza to Doqqi)

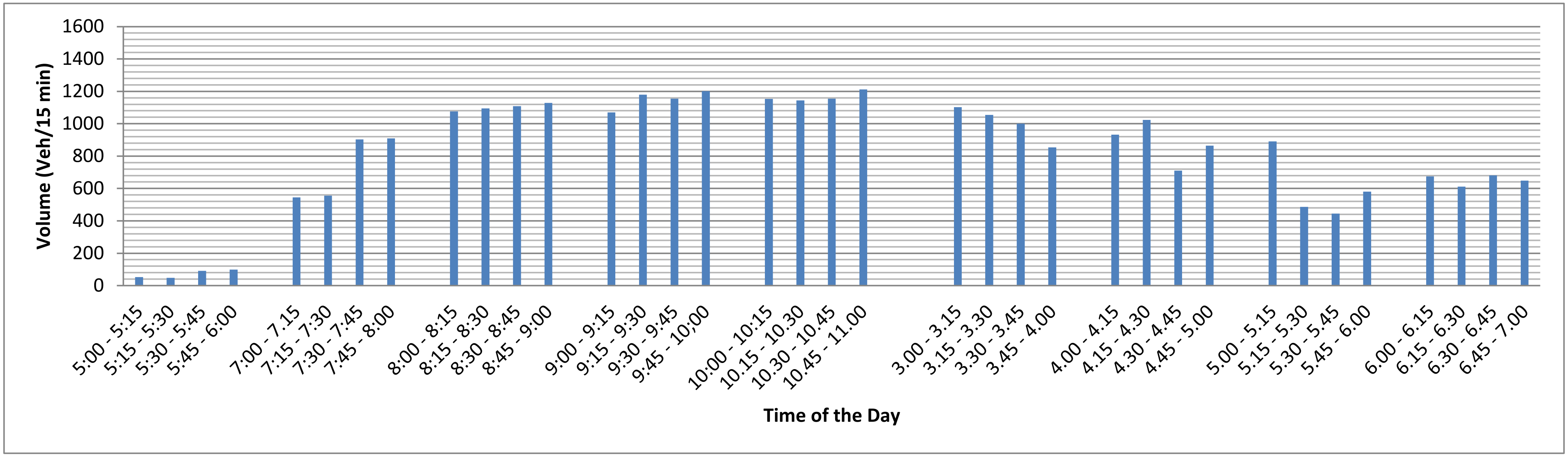


Figure B.13 Traffic Volumes on Route 6 –Location L6-1- Direction 1 (From Giza to Pyramid)

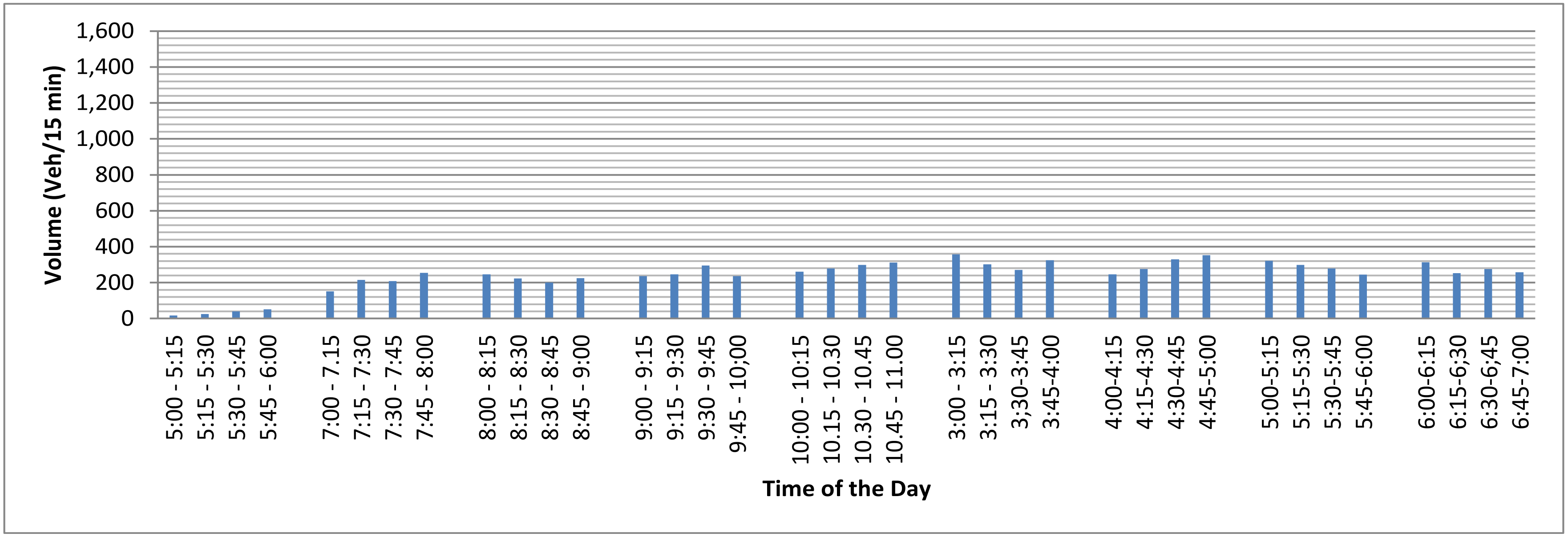


Figure B.14 Traffic Volumes on Route 6 –Location L6-1- Direction 2 (From Pyramid to Giza)

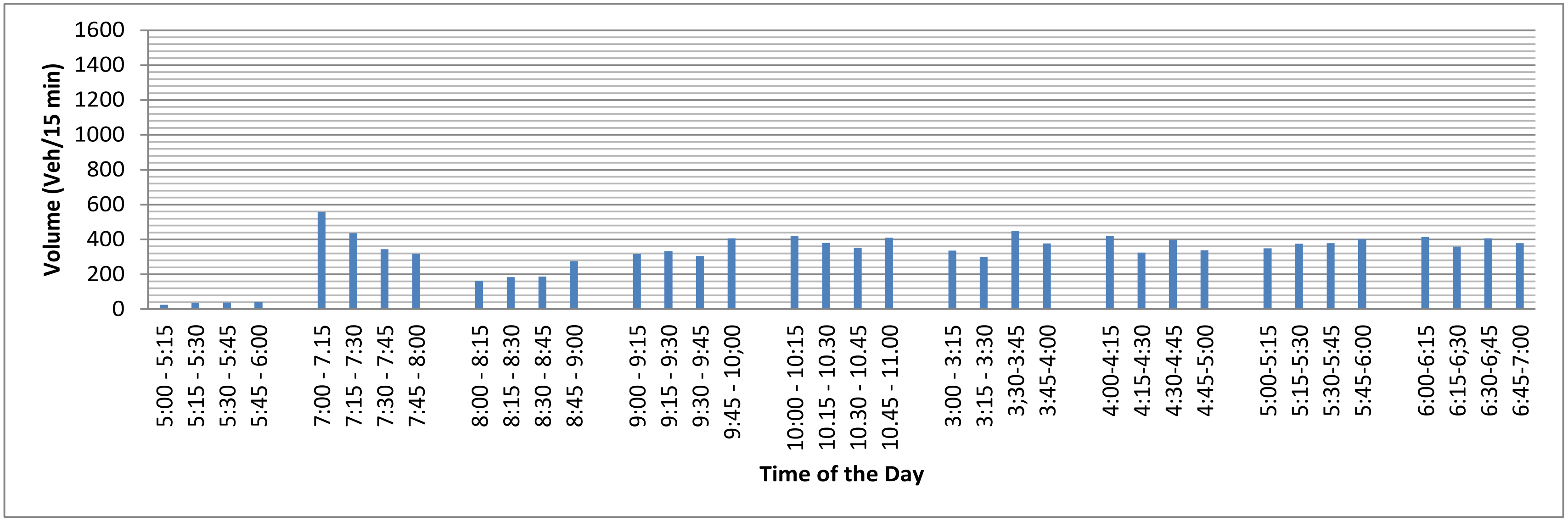


Figure B.15 Traffic Volumes on Route 6 –Location L6-2- Direction 1 (From Pyramid to Giza)

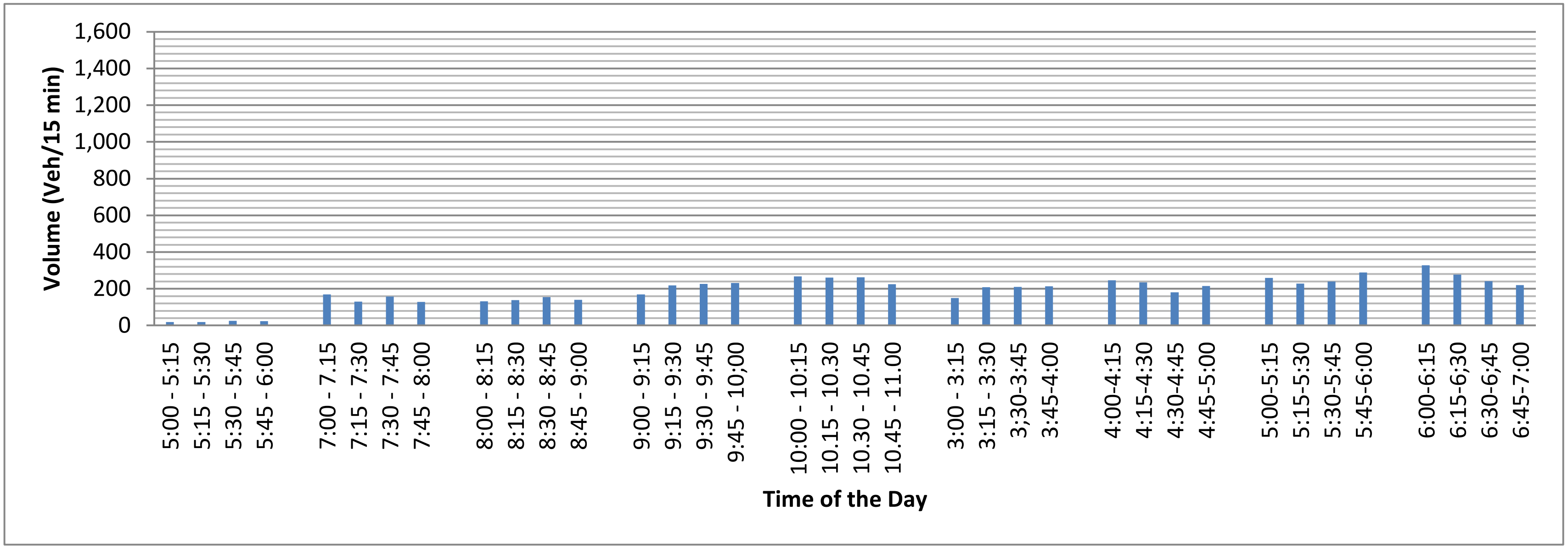


Figure B.16 Traffic Volumes on Route 6 –Location L6-2- Direction 2 (From Giza to Pyramid)

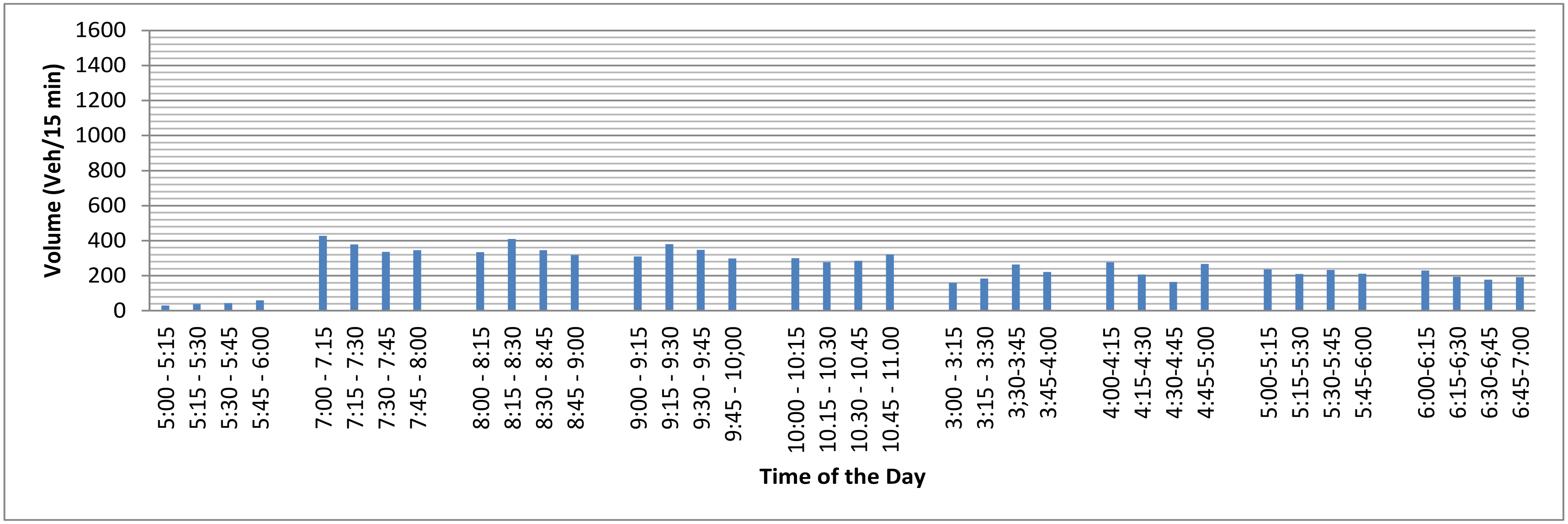


Figure B.17 Traffic Volumes on Route 7 –Location L7-1- Direction 1 (From El Nasr Road to Mostafa El Nahas Road)

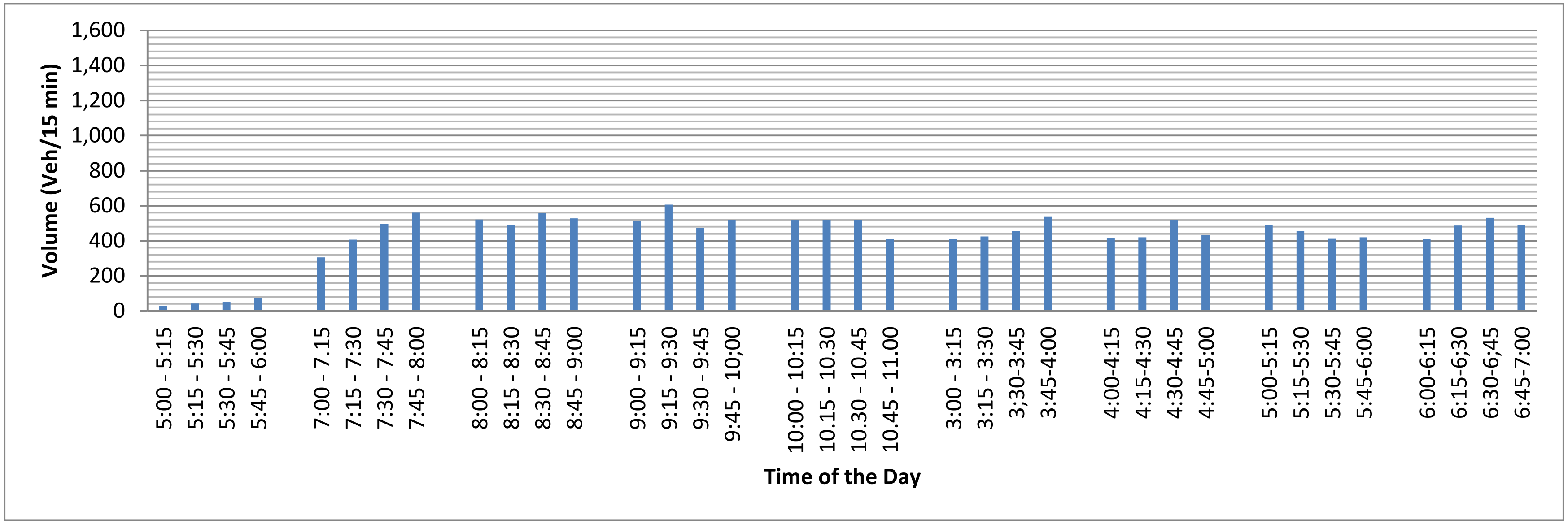


Figure B.18 Traffic Volumes on Route 7 –Location L7-1- Direction 2 (From Mostafa El Nahas Road to El Nasr Road)

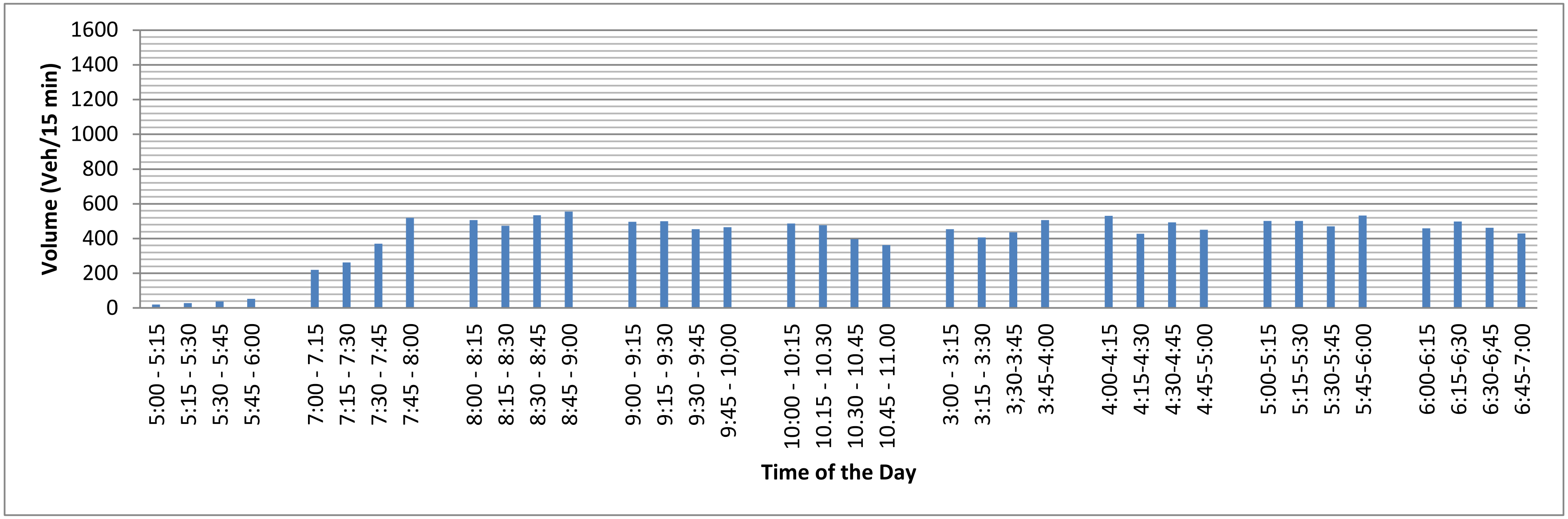


Figure B.19 Traffic Volumes on Route 7 –Location L7-2- Direction 1 (From El Nasr Road to Mostafa El Nahas Road)

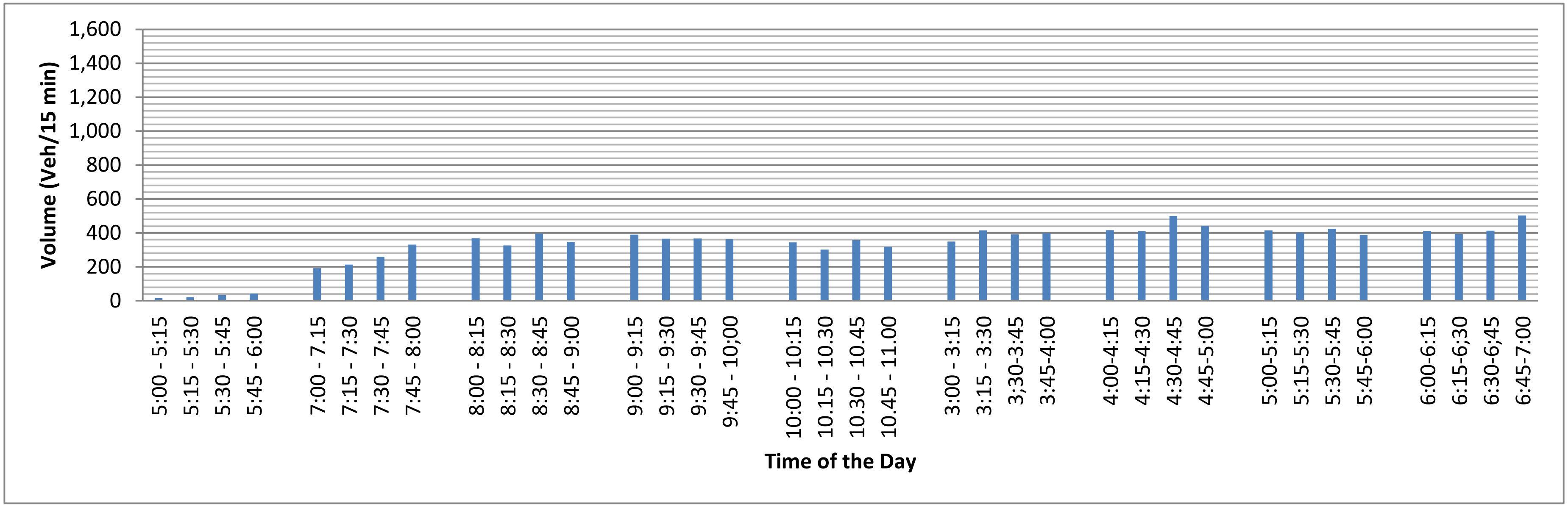


Figure B.20 Traffic Volumes on Route 7 –Location L7-2- Direction 2 (From Mostafa El Nahas Road to El Nasr Road)

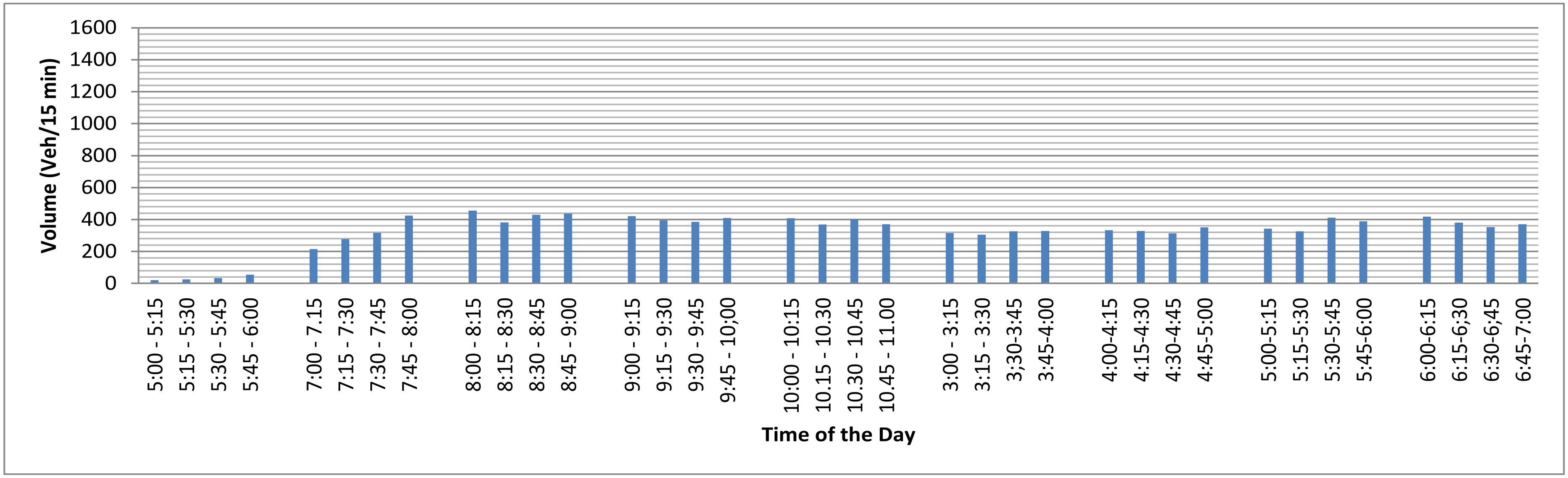


Figure B.21 Traffic Volumes on Route 8 –Location L8-1- Direction 1 (From Ring Road to Central Cairo)

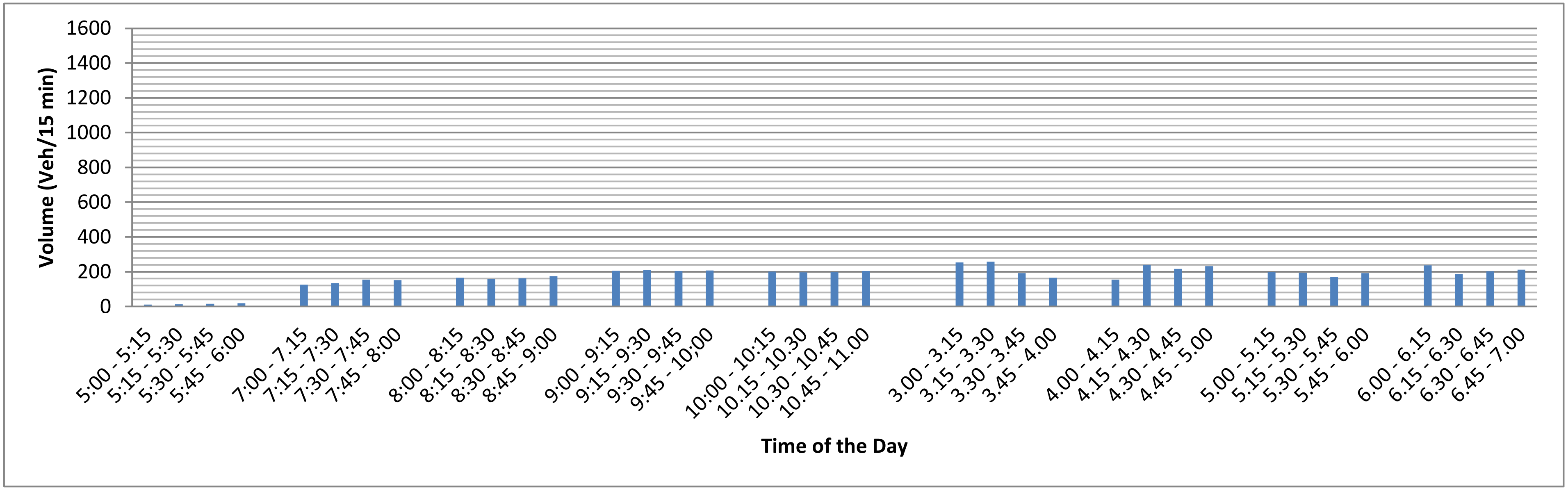


Figure B.22 Traffic Volumes on Route 8 –Location L8-1- Direction 2 (From Central Cairo to Ring Road)

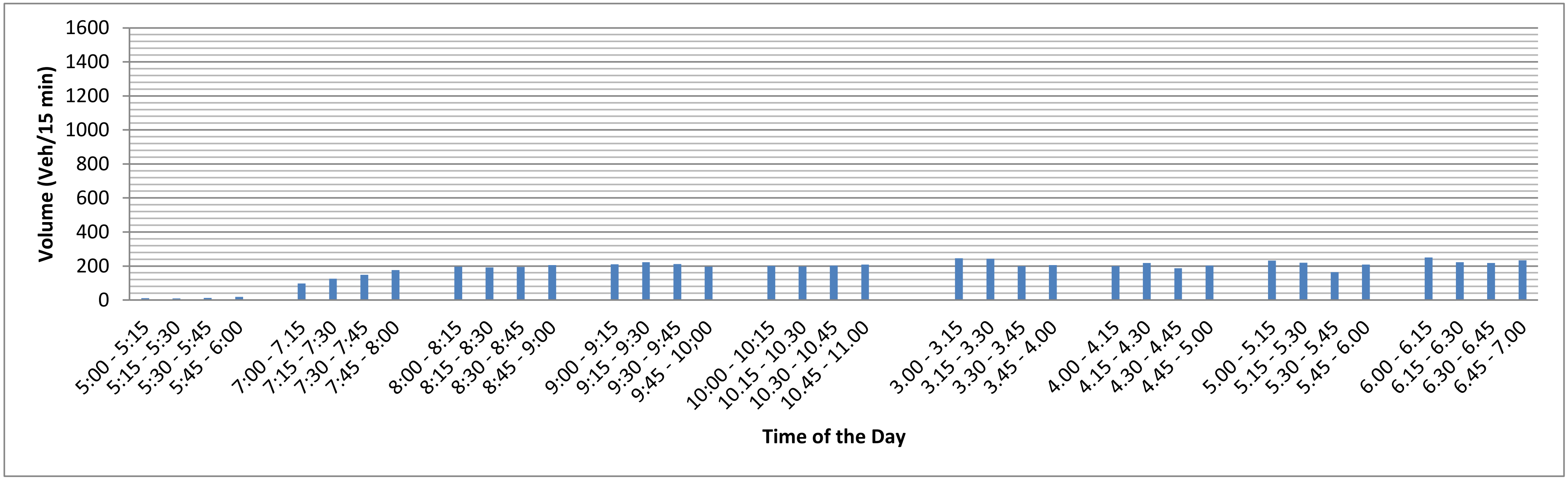


Figure B.23 Traffic Volumes on Route 8 –Location L8-2- Direction 1 (From Ring Road to Central Cairo)

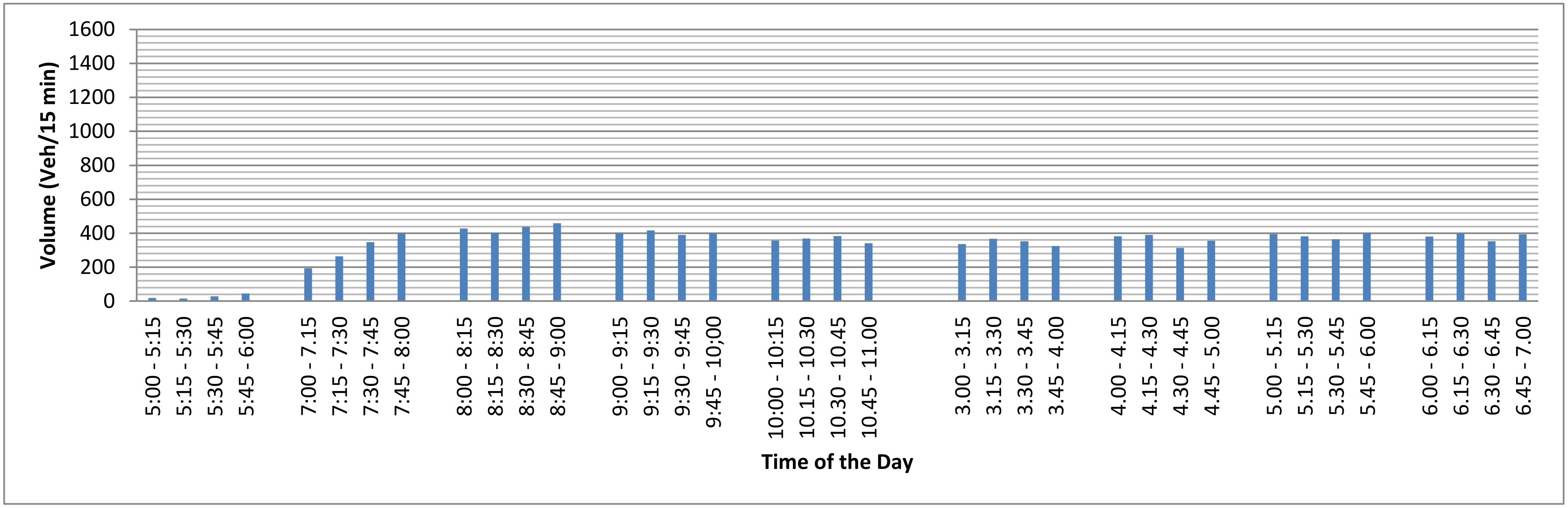
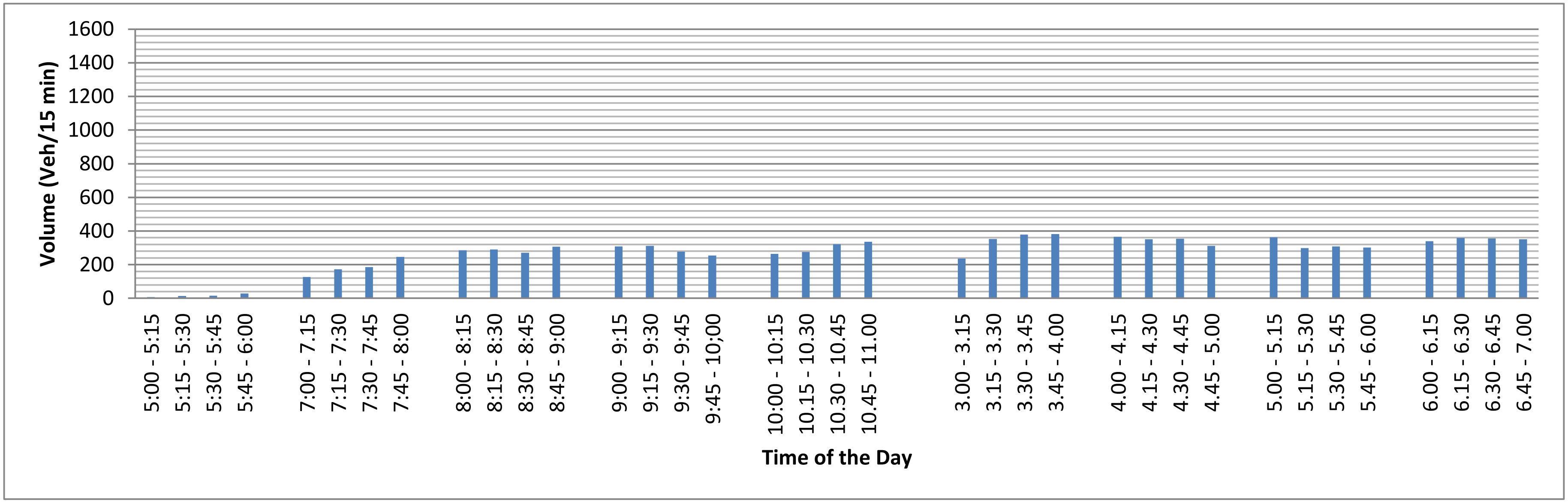


Figure B.24 Traffic Volumes on Route 8 –Location L8-2- Direction 2 (From Central Cairo to Ring Road)



B.5 ESTIMATION PROCEDURES FOR SPEEDS AND BUFFER INDEX

Route Average Speed Estimation Procedure

This procedure is used to calculate the average speed and the coefficient of variation (of speeds) per hour per peak period per direction per route given floating-car data for a given day for 2 peak periods consisting of 5 minute intervals of distance measurements which are truncated at the time the driver reaches the end of the route.

The aggregation procedures chosen will treat a given hour as a sample space. Since there is only one particular date on which measurement is made, we consider this a rough estimate. Since the distance measurements are recorded over varying intervals of time, it is best to apply a weighted aggregation procedure.

The following is the explicit formulation of the solution:

If $d_1, d_2, \dots, d_n$ are all the recorded marginal distances for a particular hour, and $t_1, t_2, \dots, t_n$ are the corresponding times then an estimation for average speed during that hour is given by Eq. 1:

$$\bar{v} = \frac{d_1 + d_2 + \cdots + d_n}{t_1 + t_2 + \cdots + t_n} \quad (1)$$

Because of the sampling in non-uniform intervals of time $t_i \neq t_j$ for some $1 \leq i, j \leq n$. Therefore, Eq. 1 can be written in the following form (as a weighted average of speeds):

$$\bar{v} = \sum_{i=1}^{n} w_i v_i \quad (2)$$

Where

$$w_i = \frac{t_i}{\sum_1^n t_i} \qquad \text{and} \qquad v_i = \frac{d_i}{t_i}$$

This facilitates the calculation of the coefficient of variation, where the standard deviation is taken from the sample data.

Then the coefficient of variation can be written:

$$c_{\bar{v}} = \frac{\sqrt{\widehat{\sigma^2}_w}}{\bar{v}}$$

where $\widehat{\sigma^2}_w$ is the unbiased estimator of the weighted variance of the speeds $\frac{d_i}{t_i}$. Which is given by the following formula, which reduces to the well-known unbiased estimator for the variance when $t_i = t_j$.

$$\widehat{\sigma^2}_w = \frac{1}{1 - V_1} \sum_{i=1}^{n} w_i (v_i - \bar{v})^2$$

Where

- $V_1 = \sum_{i=1}^{n} w_i^2$

-

-

Route Free Flow Speed Estimation Procedure

For local roads the free flow speed is determined by measuring the average speed during off-peak hours. In this case the measurement period is 5-6 AM.

Buffer Index Estimation Procedure

The buffer indices are determined by the following formula:

$$\text{BTI} = \frac{\text{95th percentile travel rate } \left(\frac{\text{hr}}{\text{km}}\right) - \text{ average travel rate } \left(\frac{\text{hr}}{\text{km}}\right)}{\text{average travel rate } \left(\frac{\text{hr}}{\text{km}}\right)}$$

12.0 APPENDIX C

Other Route Schematics and Aerial Photos, Time Space Diagrams, and Incidents

C.1 Route 1

Figure C.1 Route 1 Schematic

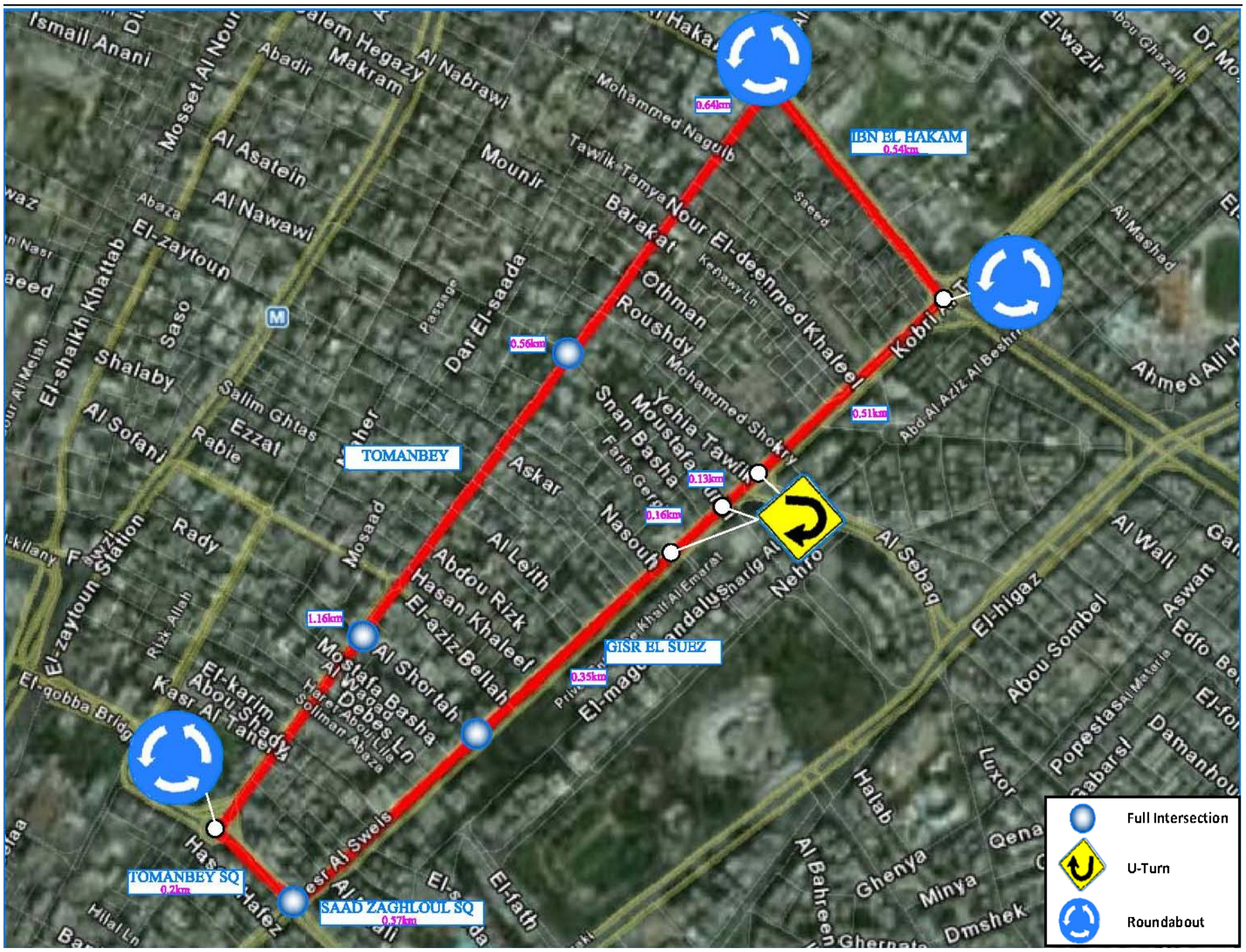


Figure C.2 Route 1, Start Point at Tomanbay St.

Figure C.3 Route 1, First Section

Figure C.4 Route 1, Intersection

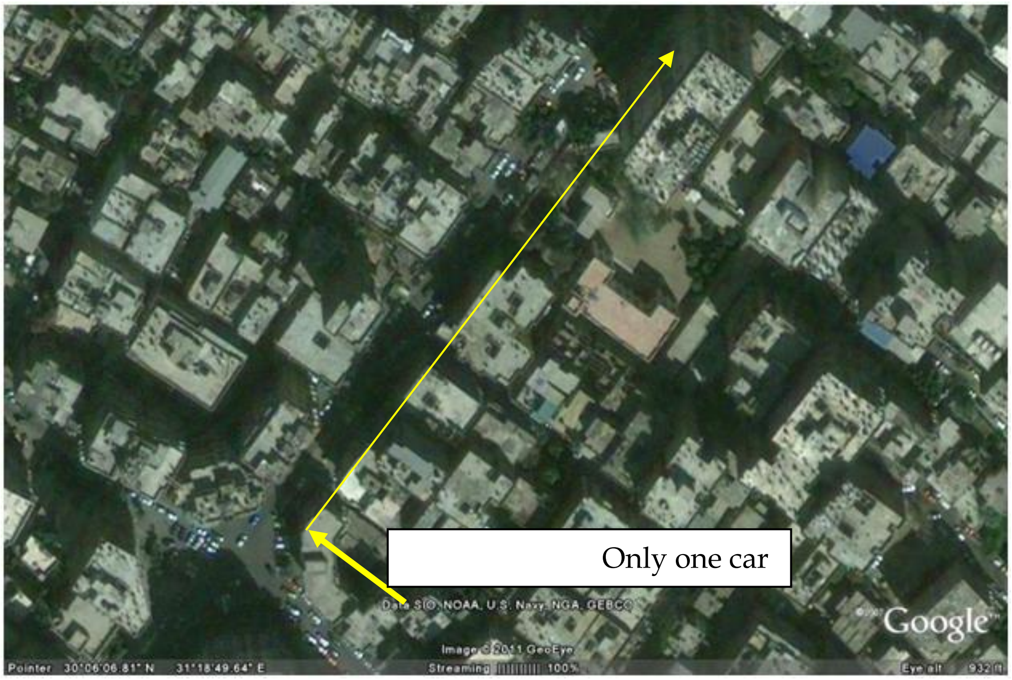


Figure C.5 Route 1, End of Tomanbay St.

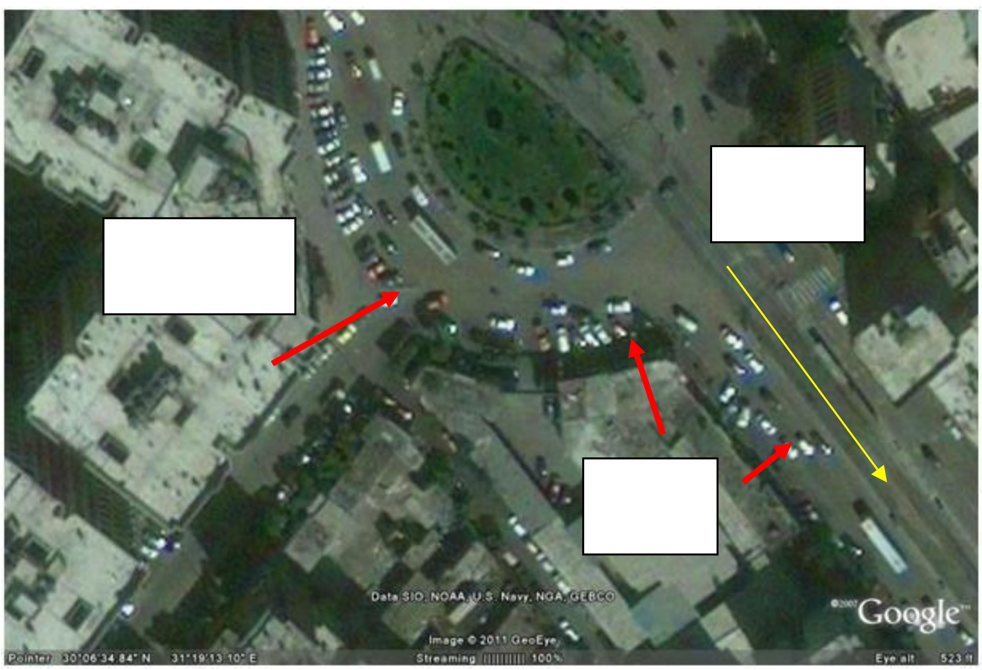


Figure C.6 Route 1, Gisr El Sueze St.

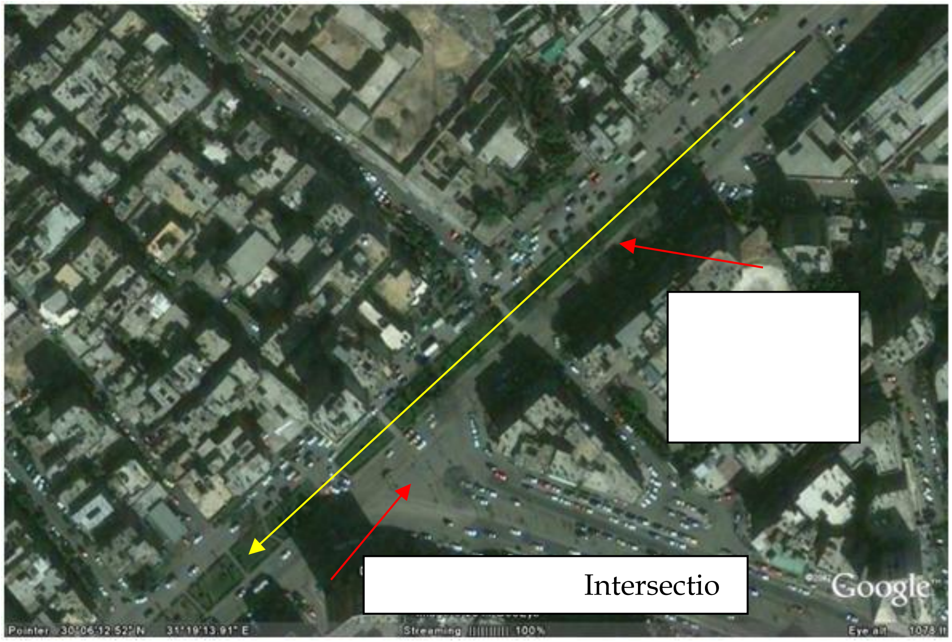


Figure C.7 Route 1, End of Gisr El Sueze St.

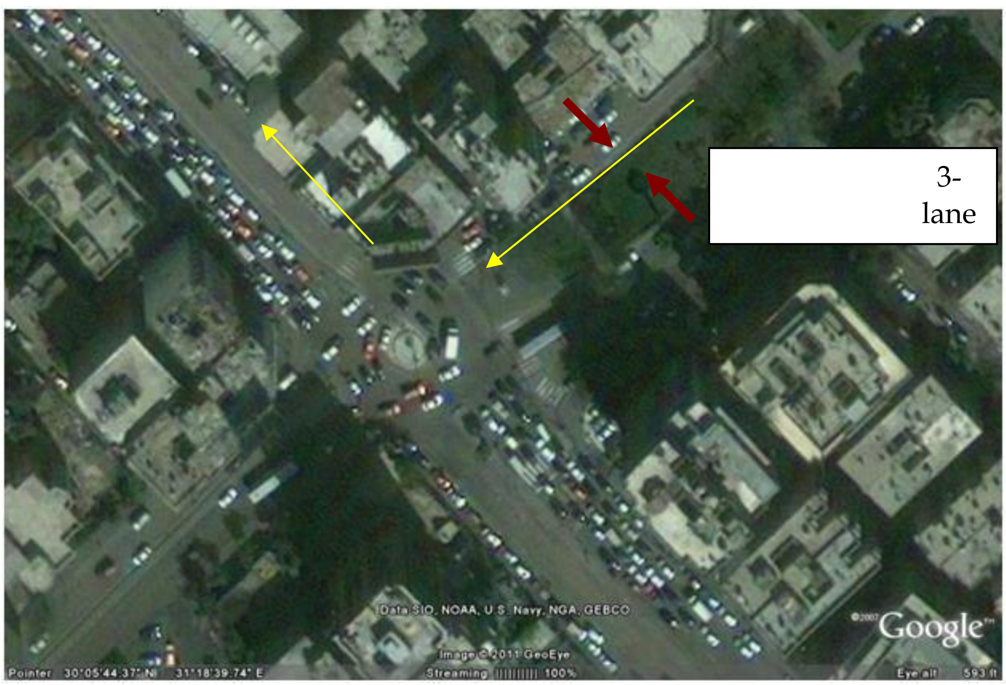


Figure C.8 Route 1, Time-Space Plot

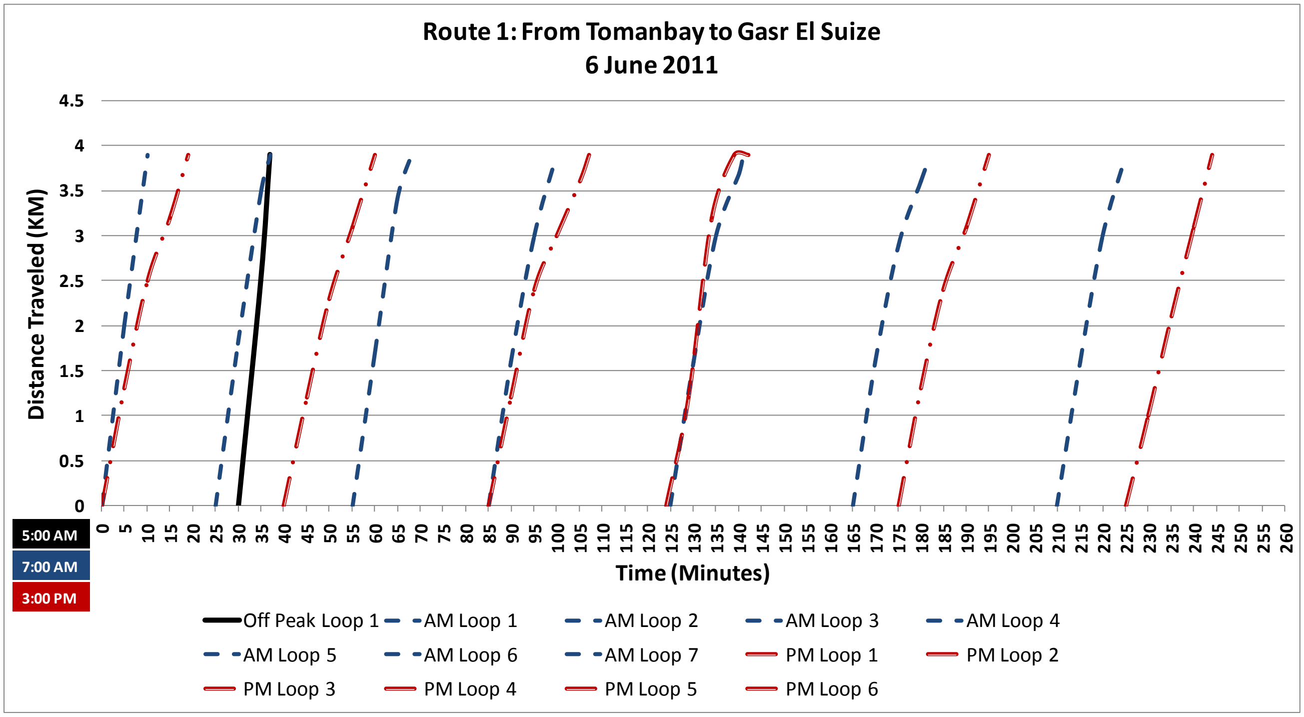


Table C.1 Route 1, Traffic Influencing Events During Survey Periods

Random Stops	16
Random Pedestrian Crossings	47
Intersections	48

C.2 ROUTE 2

Figure C.9 Route 2 Schematic

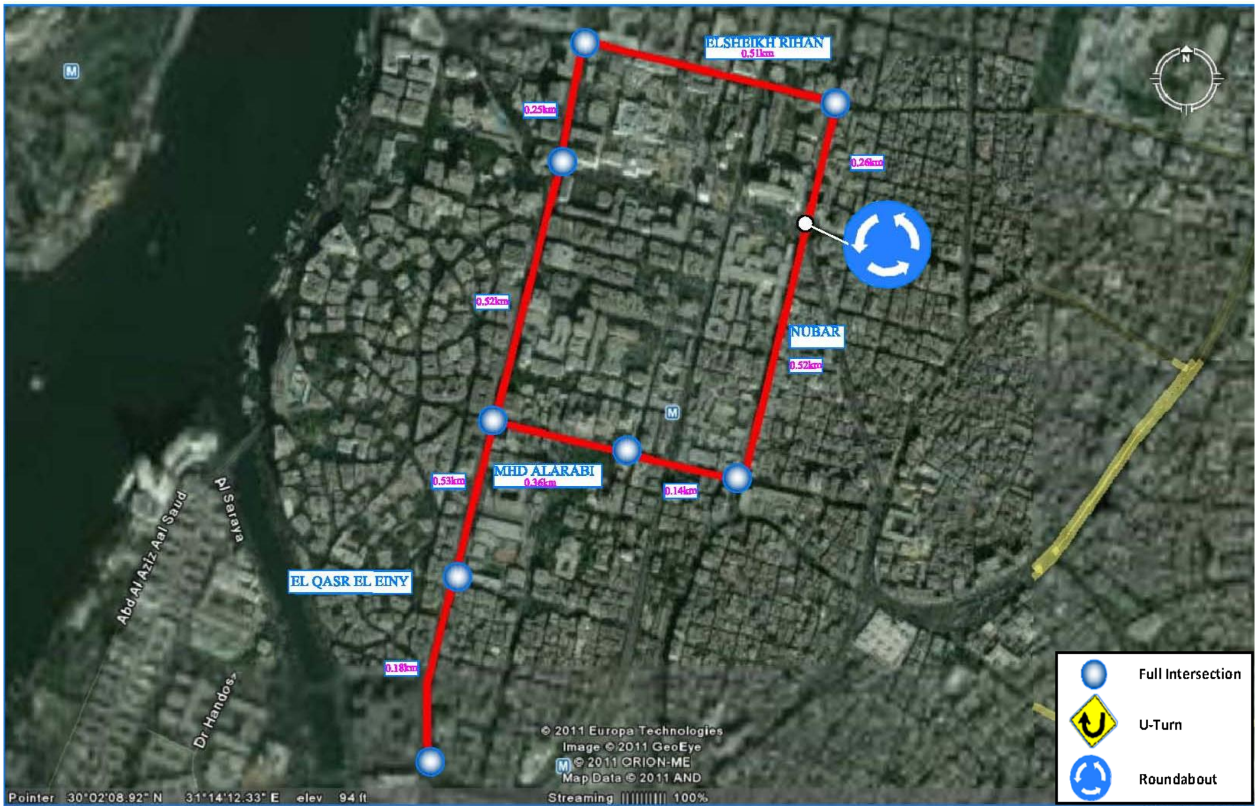


Figure C.10 Route 2, Start Point

Figure C.11 Route 2, El Kasr El Aini St.

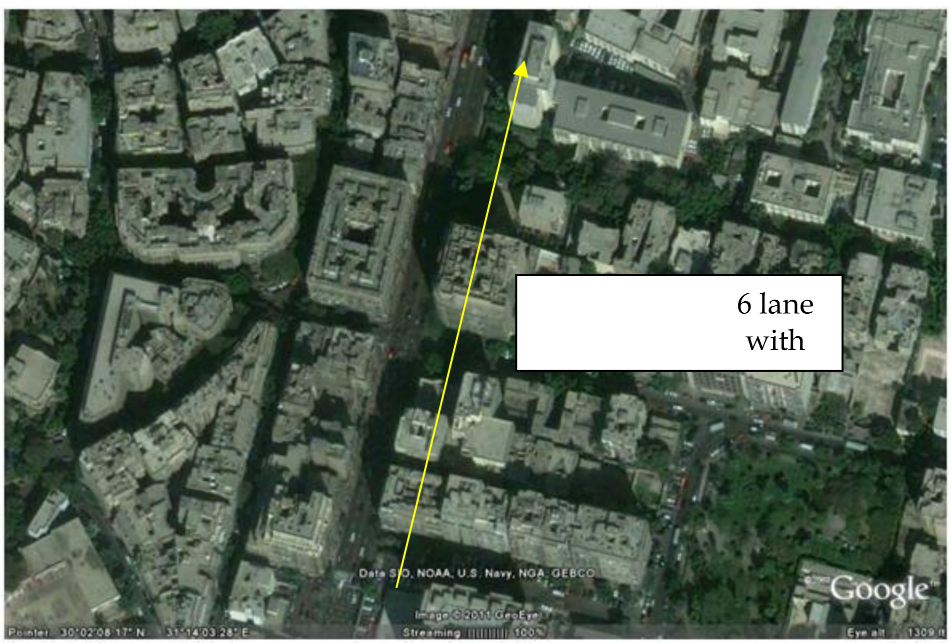


Figure C.12 Route 2, Rihan St.

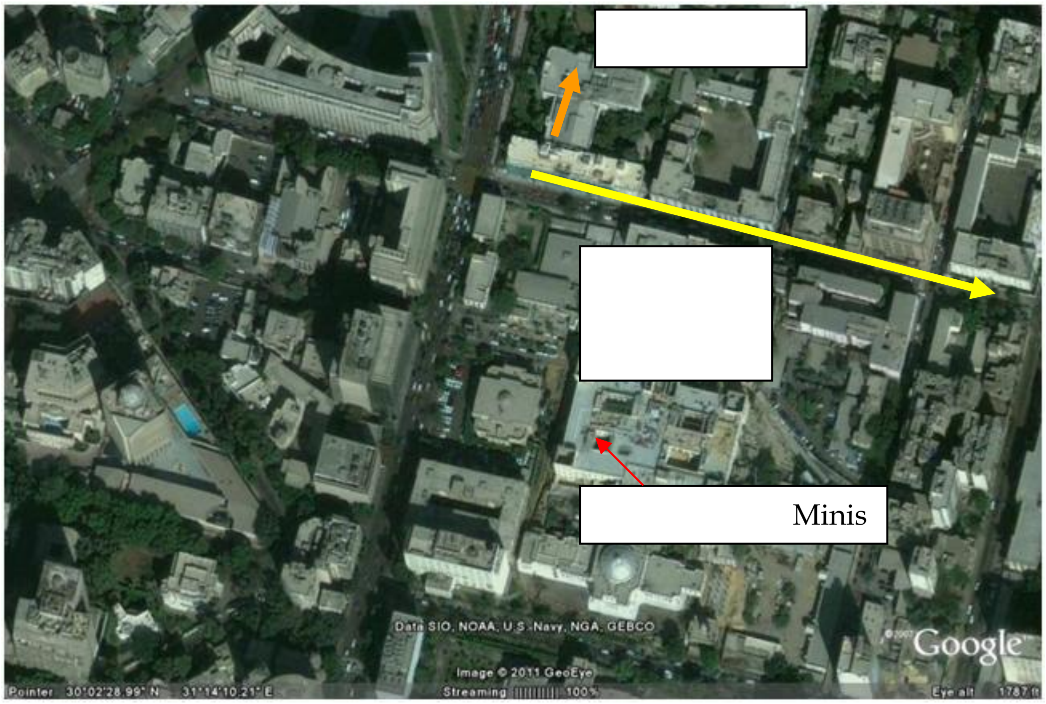


Figure C.13 Route 2, Nubar St.

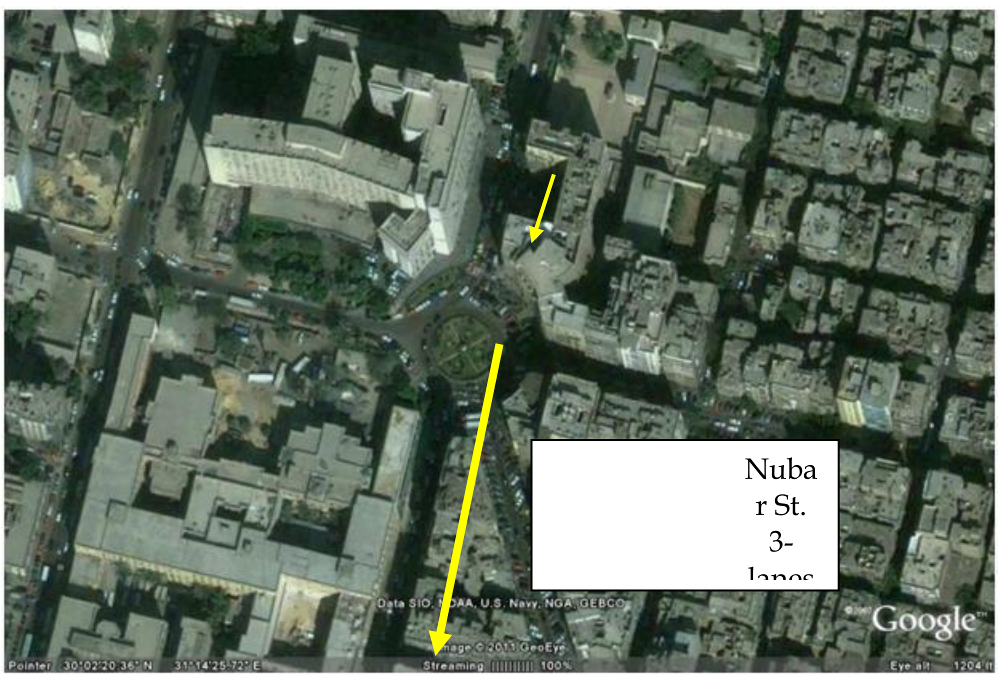


Figure C.14 Route 2, Nubar St.

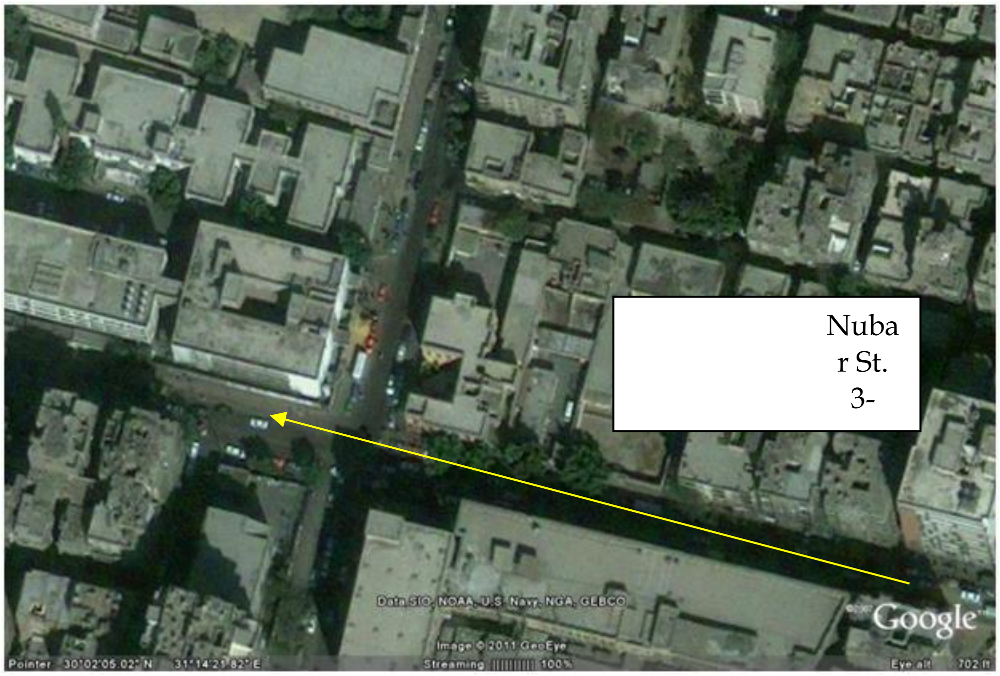


Figure C.15 Route 2, End Point

Figure C.16 Route 2, Time-Space Plot

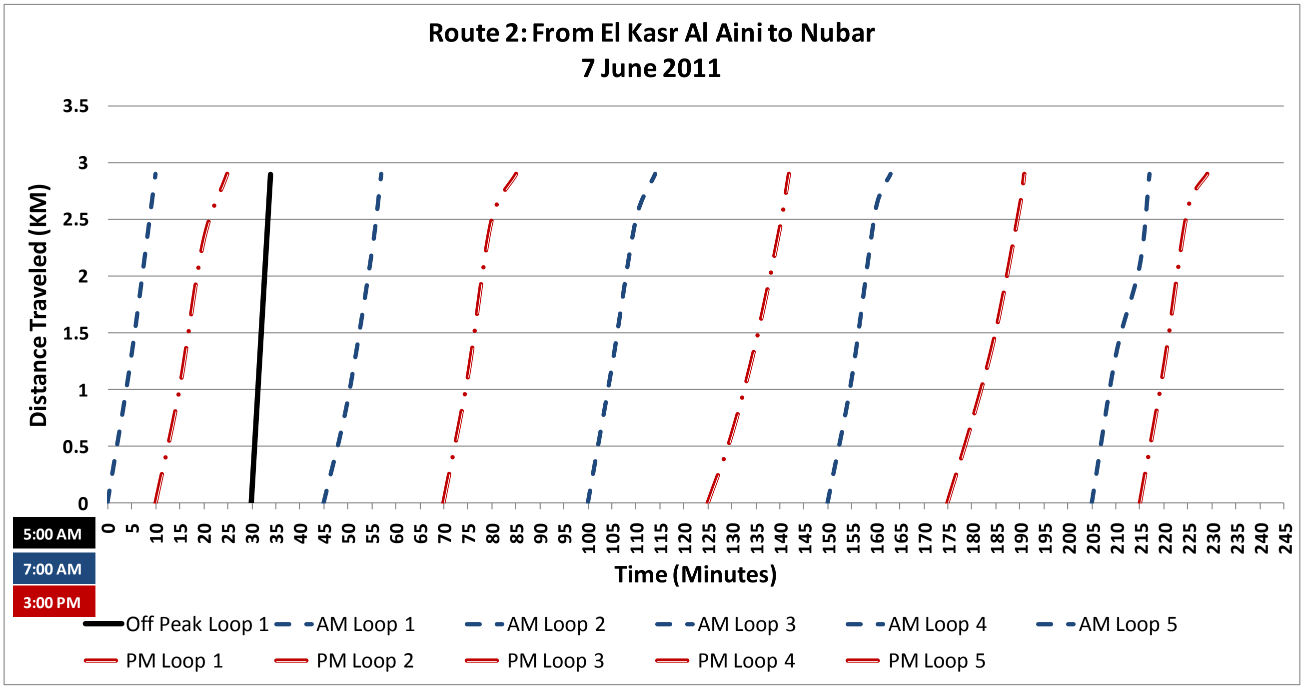


Table C.2 Route 2, Traffic Influencing Events During Survey Periods

Random Stops	4
Random Pedestrian Crossings	29
Intersections	33

C.3 ROUTE 3

Figure C.17 Route 3 Schematic

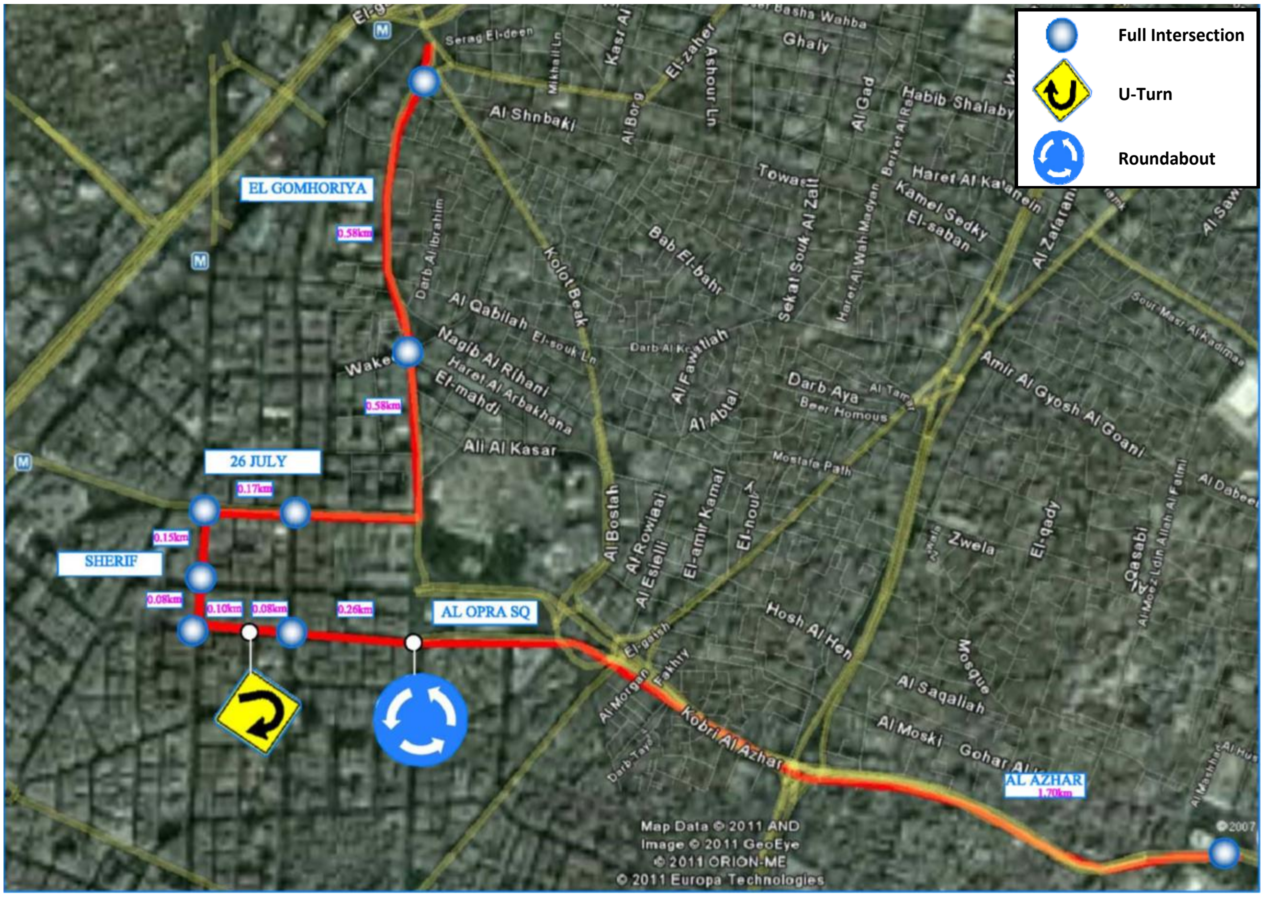


Figure C.18 Route 3, Start Point

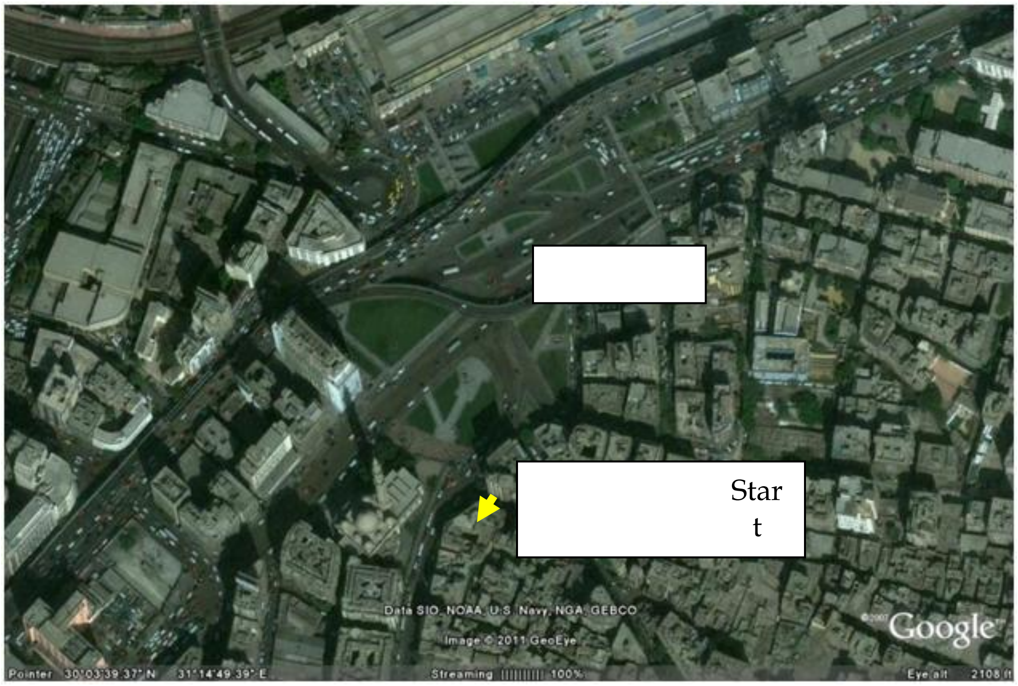


Figure C.19 Route 3, El Gomhoreya St.

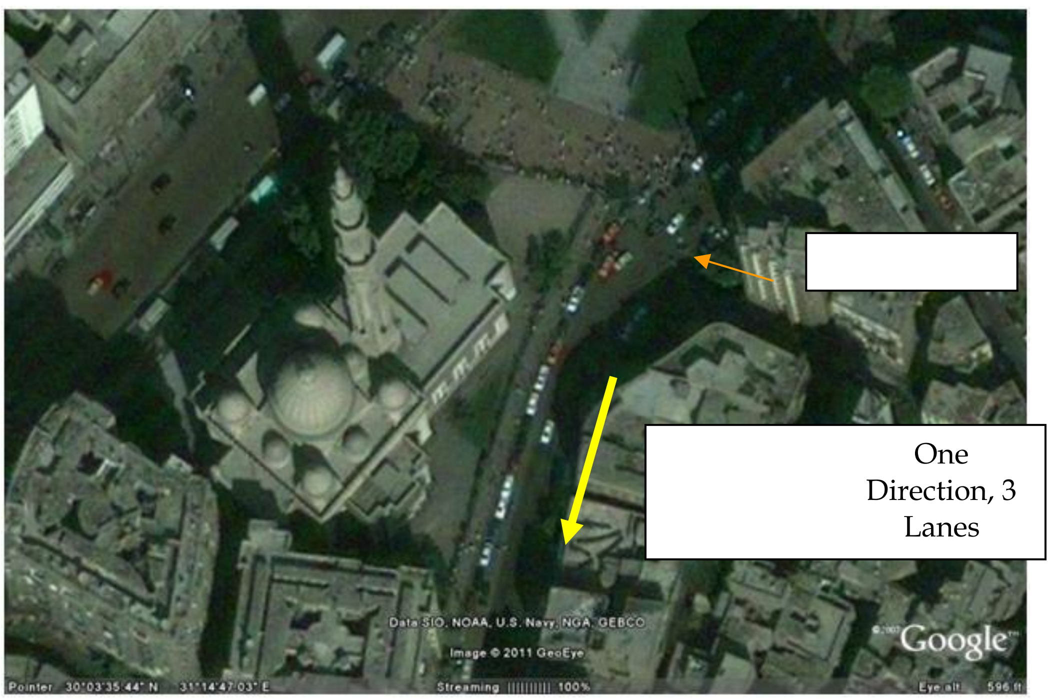


Figure C.20 Route 3, 26 of July St. and Sherif Basha St.

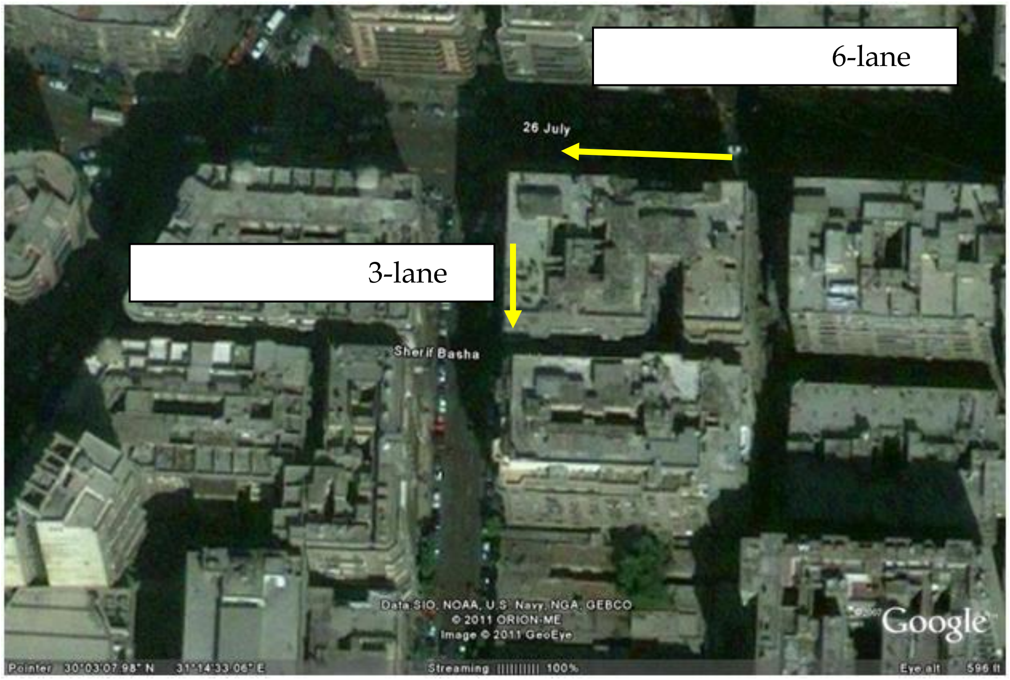


Figure C.21 Route 3, End Point

Figure C.22 Route 3, Time-Space Plot

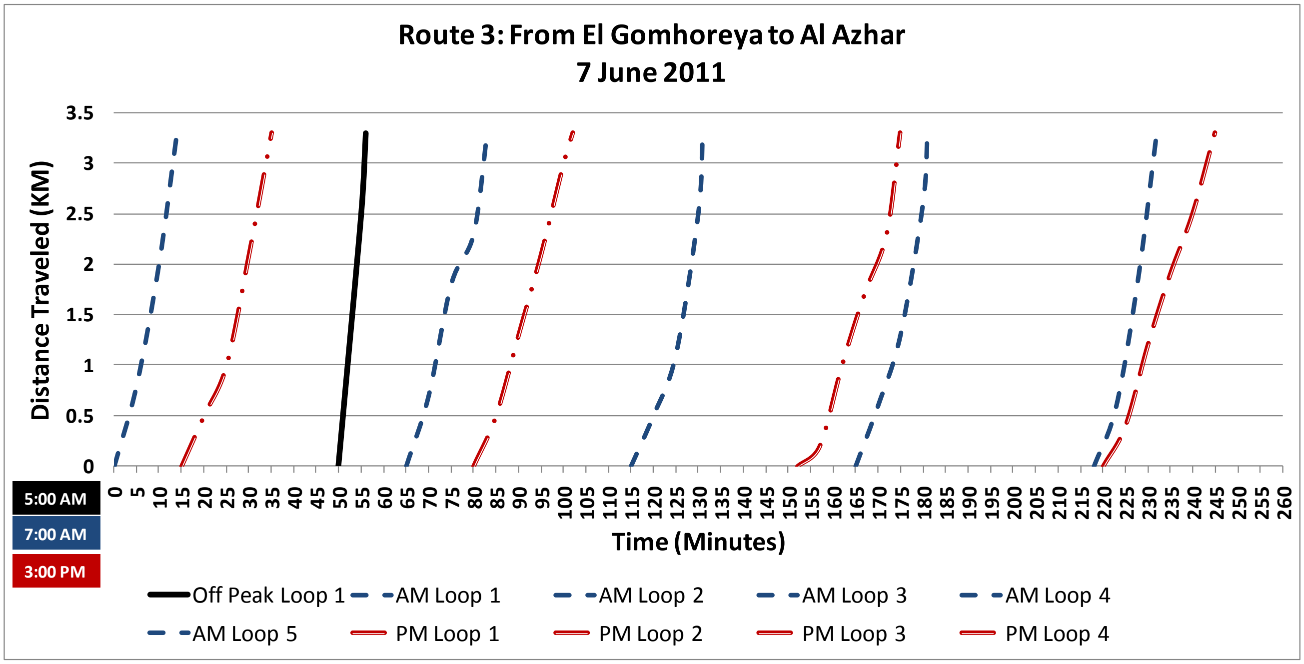


Table C.3 Route 3, Traffic Influencing Events During Survey Periods

Random Stops	9
Crossings Random Pedestrian	33
Intersections	26

C.4 ROUTE 4

Figure C.23 Route 4 Schematic

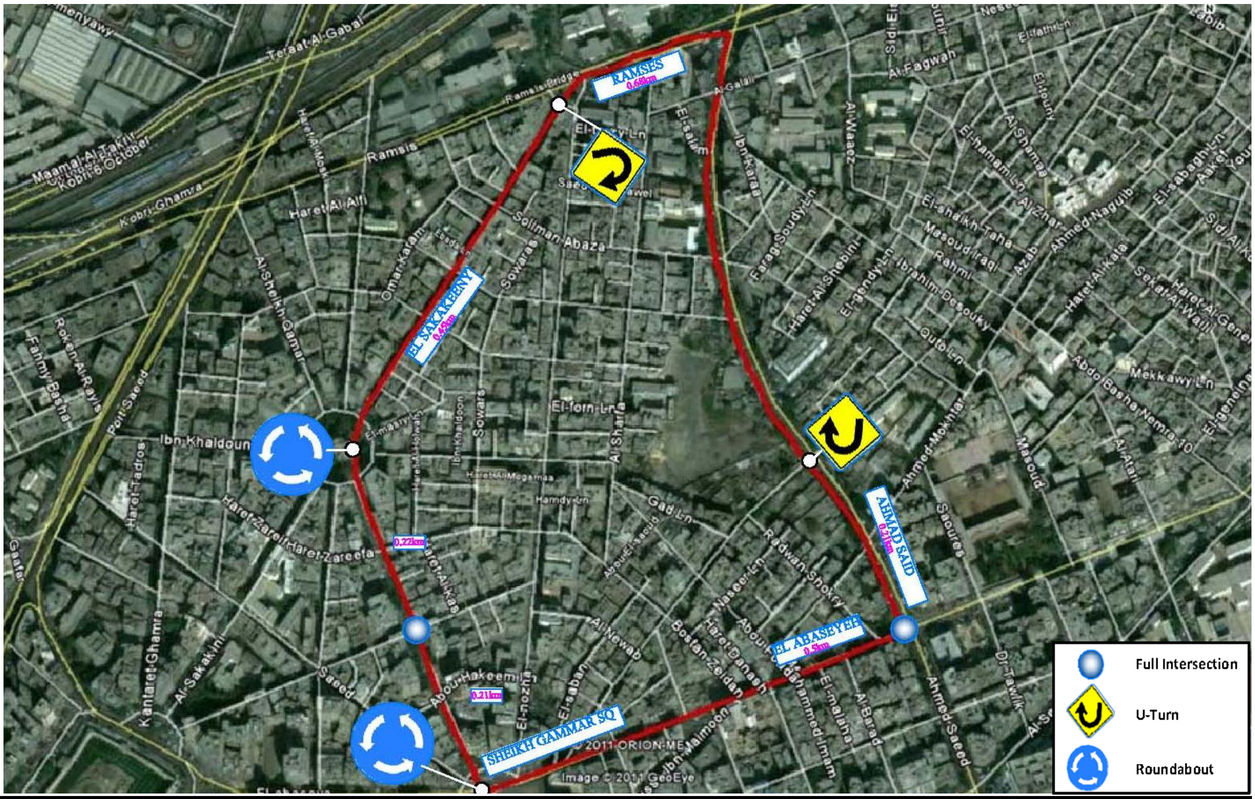


Figure C.24 Route 4, Start Point

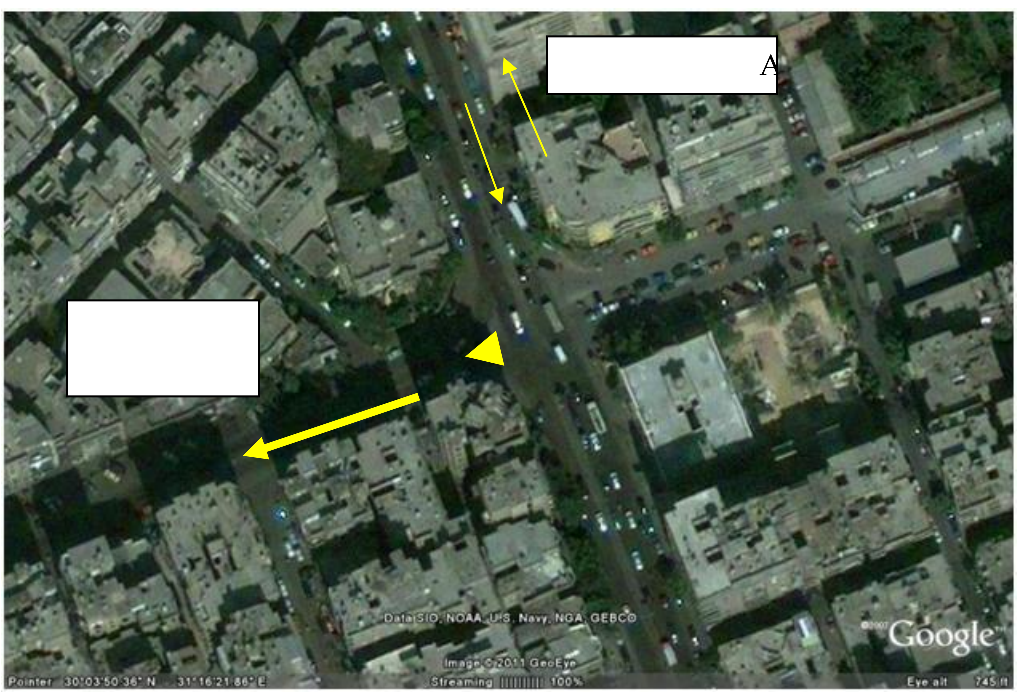


Figure C.25 Route 4, El Gaish Square and El Shak Kamer St.

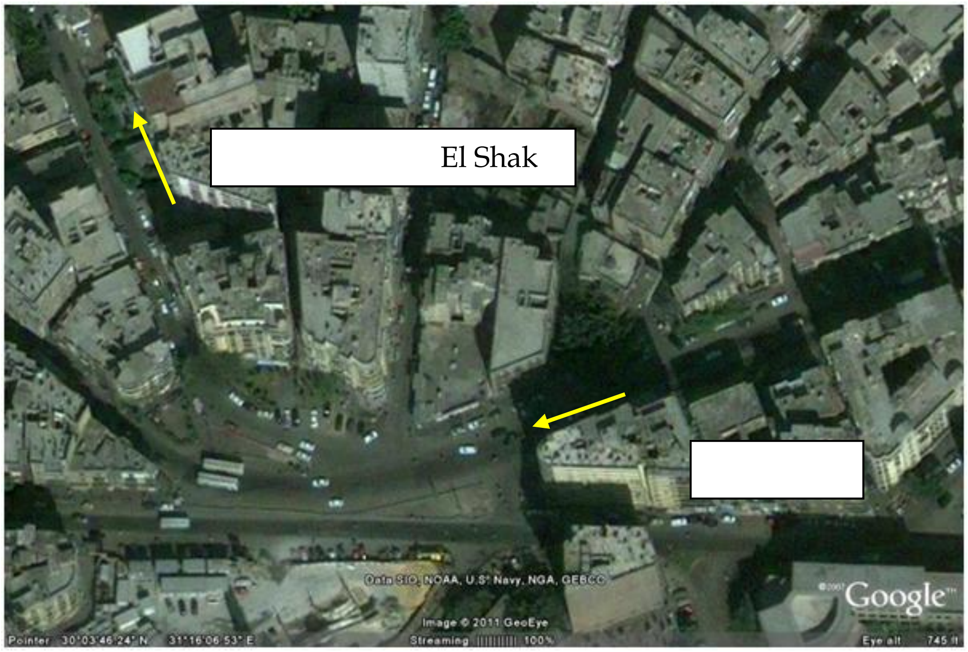


Figure C.26 Route 4, El Sakakini Square

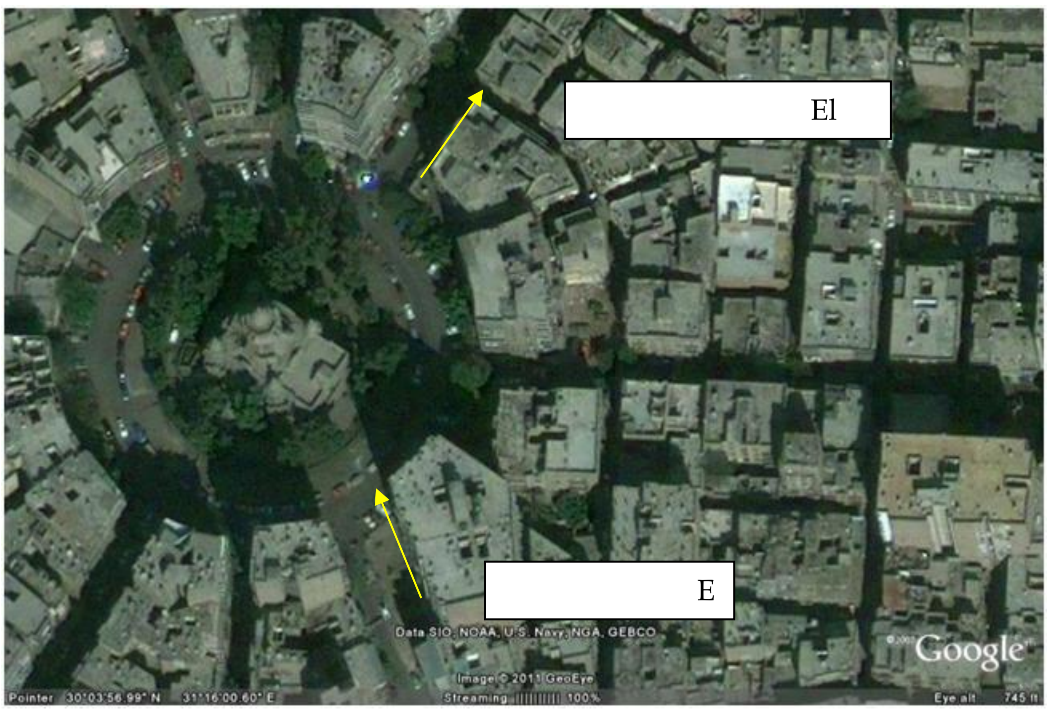


Figure C.27 Route 4, Ramses St.

Figure C.28 Route 4, Time-Space Plot

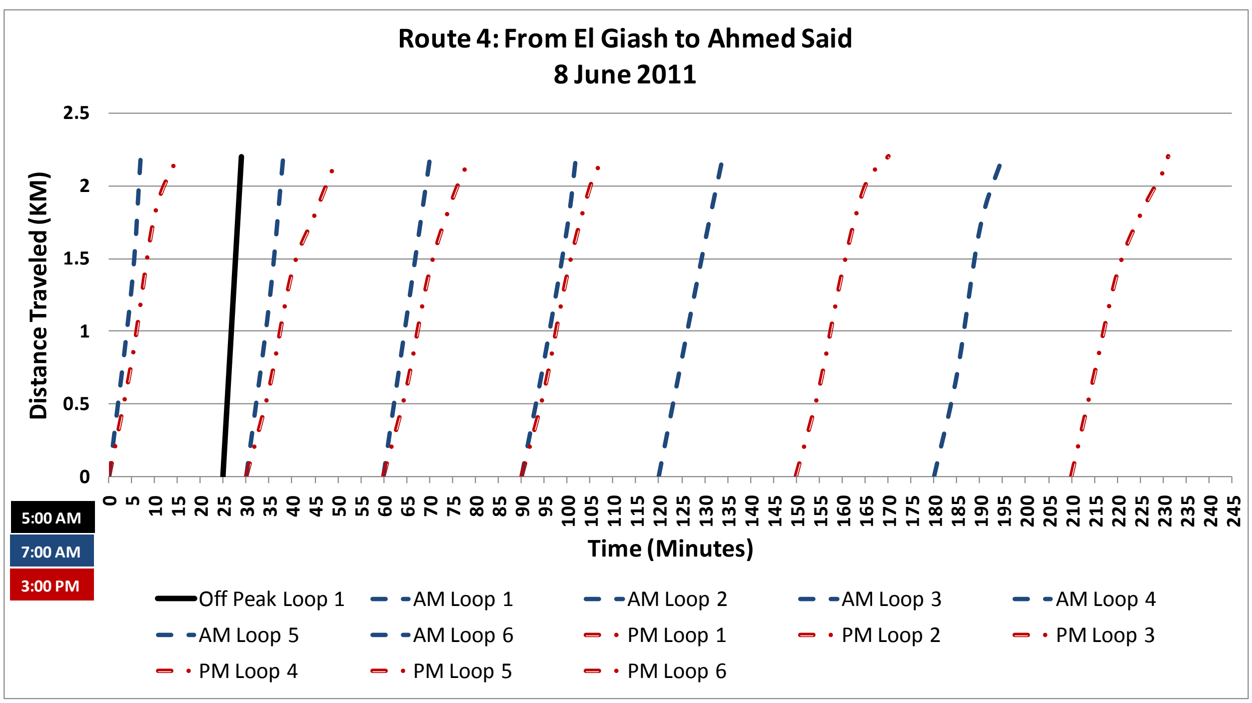


Table C.4 Route 4, Traffic Influencing Events During Survey Periods

Random Stops	17
Random Pedestrian Crossings	39
Intersections	40

C.5 ROUTE 5

Figure C.29 Route 5 Schematic

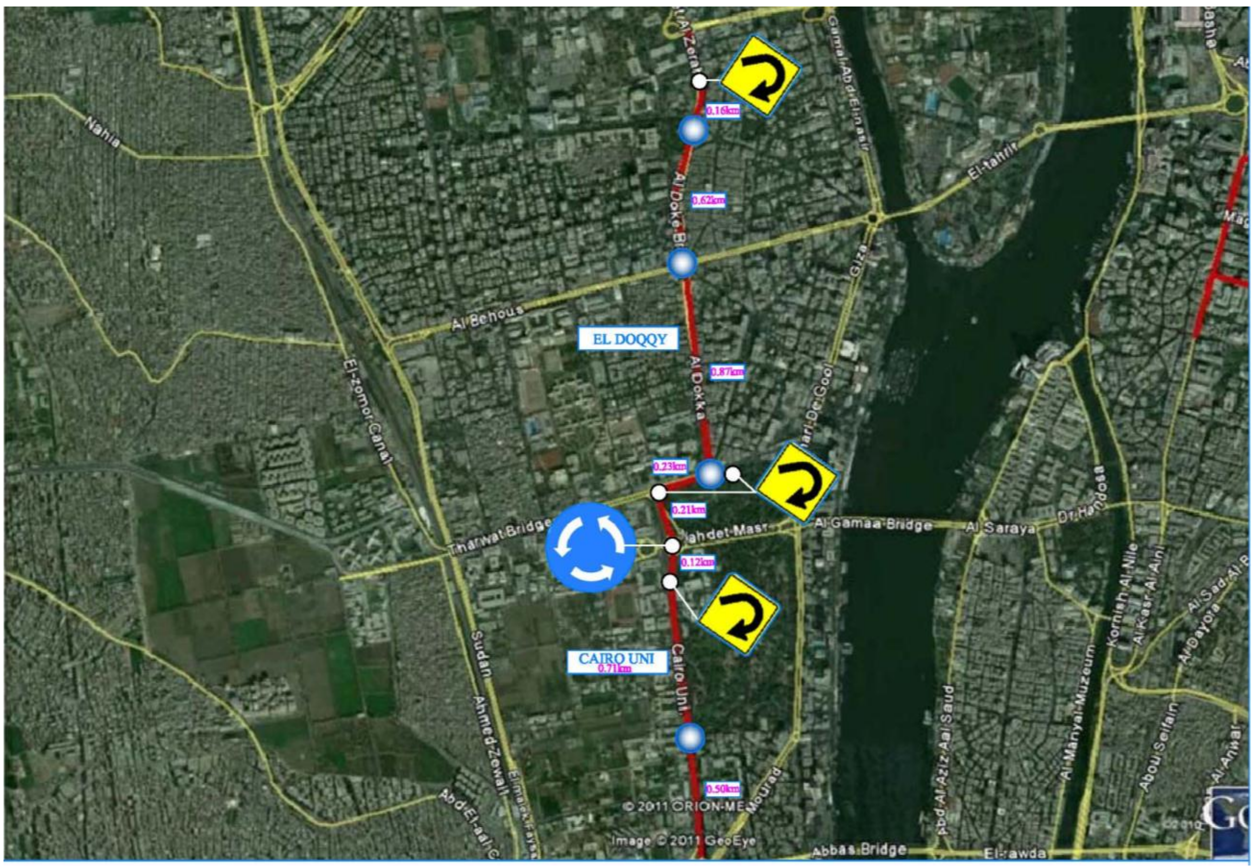


Figure C.30 Route 5, Start Point, El Doggi St.

Figure C.31 Route 5, End of El Doggi St.

Figure C.32 Route 5, Cairo University St. next to Doqqi

Figure C.33 Route 5, Intersection in front of Cairo University

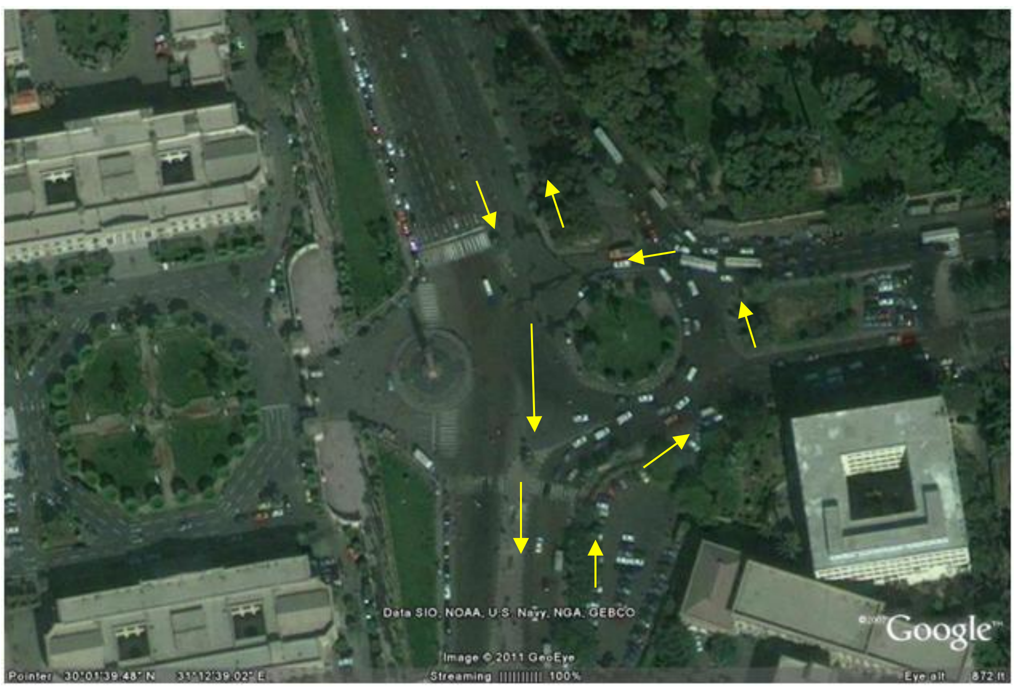


Figure C.34 Route 5, Cairo University St. near Cairo Zoo

Figure C.35 Route 5, End Point Next to Giza Square

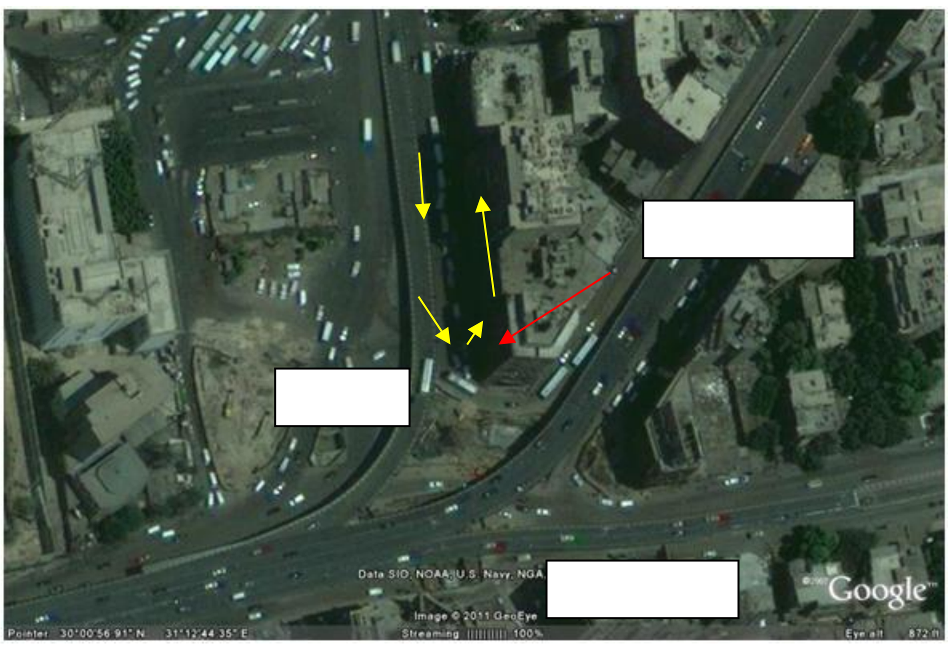


Figure C.36 Route 5, Time-Space Plot

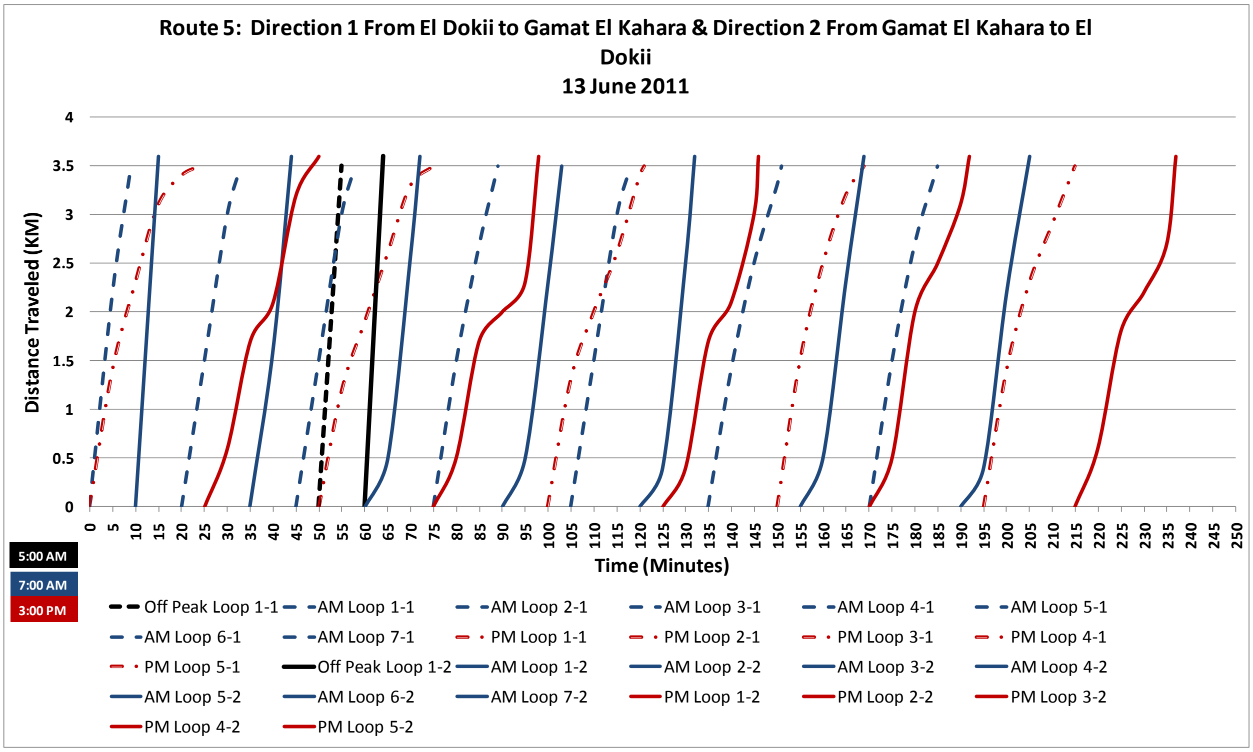


Table C.5 Route 5, Traffic Influencing Events During Survey Periods

	Direction 1	Direction 2	Total
Random Stops	17	18	35
Random Pedestrian Crossings	44	43	87
Intersections	45	44	89

C.6 ROUTE 6

Figure C.37 Route 6 Schematic

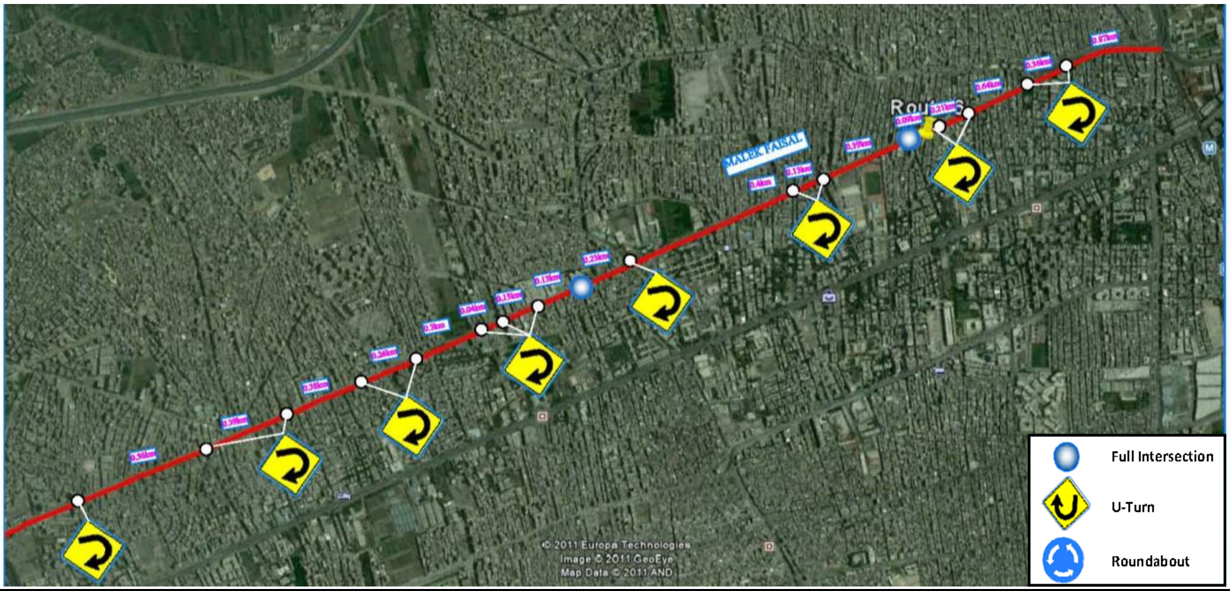


Figure C.38 Route 6, Start Point Next to Giza

Figure C.39 Route 6, Typical U-Turn

Figure C.40 Route 6, Intersections

Figure C.41 Route 6, End Point Near Pyramids

Figure C.42 Route 6, Time-Space Plot

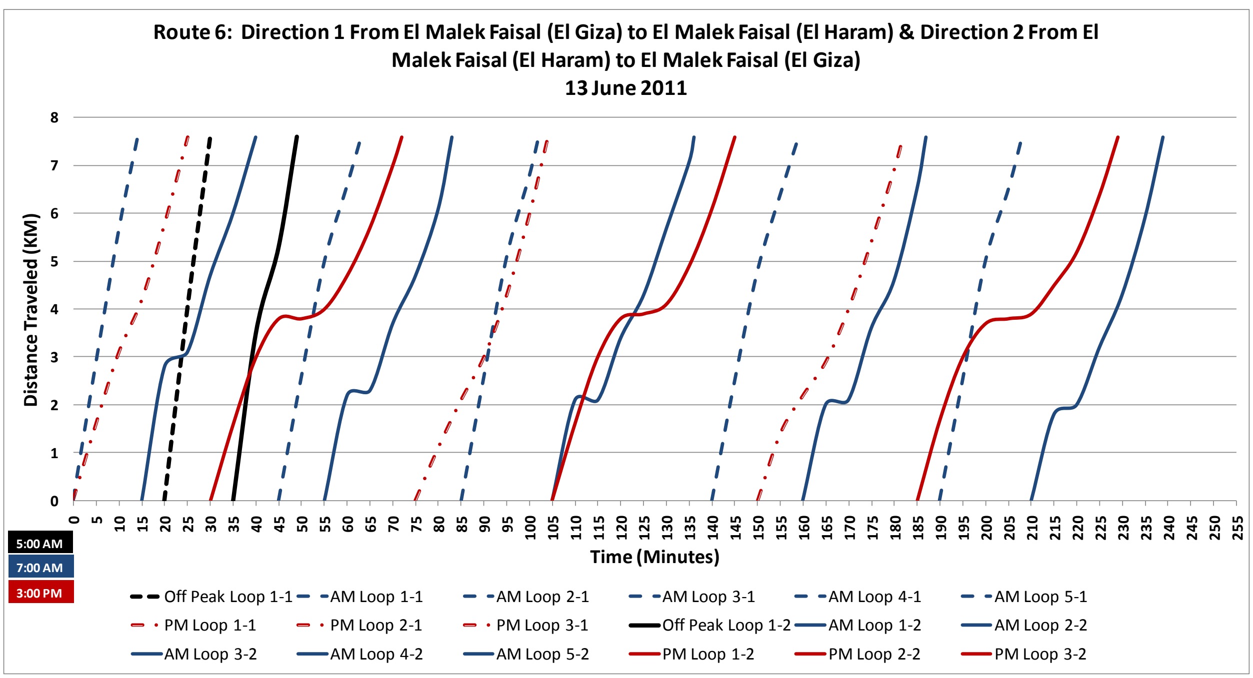


Table C.6 Route 6, Traffic Influencing Events During Survey Periods

	Direction 1	Direction 2	Total
Random Stops	17	35	52
Random Pedestrian Crossings	37	56	93
Intersections	39	56	95

a)

b)

C.7 ROUTE 7

Figure C.42 Route 7 Schematic

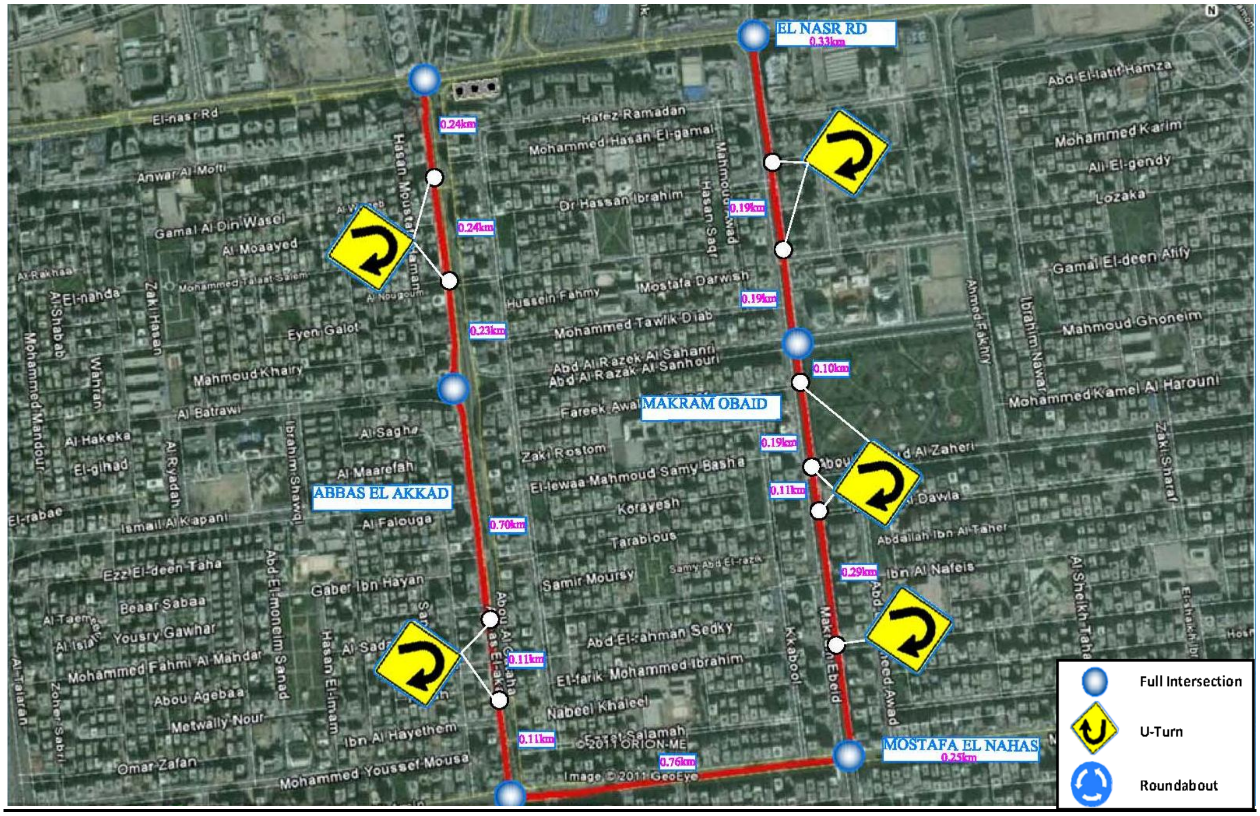


Figure C.43 Route 7, Start Point

Figure C.44 Route 7, U-Turn

Figure C.45 Route 7, Intersection of Abbas El Alkad and Mostafa El Nahas

Figure C.46 Route 7, Intersection of Mostafa El Nahas and Makram Ebiad

Figure C.47 Route 7, Mid-Section on front of Children Garden with several cross roads

Figure C.48 Route 7, End Point at intersection of Makram Ebid and El Nasr Road

Figure C.49 Route 7, Time-Space Plot

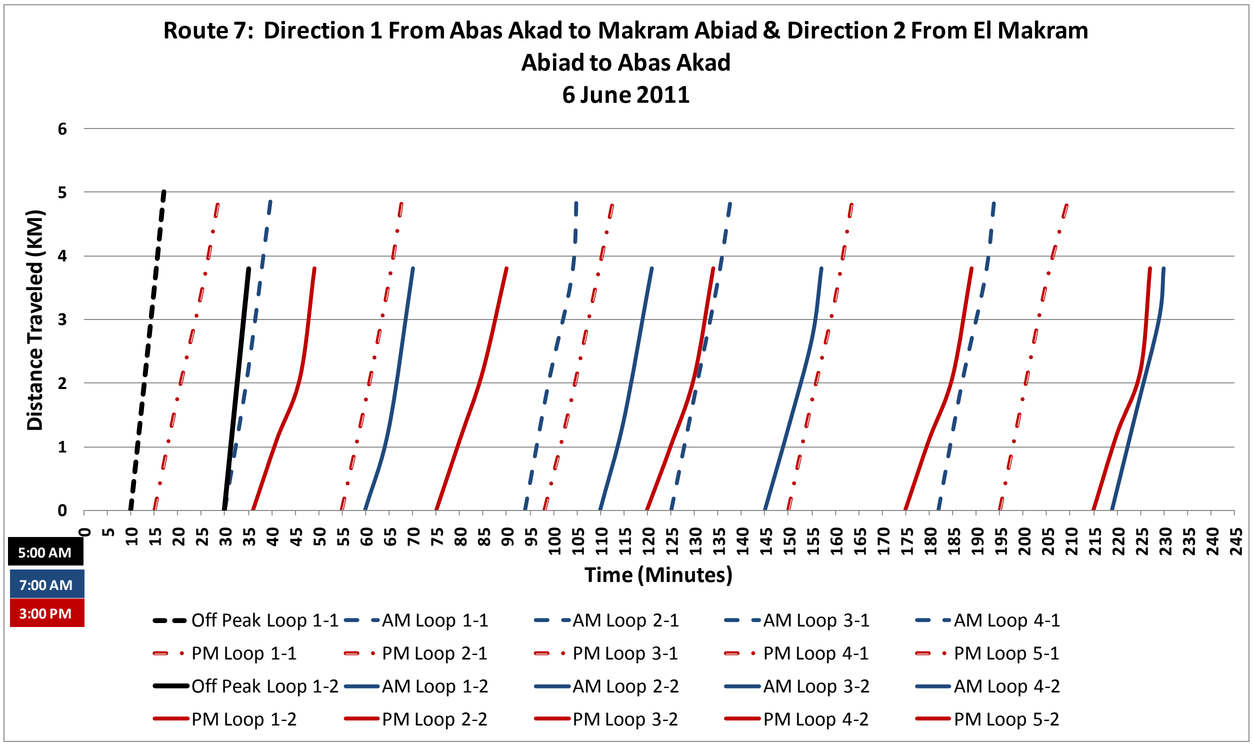


Table C.7 Route 7, Traffic Influencing Events During Survey Periods

	Direction 1	Direction 2	Total
Random Stops	9	9	18
Random Pedestrian Crossings	26	27	53
Intersections	28	27	55

C.7 ROUTE 8

Figure C.50 Route 8 Schematic

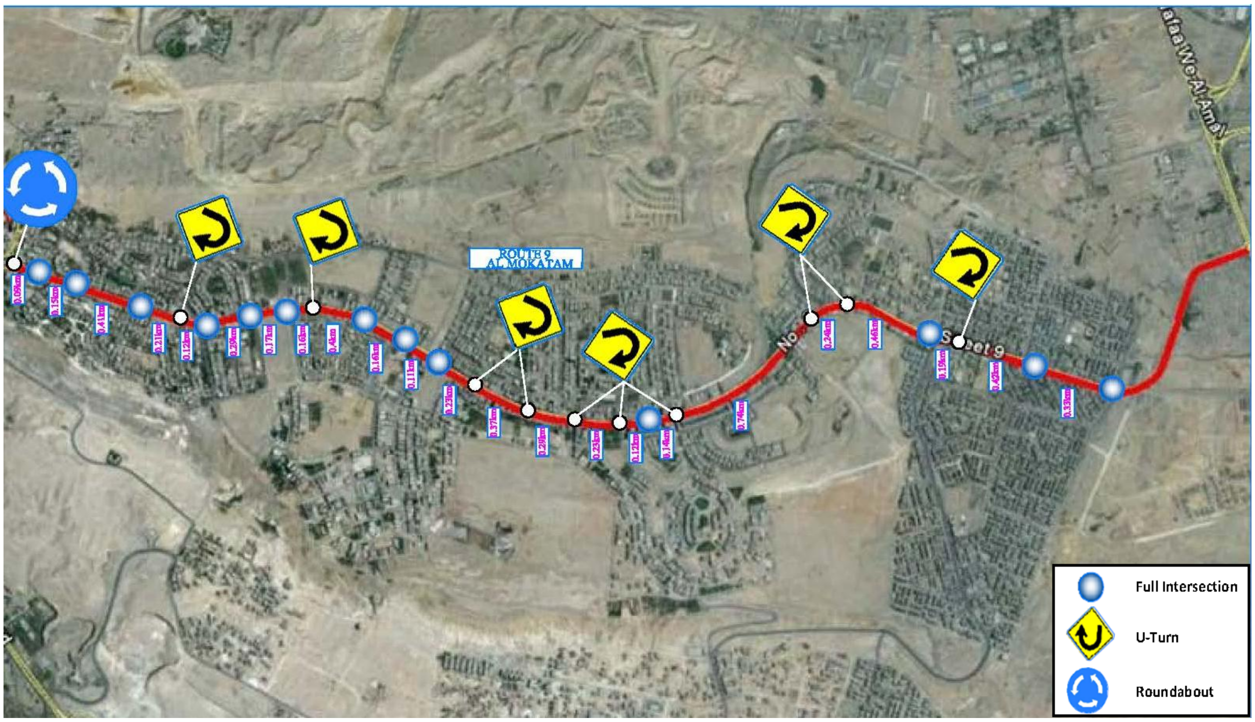


Figure C.51 Route 8, Start and End Points

Figure C.52 Route 8, Random Parking Along Street Number 9

Figure C.53 Route 8, Intersection Along Street Number 9 at Curved Section

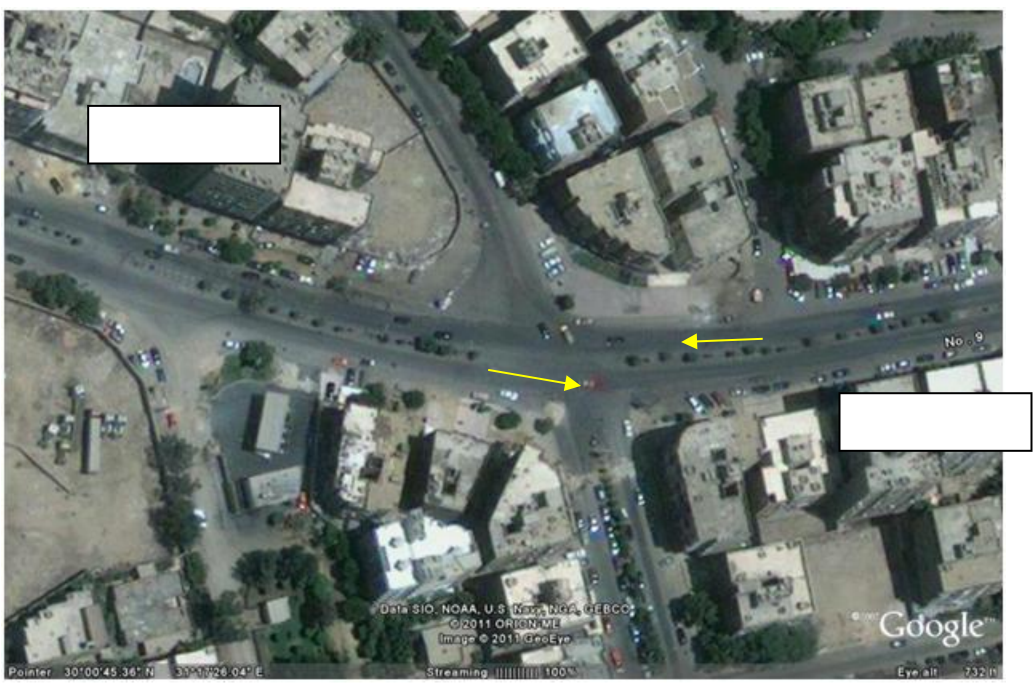


Figure C.54 Route 8, Start and End Points Near Ring Road

Figure C.55 Route 8, Time-Space Plot

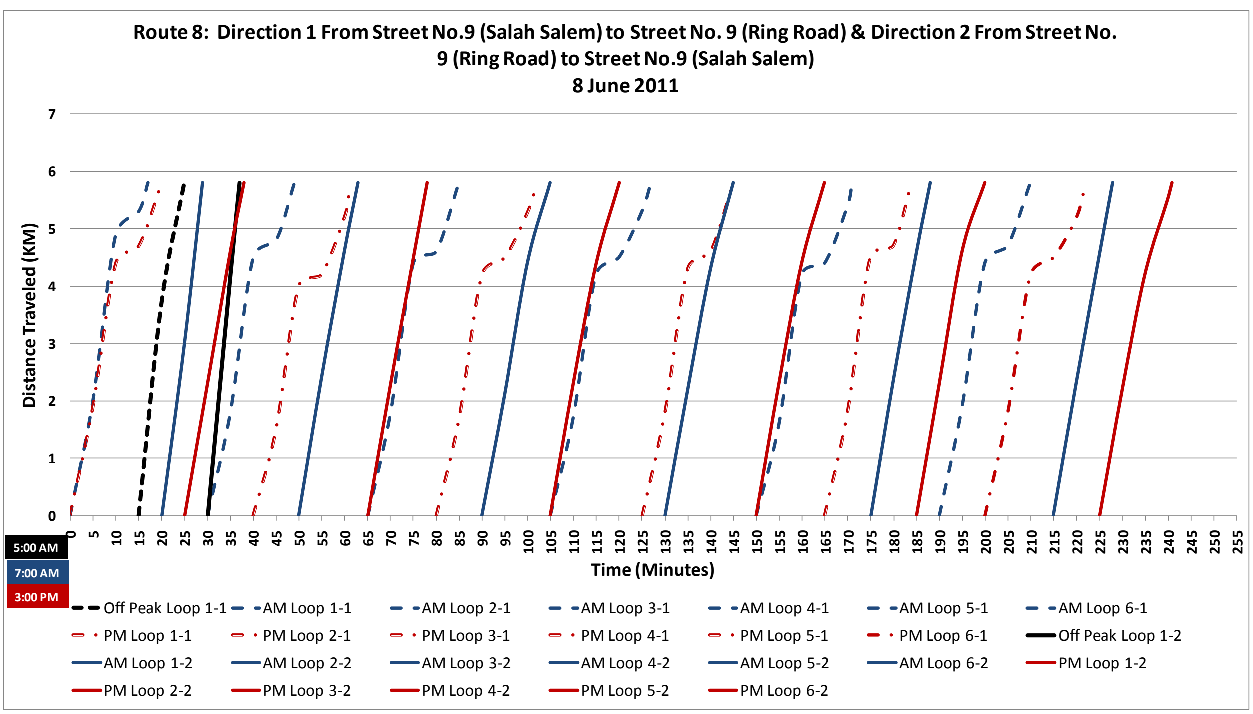


Table C.8 Route 8, Traffic Influencing Events During Survey Periods

	Direction 1	Direction 2	Total
Random Stops	14	12	26
Random Pedestrian Crossings	52	36	88
Intersections		38	82

13.0 APPENDIX D

- **Socioeconomic Data for Travel Demand Model**

a) The socioeconomic data for the GCMA area were obtained from the Strategic Urban Development Master Plan Study for Sustainable Development of the Greater Cairo Region in the Arab Republic of Egypt (Volume 1), conducted by JICA. The socioeconomic data provided for the 18 zones in the GCMA include population, employment (primary, secondary and tertiary), and students (non-university and university), in addition to trips generated, for each of the years 2007, 2012, 2022, and 2027 (Tables D.1 through D.4).

Table D.1 Socioeconomic Framework, 2007

			Employment			Students		
	Sector	Population	Primary	Secondary	Tertiary	Non-Univ	University	Trips Generated
1	6th of October	212,574	2,318	99,374	22,966	4,273	19,785	76,042
2	ImbabaMarkaz	1,660,231	62,742	76,133	149,677	29,185	-	281,597
3	Doqy	1,345,855	470	85,947	259,433	32,286	-	308,593
4	Giza	1,532,983	29,292	112,923	207,846	33,518	242,577	464,444
5	South Giza	525,737	27,170	34,862	39,401	13,535	-	111,035
6	Helwan	806,093	5,846	201,608	92,751	38,550	-	197,349
7	Maadi	1,038,498	12,882	109,655	114,565	37,845	-	250,055
8	Khaleefa	850,018	47	70,383	141,339	39,140	-	204,802
9	CBD	407,156	-	40,472	314,017	32,482	4,006	185,536
10	Shobra	1,029,514	3	82,365	130,143	38,504	4,389	243,676
11	Masr El Gedeeda	879,293	21,130	91,253	236,522	52,332	247,990	338,238
12	Nasr City	1,019,609	1,101	146,091	225,160	40,963	-	298,785
13	Ain Shams	1,017,588	2	66,541	113,286	47,677	-	216,242
14	Salam City	844,972	956	59,264	88,923	26,779	-	183,587
15	Shobra El-Kheima	1,042,303	10,916	98,684	136,346	50,325	-	229,565
16	Qalyob	874,049	36,585	65,921	78,691	39,108	-	164,292
17	Qanater	1,241,229	54,908	130,018	107,596	50,865	-	239,400
18	10th of Ramadan City	136,538	91	169,617	8,660	5,054	-	53,622
		16,464,240	**266,457**	**1,741,114**	**2,467,324**	**612,422**	**518,746**	**4,046,860**

Table D.2 Socioeconomic Framework, 2012

	Sector	Population	Employment Primary	Employment Secondary	Employment Tertiary	Students Non-Univ	Students University	Trips Generated
1	6th of October	441,470	2,581	123,309	49,274	13,006	27,367	141,735
2	ImbabaMarkaz	2,057,377	69,846	94,828	195,891	56,299	1,945	370,571
3	Doqy	1,375,369	523	85,258	256,473	44,023	2,705	349,155
4	Giza	1,641,374	32,608	116,168	214,020	49,928	245,382	534,950
5	South Giza	548,502	30,246	36,378	41,237	18,642	50	127,647
6	Helwan	855,146	6,791	211,346	119,090	38,258	1,682	223,608
7	Maadi	1,216,145	14,967	134,539	154,870	43,843	2,392	300,960
8	Khaleefa	889,611	55	84,949	164,549	37,100	1,750	215,983
9	CBD	402,299	-	45,998	314,065	26,598	4,797	175,606
10	Shobra	1,038,096	3	96,833	153,691	38,647	6,431	262,880
11	Masr El Gedeeda	891,072	24,549	104,770	262,000	46,844	250,041	361,447
12	Nasr City	1,245,899	1,280	178,575	284,465	45,746	8,865	351,738
13	Ain Shams	1,145,003	3	90,177	149,810	51,250	2,252	250,761
14	Salam City	806,700	1,110	66,273	103,786	27,163	1,586	198,395
15	Shobra El-Kheima	1,153,583	12,916	111,009	143,973	55,442	2,269	270,003
16	Qalyob	998,681	43,286	79,821	91,556	44,936	375	194,436
17	Qanater	1,493,999	64,964	158,069	146,272	63,555	4,374	301,009
18	10th of Ramadan City	210,288	105	195,889	31,027	8,212	414	88,675
		18,410,614	**305,831**	**2,014,189**	**2,876,050**	**709,490**	**564,677**	**4,719,559**

Table D.3 Socioeconomic Framework, 2022

	Zone	Population	Employment: Primary	Employment: Secondary	Employment: Tertiary	Students: Non-Univ	Students: University	Trips Generated
1	6th of October	1,120,364	3,208	216,238	119,219	57,814	55,420	412,466
2	ImbabaMarkaz	2,539,466	86,811	115,496	260,690	129,419	12,324	554,566
3	Doqy	1,409,739	650	83,945	268,097	73,712	13,629	434,638
4	Giza	1,844,470	40,529	116,550	245,471	95,273	258,288	697,743
5	South Giza	574,496	37,593	35,361	48,880	30,635	231	162,910
6	Helwan	937,043	8,811	218,634	167,624	43,352	9,059	276,122
7	Maadi	1,524,869	19,418	182,488	231,984	65,773	14,742	431,676
8	Khaleefa	937,678	71	109,620	199,303	41,807	9,065	254,237
9	CBD	389,553	1	54,797	299,293	20,770	7,772	196,715
10	Shobra	1,040,147	4	120,742	190,206	45,426	14,445	306,484
11	Masr El Gedeeda	947,948	31,850	132,775	328,446	46,337	258,422	427,708
12	Nasr City	1,944,114	1,660	270,138	493,023	82,220	42,331	548,872
13	Ain Shams	1,338,631	3	135,422	214,379	63,220	12,941	335,684
14	Salam City	746,741	1,440	76,524	126,425	31,884	7,219	202,805
15	Shobra El-Kheima	1,333,275	17,211	133,241	171,645	74,560	12,889	354,961
16	Qalyob	1,199,685	57,681	106,188	119,390	65,651	2,441	256,106
17	Qanater	2,064,134	86,569	226,344	217,955	110,699	21,554	433,497
18	10th of Ramadan City	441,503	135	281,154	83,855	22,115	4,268	178,719
		22,333,856	**393,645**	**2,615,657**	**3,785,885**	**1,100,667**	**757,040**	**6,465,909**

Table D.4 Socioeconomic Framework, 2027

			Employment			Students		
	Zone	Population	Primary	Secondary	Tertiary	Non-Univ	University	Trips Generated
1	6th of October	1,449,364	3,424	253,079	148,995	90,664	101,384	573,188
2	ImbabaMarkaz	2,684,164	92,682	118,213	277,289	167,907	12,673	632,146
3	Doqy	1,429,463	694	81,921	270,822	89,419	13,525	476,427
4	Giza	1,974,991	43,269	117,809	258,674	123,545	259,158	786,705
5	South Giza	590,495	40,135	35,437	51,174	36,938	222	180,362
6	Helwan	995,041	9,526	219,008	185,382	47,096	9,415	306,983
7	Maadi	1,655,522	20,992	202,035	257,160	78,357	15,664	501,810
8	Khaleefa	951,550	77	116,325	208,012	45,037	9,003	272,850
9	CBD	384,529	1	56,633	291,417	18,200	7,644	208,277
10	Shobra	1,041,766	4	127,244	198,199	49,307	14,246	326,385
11	Masr El Gedeeda	976,786	34,432	142,005	351,503	46,232	261,070	458,666
12	Nasr City	2,355,577	1,795	313,546	599,532	111,491	86,335	650,578
13	Ain Shams	1,401,467	4	149,705	232,024	66,332	13,260	374,335
14	Salam City	725,064	1,557	78,603	130,360	34,318	6,860	207,803
15	Shobra El-Kheima	1,406,107	18,985	137,063	180,329	83,615	13,304	392,634
16	Qalyob	1,270,396	63,628	112,184	127,948	75,545	2,597	284,240
17	Qanater	2,313,704	95,495	251,238	248,348	137,586	44,813	494,133
18	10th of Ramadan City	586,024	146	312,416	109,247	32,722	5,545	238,389
		24,192,010	**426,846**	**2,824,464**	**4,126,415**	**1,334,311**	**876,718**	**7,365,911**

b)

c) Table D.5 shows the socioeconomic framework estimated for 2010.

Table D.5 Socioeconomic Framework, 2010

	Sector	Population	Primary	Secondary	Tertiary	Non-Univ	University	Trips Generated
1	6th of October	349,912	2,476	113,735	38,751	9,513	24,334	118,794
2	ImbabaMarkaz	1,898,519	67,004	87,350	177,405	45,453	1,167	376,963
3	Doqy	1,363,563	502	85,534	257,657	39,328	1,623	304,283
4	Giza	1,598,018	31,282	114,870	211,550	43,364	244,260	481,818
5	South Giza	539,396	29,016	35,772	40,503	16,599	30	122,700
6	Helwan	835,525	6,413	207,451	108,554	38,375	1,009	227,071
7	Maadi	1,145,086	14,133	124,585	138,748	41,444	1,435	260,274
8	Khaleefa	873,774	52	79,123	155,265	37,916	1,050	211,231
9	CBD	404,242	-	43,788	314,046	28,952	4,481	173,766
10	Shobra	1,034,663	3	91,046	144,272	38,590	5,614	236,186
11	Masr El Gedeeda	886,360	23,181	99,363	251,809	49,039	249,221	395,821
12	Nasr City	1,155,383	1,208	165,581	260,743	43,833	5,319	300,705
13	Ain Shams	1,094,037	3	80,723	135,200	49,821	1,351	243,652
14	Salam City	822,009	1,048	63,469	97,841	27,009	952	180,870
15	Shobra El-Kheima	1,109,071	12,116	106,079	140,922	53,395	1,361	257,947
16	Qalyob	948,828	40,606	74,261	86,410	42,605	225	215,770
17	Qanater	1,392,891	60,942	146,849	130,802	58,479	2,624	318,687
18	10th of Ramadan City	180,788	99	185,380	22,080	6,949	248	92,971
		17,632,064	**290,083**	**1,904,958**	**2,712,558**	**670,664**	**546,305**	**4,519,508**

d)

e) To estimate the socioeconomic data for 2030, the yearly growth rates between 2022 and 2027 were calculated and used to project the socioeconomic data to the year 2030 (Table D.6).

Table D.6 Socioeconomic Framework for 2030 - Medium Scenario

			Employment			Students		
	Sector	Population	Primary	Secondary	Tertiary	Non-Univ	University	Trips Generated
1	6th of October	1,704,731	3,562	278,950	171,323	121,573	151,835	600,309
2	ImbabaMarkaz	2,775,930	96,443	119,882	287,883	197,867	12,888	691,951
3	Doqy	1,441,463	722	80,736	272,474	100,851	13,463	413,020
4	Giza	2,058,845	45,024	118,573	267,022	145,542	259,682	770,392
5	South Giza	600,362	41,763	35,483	52,615	41,498	217	221,565
6	Helwan	1,031,994	9,990	219,233	197,166	49,536	9,637	308,090
7	Maadi	1,740,631	22,013	215,019	273,905	87,352	16,252	450,102
8	Khaleefa	959,996	81	120,594	213,466	47,125	8,966	291,942
9	CBD	381,553	1	57,772	286,816	16,849	7,568	183,168
10	Shobra	1,042,739	4	131,355	203,196	51,835	14,128	312,517
11	Masr El Gedeeda	994,615	36,107	147,928	366,308	46,169	262,675	538,639
12	Nasr City	2,654,705	1,883	343,776	677,243	135,306	140,183	754,046
13	Ain Shams	1,440,938	5	159,179	243,482	68,291	13,456	384,564
14	Salam City	712,435	1,633	79,884	132,794	35,890	6,655	240,874
15	Shobra El-Kheima	1,452,193	20,159	139,422	185,803	89,708	13,561	403,962
16	Qalyob	1,315,323	67,564	115,985	133,451	82,376	2,697	367,191
17	Qanater	2,481,551	101,403	267,817	269,127	157,636	73,828	675,386
18	10th of Ramadan City	701,121	153	333,259	129,096	42,139	6,540	254,027
		25,491,127	**448,510**	**2,964,845**	**4,363,168**	**1,517,543**	**1,014,232**	**7,861,745**

f) Unlike the population, students, and employment data, the generated trips for the years 2010 and 2030 were not calculated using yearly growth rates. Rather, the generated trips were obtained using a multi-regression model relating the generated trips with population, employment and total number of students.

g) As shown in Table D.7, the three socioeconomic variables have a low correlation ranging between 0.49 and 0.65. Hence, all three variables can be used to form a multi-linear regression model between the generated trips and these socioeconomic variables.

Table D.7 Correlation between the Socioeconomic Data Variables

	Population	*Employment*	*Students*
Population	1		
Employment	0.6598859	1	
Students	0.5839007	0.498681588	1

h) The multi-linear regression model is formed between the trips generated in 2027 and the socioeconomic variables. The formula exhibits a highR2 value of 0.90, indicating a good fit of the model (Table D.8).

Table D.8 Regression Value of the Multi-linear Formula

Regression Statistics	
Multiple R	0.9524959
R Square	0.9072485
Adjusted R Square	0.8873732
Standard Error	58445.959
Observations	18

i) The coefficients of the multi-regression formula between the generated trips and socioeconomic variables are shown in Table 5 below.

Table D.9 Coefficients of the Multi-regression Formula

	Coefficients
Intercept	95359.862
Population	0.138
Employment	0.036
Students	0.926

j) The following is the formula used to calculate the trips generated for the 18 zones of GCMA in the year 2030:

k) $Y_{Trips} = 0.138\, X_{Population} + 0.0364\, X_{Employment} + 0.926\, X_{Students} + 95360$

l)

m)

14.0 APPENDIX E

- **Origin-Destination Vehicle Trip Tables**

Table E.1 Origin-Destination Matrix for All Vehicles, 2010

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total trips
6th of	1	22.098	5.654	7.746	17.374	1.218	1.119	1.584	2.717	5.936	1.631	1.559	1.467	0.861	0.697	1.251	1.433	0.453	1.033	**75.832**
Imbaba	2	5.654	73.430	36.337	22.866	1.443	1.951	4.098	6.019	17.507	6.115	7.858	6.121	2.867	2.447	4.150	4.369	1.872	0.770	**205.875**
Dokki	3	7.746	36.337	95.075	51.394	5.275	7.920	14.793	19.698	42.654	20.521	24.003	17.519	9.174	6.635	14.582	7.674	5.517	1.059	**387.575**
Giza	4	17.374	22.867	51.394	115.567	13.007	7.387	16.645	22.786	32.453	11.181	14.777	12.384	4.949	3.521	7.126	3.858	2.669	0.754	**360.699**
South Giza	5	1.218	1.443	5.275	13.007	33.987	7.051	2.795	3.160	4.347	1.164	2.108	2.081	0.524	0.367	0.774	0.381	0.299	0.213	**80.195**
Helwan	6	1.119	1.951	7.921	7.386	7.050	87.565	20.555	7.078	11.367	3.376	7.196	6.362	2.372	1.799	2.324	1.124	1.123	0.851	**178.520**
Maadi	7	1.584	4.098	14.793	16.644	2.795	20.555	54.664	18.051	21.724	6.640	13.862	12.001	3.866	2.847	3.730	2.027	1.861	0.567	**202.310**
Khaleefa	8	2.717	6.019	19.699	22.786	3.160	7.079	18.051	24.505	24.402	9.874	19.127	16.439	5.972	4.139	5.053	2.009	2.047	0.564	**193.641**
CBD	9	5.937	17.507	42.653	32.454	4.347	11.366	21.723	24.404	46.825	30.429	34.142	28.276	15.600	11.079	16.994	7.953	6.759	1.640	**360.090**
Shoubra	10	1.631	6.115	20.521	11.181	1.164	3.376	6.640	9.874	30.429	39.708	26.818	17.792	11.102	7.097	15.307	7.108	5.599	1.206	**222.670**
Masr El	11	1.559	7.857	24.004	14.776	2.108	7.196	13.862	19.127	34.143	26.818	81.262	61.257	34.691	23.038	17.862	7.846	11.905	2.621	**391.935**
Nasr City	12	1.467	6.123	17.520	12.384	2.080	6.362	12.001	13.014	28.276	17.790	61.256	114.010	25.988	25.691	13.326	6.936	11.015	9.371	**384.611**
Ain Shams	13	0.861	2.867	9.174	4.949	0.524	2.371	3.866	5.972	15.619	11.102	34.691	25.988	28.838	15.401	10.059	4.604	7.448	2.491	**186.826**
Salam City	14	0.697	2.446	6.635	3.521	0.367	1.799	2.847	4.139	11.079	7.097	23.038	25.691	15.401	31.163	8.000	5.593	11.249	2.395	**163.158**
Shoubra	15	1.251	4.150	14.582	7.126	0.774	2.324	3.730	5.053	16.994	15.307	17.862	13.326	10.059	8.000	31.663	11.795	9.105	2.318	**175.421**
Qalioub	16	1.433	4.369	7.674	3.858	0.381	1.124	2.027	2.009	7.954	7.108	7.846	6.936	4.604	5.593	11.795	40.790	7.741	1.817	**125.060**
Qanater	17	0.453	1.872	5.517	2.668	0.299	1.123	1.861	2.047	6.759	5.599	11.903	11.015	7.448	11.250	9.105	7.741	70.440	1.470	**158.571**
10th of	18	1.033	0.770	1.059	0.754	0.213	0.851	0.567	0.564	1.640	1.206	2.621	9.371	2.491	2.395	2.318	1.817	1.470	28.001	**59.140**
Total		**75.833**	**205.876**	**387.578**	**360.694**	**80.193**	**178.521**	**202.310**	**190.217**	**360.110**	**222.669**	**391.930**	**388.037**	**186.807**	**163.160**	**175.421**	**125.058**	**158.573**	**59.140**	**3,912.129**

Table E.2 Origin-Destination Matrix for All Vehicles, 2030

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total trips
6th of	1	305.7	48.67	26.83	108.1	8.87	5.94	10.77	13.03	9.26	7.19	6.51	7.71	5.51	2.83	8.51	11.33	4.25	9.26	**600.31**
Imbaba	2	48.67	358.2	64.37	69.03	5.12	5.52	13.80	14.87	14.59	13.65	17.67	18.63	8.26	4.35	11.86	13.78	6.10	3.51	**691.95**
Dokki	3	26.82	64.36	66.41	62.12	7.23	9.03	20.42	19.21	13.99	19.00	21.63	21.44	11.89	6.02	19.75	11.37	10.26	2.06	**413.02**
Giza	4	108.1	69.03	62.12	259.5	33.42	14.13	38.93	39.36	19.29	18.80	23.23	26.09	11.38	5.83	17.87	11.10	9.55	2.56	**770.39**
South Giza	5	8.87	5.12	7.23	33.41	114.2	15.91	7.92	6.57	3.14	2.37	4.01	4.92	1.49	0.75	2.27	1.29	1.25	0.78	**221.56**
Helwan	6	5.94	5.51	9.03	14.13	15.91	150.7	44.88	10.75	5.77	4.84	9.53	9.79	4.48	2.41	5.46	3.09	3.50	2.37	**308.09**
Maadi	7	10.77	13.79	20.41	38.92	7.92	44.89	157.2	35.42	14.34	12.67	24.42	27.08	9.69	5.16	11.02	6.97	7.27	2.12	**450.10**
Khaleefa	8	13.03	14.86	19.21	39.36	6.58	10.75	35.42	35.64	11.66	13.65	24.72	28.37	10.65	5.35	10.49	4.90	5.80	1.51	**291.94**
CBD	9	9.26	14.59	13.99	19.29	3.14	5.77	14.35	11.66	7.39	13.56	14.07	16.40	9.48	4.87	11.22	6.11	6.47	1.57	**183.17**
Shoubra	10	7.18	13.64	18.99	18.79	2.37	4.84	12.67	13.65	13.56	54.60	31.76	29.13	19.44	8.69	29.01	15.76	15.25	3.17	**312.52**
Masr El	11	6.51	17.66	21.63	23.23	4.01	9.53	24.42	24.72	14.07	31.76	93.30	96.55	58.28	27.84	32.02	16.19	30.55	6.35	**538.64**
Nasr City	12	7.71	18.64	21.44	26.08	4.92	9.79	27.08	28.37	16.40	29.12	96.54	247.1	58.82	42.14	32.58	19.02	36.21	32.08	**754.05**
Ain Shams	13	5.51	8.26	11.89	11.38	1.49	4.48	9.69	10.64	9.50	19.44	58.27	58.82	71.51	26.88	26.84	13.38	26.95	9.63	**384.56**
Salam City	14	2.83	4.34	6.02	5.83	0.75	2.41	5.16	5.35	4.86	8.69	27.85	42.14	26.88	40.01	14.20	10.19	27.13	6.25	**240.87**
Shoubra	15	8.51	11.86	19.75	17.87	2.27	5.46	11.02	10.49	11.22	29.01	32.02	32.58	26.84	14.20	88.92	37.60	34.28	10.07	**403.96**
Qalioub	16	11.33	13.77	11.37	11.10	1.29	3.09	6.97	4.90	6.11	15.76	16.19	19.02	13.38	10.19	37.60	143.9	32.63	8.57	**367.19**
Qanater	17	4.25	6.09	10.26	9.55	1.25	3.50	7.27	5.80	6.47	15.25	30.55	36.21	26.95	27.13	34.28	32.63	410.2	7.73	**675.39**
10th of	18	9.26	3.51	2.06	2.56	0.78	2.37	2.12	1.51	1.57	3.17	6.35	32.08	9.63	6.25	10.07	8.57	7.73	144.4	**254.03**
Total		**600.31**	**691.95**	**413.02**	**770.39**	**221.56**	**308.09**	**450.10**	**291.94**	**183.17**	**312.52**	**538.64**	**754.05**	**384.56**	**240.87**	**403.96**	**367.19**	**675.39**	**254.03**	7,861.74

n)

o)

15.0 APPENDIX F

- **Extrapolation and Forecasting Methodologies**

F.1 Extrapolation to GCMA Network

1. Major Corridors

p) First the average V/C weighted by lane-kilometers is calculated. Table F.1 shows, for each zone, the lane-kilometers for the sample and total major corridor network in each zone.

Table F.1 Lane-Kilometers by Zone for Major Corridors

-	a) one A	b) one B	c) one C	d) otal
Sample	242	594	27	863
Total GCMA	426.67	467.875	1403.625	2298.17

q) The total cost of congestion of the major corridors in the GCMA using the average weighted V/C by lane-kilometers is calculated as:

r) $$\textbf{Total Cost (GCMA)} = \textbf{Cost}_{TA} + \textbf{Cost}_{TB} + \textbf{Cost}_{TC}$$

s) The Total Cost is divided into Central (TA), Intermediate (TB), and External (TC) zones, where T stands for total GCMA and S stands for Sample. Each cost for each zone is defined as:

t) $$\mathbf{Cost_T = Cost_S * \frac{Lane{-}km_T}{Lane{-}km_S}}$$

u) The Unit Cost (UC) for each area is defined as:

v) $$\mathbf{UC_S = \frac{Cost_S}{Lane{-}km_S}}$$

w) Thus, we get: $\boxed{Cost_T = UC_S * Lane\text{-}km_T}$

x) Assuming that the UC is proportional to the V/C ratio, then:

y) $$\mathbf{\frac{UC_A}{UC_B} = \frac{V/C_{SA}}{V/C_{SB}}}$$

z) $$\mathbf{\frac{UC_B}{UC_C} = \frac{V/C_{SB}}{V/C_{SC}}}$$

aa) Substituting one unit cost for the other:

bb) $$\boxed{\mathbf{UC_B = UC_A * \frac{V/C_{SB}}{V/C_{SA}}}}$$

cc) $$\mathbf{UC_C = UC_B * \frac{V/C_{SC}}{V/C_{SB}} = \left[UC_A * \frac{V/C_{SB}}{V/C_{SA}}\right] * \frac{V/C_{SC}}{V/C_{SB}}}$$

dd) $$\boxed{\mathbf{UC_C = UC_A * \frac{V/C_{SC}}{V/C_{SA}}}}$$

ee) Writing the above for only the sample roads yields:

ff) $\text{Cost}_S = UC_A * \text{Lane-km}_{SA} + UC_B * \text{Lane-km}_{SB} + UC_C * \text{Lane-km}_{SC}$

gg) Given that Cost $_S$ is 5.641 Billion LE based on the total direct costs on the sample major corridors and given the lane-kilometers in Table 4.10, we get:

hh) $$\text{Cost}_S = 5.641 \text{ Billion} = UC_A * \text{Lane-km}_{SA} + UC_A * \frac{V/C_{SB}}{V/C_{SA}} * \text{Lane-km}_{SB} + UC_A * \frac{V/C_{SC}}{V/C_{SA}} * \text{Lane-km}_{SC}$$

ii) $$\text{Cost}_S = 5.641 \text{ Billion} = UC_A * \left(\text{Lane-km}_{SA} + \frac{V/C_{SB}}{V/C_{SA}} * \text{Lane-km}_{SB} + \frac{V/C_{SC}}{V/C_{SA}} * \text{Lane-km}_{SC}\right)$$

jj) $$UC_A = \frac{5.641}{\left(\text{Lane-km}_{SA} + \frac{V/C_{SB}}{V/C_{SA}} * \text{Lane-km}_{SB} + \frac{V/C_{SC}}{V/C_{SA}} * \text{Lane-km}_{SC}\right)}$$

kk) The same method is then used to calculate UC_B and UC_C.

ll) Finally, using the UC calculated above, we generalize the cost to the primary road network of GCMA:

mm) Total Cost (GCMA) = $UC_A * \text{Lane-km}_{TA} + UC_B * \text{Lane-km}_{TB} + UC_C * \text{Lane-km}_{TC}$

nn) The V/C ratios were calculated using the traffic volume results obtained from the GCMA model and the road capacities available for each sample road. In this section, we only show the calculations using the V/C ratios based on the weighted lane-kilometers; the calculations based on weighted traffic volume are not presented here, but they follow the same calculation procedure. The results for both sets of weighted V/C ratios are presented in Table F.2.

Table F.2 Average Weighted V/C Ratio by Zone for Major Corridors (2010)

- Zone	e) V/C Weighted by Lane-Km	f) V/C Weighted by Volume
A	0.586	0.790
B	0.487	0.652
C	0.215	0.507

oo) Using the unit cost formulas developed in the methodology as discussed above, we get the following relationships:

pp) $$\frac{UC_A}{UC_B} = \frac{V/C_{SA}}{V/C_{SB}} = \frac{0.586}{0.487}$$

qq) $$\frac{UC_B}{UC_C} = \frac{V/C_{SB}}{V/C_{SC}} = \frac{0.487}{0.215}$$

rr) Substituting the above numbers in the sample roads cost, we compute the unit costs as follows:

ss) $$\text{Cost}_S\text{=5.641 Billion}= UC_A * \text{Lane-km}_{SA} + UC_A * \frac{V/C_{SB}}{V/C_{SA}} * \text{Lane-km}_{SB} + UC_A * \frac{V/C_{SC}}{V/C_{SA}} * \text{Lane-km}_{SC}$$

tt) $$UC_A = \frac{5.641*1000}{(242 + \frac{0.487}{0.586}*594 + \frac{0.215}{0.586}*27)} = 7.57 \text{Mil/Lane-km}$$

uu)

vv) $$\boxed{UC_B = UC_A * \frac{V/C_{SB}}{V/C_{SA}} = 7.57 * \frac{0.487}{0.586} = 6.29 \text{Mil/Lane} - \text{km}}$$

ww) $$\boxed{UC_C = UC_A * \frac{V/C_{SC}}{V/C_{SA}} = 7.57 * \frac{0.215}{0.586} = 2.78 \text{Mil/Lane} - \text{km}}$$

xx) The unit costs for each of the 3 zones then allow for the calculation of the total cost of congestion on the major corridors. Before extrapolating the sample cost to the entire GCMA, however, an adjustment factor is created for zone C to account for the fact that not all major corridors in that zone experience congestion, and therefore do not contribute to congestion cost. Based on the results of the GCMA model, only 82 percent of the major corridors in zone C have a V/C greater than 0.5: these are assumed to contribute to the cost of congestion. Accordingly, the total direct cost of congestion in 2010 can be calculated as follows:

yy) Total Cost (GCMA) = UCA * Lane-kmTA + UCB * Lane-kmTB + 0.82 * UCC * Lane-kmTC

zz) = 7.57 *426.67 + 6.29*467.875 +0.82 * 2.78*1403.625 = 9.56 Billion LE

aaa) The same method is used for calculating the total cost using the V/C ratios weighted by volume, resulting in a value of 12.01 Billion LE. Averaging the results of the two methods mentioned above, the cost of congestion on major corridors is estimated to be 10.79 Billion LE.

2. Other Routes

bbb) The same methodology for calculating the cost of congestion on the major corridors was adopted for the Other Routes (using V/C ratios based on weighted lane-kms). The sample cost for the Other Routes was calculated to be **0.79 Billion LE**. However, the V/C ratios used for calculating the cost of congestion for this category of roads are not obtained from the EMME model since this category is not represented in EMME due to the lack of data. Hence, the same V/C ratios that are used in the calculation of the cost of the sample roads of this category are used for extrapolating the cost of congestion to the entire GCMA. Tables F.3 and F.4 below present, for each zone, the Lane-Km values and the v/c ratios for the Other Routes.

Table F.3 Lane-Kilometers by Zone for Other Routes

-	g) one A	h) one B	i) one C	j) otal
Sample	50.86	71.20	7.75	129.81
Total GCMA	654.61	1028.04	3977.92	5660.57

Table F.4 Average Weighted V/C Ratio by Zone for Other Routes (2010)

-	Zone	k) V/C Weighted by Lane-Km	l) V/C Weighted by Volume
A		0.725	0.939
B		0.599	0.670
C		0.520	0.610

ccc) Assuming the following ratios as discussed in the methodology for the major corridors:

ddd) $$\frac{UC_A}{UC_B} = \frac{V/C_{SA}}{V/C_{SB}} = \frac{0.725}{0.599}$$

eee) $$\frac{UC_B}{UC_C} = \frac{V/C_{SB}}{V/C_{SC}} = \frac{0.599}{0.520}$$

fff)

ggg) The unit costs for the other routes can be calculated as follows:

hhh) $$\text{Cost}_S = 0.79 \text{ Billion} = UC_A * \text{Lane-km}_{SA} + UC_A * \frac{V/C_{SB}}{V/C_{SA}} * \text{Lane-km}_{SB} + UC_A * \frac{V/C_{SC}}{V/C_{SA}} * \text{Lane-km}_{SC}$$

iii) $$UC_A = \frac{0.79*1000}{(50.86 + \frac{0.599}{0.725}*71.20 + \frac{0.520}{0.725}*7.75)} = 6.86 \text{Mil/Lane-km}$$

jjj)

kkk) $$UC_B = UC_A * \frac{V/C_{SB}}{V/C_{SA}} = 6.86 * \frac{0.599}{0.725} = 5.66 \text{Mil/Lane} - \text{km}$$

lll) $$UC_C = UC_A * \frac{V/C_{SC}}{V/C_{SA}} = 6.86 * \frac{0.520}{0.725} = 4.92 \text{Mil/Lane} - \text{km}$$

mmm) Similar to major corridors, the extrapolation of the sample cost to the entire GCMA should take into consideration that not all other routes in zone C suffer from congestion in 2010, and therefore some roads will not contribute to the direct cost of congestion. Based on the results of the sample survey results (given that other routes are not represented in the EMME model), only **50 %** of other routes in zone 3 contribute to the cost of congestion in the GCMA. Accordingly, the total cost of congestion on other routes can be calculated as follows:

nnn) **Total Cost (GCMA) =** UC_A *** Lane-**km_{TA} **+** UC_B *** Lane-**km_{TB} **+** UC_C *** 0.5 *Lane-**km_{TC}

ooo) **= 6.86 *654.61 + 5.66*1028.4 + 4.92* 0.5 * 3977.92 = 20.09 billion LE**

ppp) The same method is used to calculate the total cost using the weighted by volume V/C ratio, resulting in **19.85 billion LE**. Averaging the results of the two methods mentioned above, the cost of congestion on other routes is estimated to be 19.97 billion LE. Combined with the major corridors, this results in total direct costs in the GCMA for 2010 of 30.76 billion LE.

F.2 Forecasting to 2030

qqq) The major difference between 2010 and 2030 calculations is that prior to extrapolating the sample cost to the entire GCMA in 2030, we first need to forecast (i.e. adjust) the 2010 sample costs on major corridors and other routes to the year 2030, in order to account for the increase in traffic volume on these sample roads. The following is a description of the procedure used to do this forecast (adjustment):

1.0 In 2010, the sample unit costs for each of the 3 zones were calculated using the total sample cost on major corridors and other routes. The total sample cost on major corridors in 2010 was **5.641 billion LE**. This number (**5.641 billion LE**) was used to calculate the unit costs for major corridors (for each of the 3 zones), resulting in the following unit costs:

- UC_A **= 7.57 Mil/Lane-km**
- UC_B **= 6.29 Mil/Lane-km**
- UC_C **= 2.78 Mil/Lane-km**

2.0 In 2030, this total sample cost on major corridors (**5.641 billion LE**) should be increased to reflect the additional cost of congestion caused by the additional traffic volumes on the sample roads. As explained earlier when presenting the methodology for estimating the cost of congestion on the 2010 sample roads, congestion costs are a function of average speeds on these roads. To estimate the cost of congestion on these sample roads in 2030, the speeds on these sample roads in

2030 must be estimated. However, given that estimating the average speeds on the sample roads is not feasible due to travel model limitations, another method of estimating the cost of congestion on the sample roads has been adopted. This method follows the assumption that congestion costs are a function of speed, which in turn is a function of the V/C ratio on these roads. Therefore, the additional cost of congestion on the sample roads in 2030, which is caused by the additional traffic volumes, can be captured by using the V/C ratios obtained from the traffic model (average of the 3 zones) for the years 2010 and 2030 as follows:

- **Rate of increase in sample cost in 2030 compared to 2010**
- **=[avg. v/c in 2030] / [avg. v/c in 2010]**

3.0 If we calculate this average rate for the three zones, this will give us a rate of increase in sample cost of **1.98**.

4.0 We can now use this rate to calculate the 2030 total sample cost on major corridors as follows:

- **2030 Sample Cost on Major Corridors = 1.98 * 5.641 = 11.17 billion LE.**

5.0 The new sample cost is then scaled down to take into account the presence of Metro Line 3. Based on the analysis of the impact of the metro line, the new sample costs are calculated to be 90% of the 11.17 billion LE (10.09 billion LE).

6.0 Using the new 2030 sample cost, we can now calculate the 2030 unit costs and then extrapolate the cost to the entire GCMA as described in the previous section.

rrr) The results of these calculations are shown in Table F.5.

Table F.5 Direct Cost of Congestion on Major Corridors (2030)

- Weighted by:	Extrapolated Using V/C	m)	Cost (Billion LE)
volume			25.89
lane-km			22.10
Average			24.00

sss) As for Other Routes, and as was discussed earlier, it was not possible to forecast the traffic on the Other Routes due to lack of available data, and due to the fact that Other Routes are not represented in the

EMME model. This implies that the 2030 cost of congestion on Other Route should be calculated by a different method.

ttt) The following method was used:

1.0 As shown earlier, the 2010 total cost of congestion in the GCMA was estimated to be 30.76 billion LE, distributed as follows: 10.79 billion LE on the major corridors (i.e., 35.1% of the total cost) and 19.97 billion LE on the other routes (i.e., 64.9% of the total cost).

2.0 In 2030,the total cost of congestion on major corridors was estimated to be **24.00 billion LE**. Using the percent distribution of the total cost between major corridors and other routes in 2010, we can assume that the **24.00 billion LE** cost on major corridors account for 35.08% of the total cost in 2030. We can use this information to calculate the 2030 total direct cost of congestion as follows:

- **2030 Total Cost = 24.00 / 0.3508 = 68.40 billion LE.**

3.0 To calculate the total cost on other routes:

- **2030 Total Cost on Other Routes= 68.40 – 24.00 = 44.40 billion LE.**

uuu)

16.0 APPENDIX G

- **Emission Rate Tables**

Table G-1 CO Emissions (g/km)

km/hr	PC	Taxi	Minibus	Bus	Med Truck	Heavy Truck	Weighted Avg.
4.0	27.96	9.90	0.98	17.96	6.76	7.11	21.787
8.0	16.79	5.95	0.59	10.78	4.06	4.27	13.080
16.1	11.25	3.98	0.40	7.22	2.72	2.86	8.763
24.1	9.44	3.34	0.33	6.06	2.28	2.40	7.357
32.2	8.31	2.94	0.29	5.34	2.01	2.11	6.479
40.2	7.14	2.53	0.25	4.58	1.73	1.81	5.562
48.3	6.67	2.36	0.23	4.28	1.61	1.70	5.198
56.3	6.11	2.17	0.21	3.93	1.48	1.55	4.765
64.4	5.64	2.00	0.20	3.63	1.37	1.43	4.398
72.4	5.35	1.90	0.19	3.44	1.29	1.36	4.170
80.5	5.23	1.85	0.18	3.36	1.27	1.33	4.077
88.5	5.24	1.86	0.18	3.37	1.27	1.33	4.083
96.6	5.37	1.90	0.19	3.45	1.30	1.37	4.188
104.6	5.60	1.98	0.20	3.60	1.35	1.42	4.365
112.7	6.08	2.15	0.21	3.91	1.47	1.55	4.740
120.7	7.87	2.79	0.28	5.06	1.90	2.00	6.136

Table G-2 VOC Emissions (g/km)

km/hr	PC	Taxi	Minibus	Bus	Med Truck	Heavy Truck	Weighted Avg.
4.0	6.61	1.03	0.24	6.62	4.29	4.74	5.172
8.0	3.45	0.54	0.12	3.45	2.24	2.47	2.699
16.1	1.87	0.29	0.07	1.87	1.21	1.34	1.463
24.1	1.34	0.21	0.05	1.35	0.87	0.96	1.051
32.2	1.07	0.17	0.04	1.07	0.70	0.77	0.840
40.2	0.89	0.14	0.03	0.90	0.58	0.64	0.700
48.3	0.77	0.12	0.03	0.77	0.50	0.55	0.601
56.3	0.67	0.10	0.02	0.67	0.44	0.48	0.527
64.4	0.60	0.09	0.02	0.60	0.39	0.43	0.470
72.4	0.55	0.09	0.02	0.55	0.36	0.39	0.428
80.5	0.51	0.08	0.02	0.51	0.33	0.37	0.398
88.5	0.48	0.07	0.02	0.48	0.31	0.34	0.376
96.6	0.46	0.07	0.02	0.46	0.30	0.33	0.360
104.6	0.45	0.07	0.02	0.45	0.29	0.32	0.351
112.7	0.45	0.07	0.02	0.45	0.29	0.32	0.354
120.7	0.49	0.08	0.02	0.49	0.32	0.35	0.380

Table G-3 NOx Emissions (g/km)

km/hr	PC	Taxi	Minibus	Bus	Med Truck	Heavy Truck	Weighted Avg.
4.0	2.49	2.61	4.64	33.22	6.91	23.59	3.609
8.0	1.75	1.84	3.26	23.36	4.86	16.59	2.538
16.1	1.31	1.38	2.44	17.48	3.64	12.42	1.900
24.1	1.10	1.16	2.05	14.69	3.06	10.43	1.596
32.2	0.95	1.00	1.78	12.73	2.65	9.04	1.383
40.2	0.85	0.89	1.58	11.33	2.36	8.05	1.231
48.3	0.72	0.76	1.34	9.61	2.00	6.82	1.044
56.3	0.67	0.70	1.25	8.93	1.86	6.34	0.970
64.4	0.64	0.67	1.19	8.53	1.78	6.06	0.927
72.4	0.63	0.66	1.17	8.38	1.74	5.95	0.910
80.5	0.64	0.67	1.20	8.57	1.78	6.09	0.931
88.5	0.65	0.69	1.22	8.74	1.82	6.20	0.949
96.6	0.66	0.70	1.23	8.84	1.84	6.28	0.961
104.6	0.68	0.71	1.27	9.08	1.89	6.45	0.987
112.7	0.73	0.76	1.36	9.71	2.02	6.89	1.055
120.7	0.80	0.84	1.48	10.63	2.21	7.55	1.155

Table G-4 PM_{10} Emissions (g/km)

km/hr	PC	Taxi	Minibus	Bus	Med Truck	Heavy Truck	Weighted Avg.
4.0	0.03	0.31	0.32	6.90	2.34	4.39	0.363
8.0	0.02	0.21	0.22	4.76	1.61	3.03	0.250
16.1	0.02	0.16	0.17	3.69	1.25	2.35	0.194
24.1	0.01	0.15	0.16	3.34	1.13	2.12	0.175
32.2	0.01	0.13	0.14	2.94	1.00	1.87	0.155
40.2	0.01	0.10	0.11	2.27	0.77	1.44	0.119
48.3	0.01	0.09	0.10	2.13	0.72	1.35	0.112
56.3	0.01	0.09	0.10	2.05	0.69	1.30	0.108
64.4	0.01	0.09	0.09	1.99	0.67	1.26	0.104
72.4	0.01	0.09	0.09	1.97	0.67	1.25	0.104
80.5	0.01	0.09	0.09	2.00	0.68	1.27	0.105
88.5	0.01	0.09	0.10	2.05	0.69	1.30	0.108
96.6	0.01	0.09	0.10	2.10	0.71	1.33	0.110
104.6	0.01	0.10	0.10	2.18	0.74	1.39	0.115
112.7	0.01	0.10	0.11	2.35	0.80	1.49	0.123
120.7	0.01	0.12	0.13	2.76	0.94	1.76	0.145

17.0 APPENDIX H

- **Literature Review and Equations for Suppressed Demand, Agglomeration Analysis, and Housing Demand**

H.1 SUPPRESSED DEMAND

vvv) Schiffer, Steinvorth, and Milam performed a more recent meta-analysis of induced travel studies to identify short- and long-term elasticities of VMT with respect to changes in traffic lane-miles.[39] They concluded that the induced travel effect exists and that: "The elasticity of VMT with respect to added lane-miles or reductions in travel time is generally greater than zero and the effects increase over time." They also concluded that:

www) Short-term induced travel effects are smaller than long-term effects. As measured by the increase in VMT with respect to an increase in lane-miles, short-term effects have an elasticity range from near zero to about 0.40, while long-term elasticities range from about 0.50 to 1.00.

xxx) Litman provides a more recent review of induced demand in theory and practice.[40] He states:

yyy) Research indicates that generated traffic often fills a significant portion of capacity added to congested urban road. Generated traffic has three implications for transport planning. First, it reduces the congestion reduction benefits of road capacity expansion. Second, it increases many external costs. Third, it provides relatively small user benefits because it consists of vehicle travel that consumers are most willing to forego when their costs increase.

zzz) The USDOT Highway Economic Requirements System (HERS) investment analysis model uses a travel demand elasticity factor of –0.8 for the short term, and –1.0 for the long term, meaning that if users' generalized costs (travel time and vehicle expenses) decrease by 10%, travel is predicted to increase 8% within 5 years, and an additional 2% within 20 years.[41] These were the values underpinning the *Moving Cooler* study.

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[39] Robert G. Schiffer, M. Walter Steinvorth, and Ronald T. Milam, *Comparative Evaluations on the Elasticity of Travel Demand,* Committee on Transportation Demand Forecasting, Transportation Research Board (http://www.trb.org); at http://www.trbforecasting. /papers/2005/ADB40/05-0313_Schiffer.pdf.

[40] Litman, T.; "Generated Traffic and Induced Travel; Implications for Transport Planning;" Victoria Transport Policy Institute; February 2009.

[41] Douglass Lee, Lisa Klein and Gregorio Camus (1998), *Induced Traffic and Induced Demand inBenefit-Cost Analysis*, USDOT Volpe National Transport. Systems Center (www.volpe.dot.gov).

aaaa) For NCHRP Project 25-21, Dowling et al. developed a complex modeling procedure for estimating demand changes and emissions impacts of transportation improvements.[42] The facility-specific results showed travel time and volume changes that were consistent with theory and expectation from previous studies. However, it was harder to validate the methodology's predictions for system-level (i.e., regionwide) performance. Some of the results fell within the broad range of results that have been reported in the literature. Other results fell outside the range of results reported in the literature.

bbbb) The concept of a travel time budget – that travelers allot an amount of time to travel as part of their daily activities – has been used in the past as a way to explain induced travel. Early studies suggested that individuals' travel time budgets are fixed at about 1.1 hours per day,[43] but later work by Toole-Holt et al. demonstrated that in the U.S., the average daily travel time per person increased by 1.9 min per year between 1983 and 2001, from 47.4 minutes per day in 1983 to 82.3 minutes per day in 2001, based on analysis of the National Household Travel Survey (NHTS).[44] The authors state: "Travel time increases could result from a combination of factors, including longer trips, more trips, and slower trips. The descriptive analysis in this and other work indicates that trip-making rate increases are the dominant factor." To explain this further, they add:

cccc) Increases in family and personal business trips accounted for 0.8 trips per person per day. Changes in the economy have resulted in increases of those types of trips, as Americans purchase more goods and services. Cultural expectations have shifted. That shift has been enabled by several cultural trends, including fewer children to care for and smaller household size; specialization of activities, such as eating out versus cooking at home; increased female labor force participation rates; multitasking during travel, for example, cell phone use; seeking socialization away from home; and increases in real income enabling greater activity participation. Small changes in a variety of areas can add up to significant changes in overall travel time expenditures.

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[42] Dowling, Richard G., et al., *Predicting Air Quality Effects of Traffic-Flow Improvements: Final Report and User's Guide*, NCHRP Report 535, Transportation Research Board, 2005.

[43] Mokhtarian, P., and C. Chen.*TTB or Not TTB, That is the Question: A Review and Analysis of the Empirical Literature on Travel Time (and Money) Budgets*. Institute of Transportation Studies and Department of Civiland Environmental Engineering, University of California, Davis, 2002.

[44] Toole-Holt, Lavenia, Polzin, Steven E., and Pendyala, Ram M., *Two Minutes per Person per Day Each Year: Exploration of Growth in Travel Time Expenditures*, Transportation Research record 1917, Transportation Research Board, 2005.

dddd) Further, they posit that changes in land use patterns have essentially no effect on the increased trip-making observed over the period:

eeee) *The increase in trip making (by all modes) is arguably not explained by land use patterns. Although both mode choice and trip length have land-use-related linkages in which more urban patterns could minimize vehicle and total travel, trip generation (which appears to explain the majority of travel time increases) would theoretically increase with more accessible urban environments. Hence, the growth in travel time expenditures does not appear to be substantially caused by or able to be changed by changes in land use. That could suggest caution with respect to the expectations of land use fixes for travel demand growth.*

ffff) The Toole-Holt study offers an interesting counterpoint to other studies that developed induced demand elasticities from the same data (i.e., the NHTS). The Toole-Holt study is longitudinal, while the previous survey-based studies are cross-sectional; the latter lacks the ability to observe the change in individuals' behavior directly, but assumes that it is inherent at different levels of the independent variable (lane-miles or travel time). The Toole-Holt study indicates that trip-making increased even in the face of increasing congestion over the same period. According to the annual Urban Mobility Study conducted by the Texas Transportation Institute, delay in urban areas increased from 1.09 billion hours in 1983 to 4.16 billion in 2001.[45] If the theory that demand can be induced by improving travel conditions is correct, then the opposite should also be true: degrading travel conditions should lead to suppressed demand, yet this clearly did not happen, or at a minimum, the effect was swamped by other exogenous factors.

gggg) Stathopoulos and Nolan considered the emissions impacts of two types of traffic flow improvements (lane addition at a bottleneck merge point and signal coordination) using the VISSIM microscopic traffic simulation model and the CMEM emissions model.[46] However, induced demand was not specifically derived as a function of the improvement; it was artificially added until the emissions equaled those assuming no induced demand was reached.

hhhh) Hymel, Small, and Van Dender used VMT data from FHWA's *Highway Statistics* correlated with congestion measures from the Texas Transportation

[45] Schrank, David, Lomax, Tim, and Turner, Shawn, *TTI's 2010 Urban Mobility Report,* http:/mobility.tamu.edu, December 2010.

[46] Stathopoulos, Fotis G., and Noland, Robert B., *Induced Travel and Emissions from Traffic Improvement Projects,* paper presented at the 82nd TRB Annual Meeting, 2002.

Institute Urban Mobility Study.[47] They estimate elasticities of statewide VMT with respect to congestion (with congestion defined as aggregate time lost due to congested road conditions, as estimated for urban areas). Their elasticities were -0.009 in the short run and -0.045 in the long run. The authors attribute the very small elasticities to the fact that the measure of travel is statewide VMT, while congestion itself is a localized phenomenon. The paper also provides elasticities of VMT with respect to highway supply (lane miles). Their long run elasticity of VMT with respect to highway supply is 0.16, very much at the low end of lane mile elasticities from other studies.

H.2 LABOR PRODUCTIVITY, BUSINESS OPERATIONS, AND AGGLOMERATION EFFECTS

iiii) Ciccone and Hall (1996) studied the relationship between agglomeration and firm-level productivity in the U.S. They posited that doubling employment density in a U.S. county increases average labor productivity by 6 percent. Similarly, Henderson (2003) employed firm-level panel data associated with machinery and high-tech industries to examine the role of various externalities brought by agglomeration on firm production. He concluded that a 10-fold increase in high-tech industry-related local plants increased labor productivity by 20 percent. In New Zealand, Mare and Timmins (2006) confirmed that labor productivity is higher for firms in locally concentrated industries compared to firms in more industrially-diversified labor markets.

jjjj) Lin, H. L et al (2011) examines the dynamics of industrial agglomeration and the effects of agglomeration on firm-level productivity in China's textile industry by using a firm-level panel dataset from 2000 to 2005 constructed from the Chinese National Bureau of Statistics. The dataset covers 22,152 textile firms from 2000 to 2005, yielding 83,801 observations. Lin, H. L et al (2001) initially established the existence of agglomeration and later estimated the effects of congestion on agglomeration. Based on conditions in the GCMA, agglomeration effects are most likely present, as are long periods of congested conditions on all studied corridors; thus it is likely that congestion is adversely affecting productivity in the GCMA.

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[47]Hymel, Kent M., Small, Kenneth A., Van Dender, Kurt, *Induced Demand and Rebound Effects in Road Transport, May 1, 2009,* http://www.socsci.uci.edu/~ksmall/Rebound_congestion_26.pdf

kkkk) The EG index (Ellison and Glaeser, 1997) was used as a measure of agglomeration for the Chinese textile industry study. The EG index, premised on Krugman (1991) is popular in economic geography literature. The EG index simultaneously accounts for an industry's share of employment in a region, the proportion of aggregate manufacturing employment in a region, as well as the market concentration of industry in the estimation of agglomeration. Other measures of agglomeration, such as the Gini Index (Krugman, 1991), may work better when the share of manufacturing employment varies significantly across the study region that the existence of agglomeration can be inferred from the Gini Index.

llll) The results of the regression analysis indicate that when the EG index increases by 0.0001, the growth rate of labor productivity will increase by 1.33% (the mean of the EG index is 0.0005). If the EG index changes by a unit standard deviation, the growth rate of labor productivity will increase by 20.02% (the standard deviation of the EG index is 0.0015). In addition, when the EG index is over 0.1015 in the quadratic model, there will be agglomeration diseconomies and labor productivity will decline. However, because the maximum value of the estimated EG index is 0.0126, there will be over-agglomeration and so it is not very likely that agglomeration diseconomies will occur. This result suggests that industrial agglomeration does have a positive impact on firm-level labor productivity in China's textile industry, while this productivity-enhancing effect decreases as the degree of industrial agglomeration increases.

mmmm) Agarwalla (2011) ascertains the existence of agglomeration economies and their role in the productivity growth in India. Agarwalla distinguished between two sources of agglomeration economies:

Industry level, or localized economies of intra-industry linkage; and

Regional level, or inter-industry urbanization economies.

nnnn) In the study, state-level data for 25 state economies in India for the period 1980/1981 to 2006/2007 were utilized to develop a panel data set for regression analysis (Table H.1).

Table H.1 Results of Econometric Analysis in India

	Manufacturing	Trade	Transport	Other Services
Intercept	1.570	1.426	-1.292	0.79
	(9.83)*	(12.48)*	(-6.79)*	(6.35)*
Urban	-0.0090	-0.032	0.0645	0.0218

	(-10.52)*	(-5.16)*	(5.34)*	(3.47)*
Urbanization Square	0.0012	0.00011	-0.001	-0.00036
	(11.22)*	(1.45)	(-6.19)*	(-4.12)
Diversity	0.773	0.375	2.0121	
	(5.01)*	(3.33)*	(7.86)*	
Localization	-0.230	-0.170	0.584	0.19
	(-4.38)*	(-6.20)*	(-12.09)*	(8.19)*
R-square	0.7923	0.8748	0.8040	0.9134

- Note: * and ** show significance at 1% and 5% levels respectively. Figures in parentheses are values of t-statistic.

oooo) A coefficient of -0.09 for the manufacturing sector indicates that a percent increase in the level of urbanization leads to a 9% reduction in the level of total factor productivity. However, due to non-linearity of the relationship (measured by urban square), urbanization economies measured by level of urbanization depict a U-shaped curve for the manufacturing sector. The study also suggests that although there are initial negative externalities for the manufacturing sector with increasing urbanization, after achieving a threshold of 37-38% urbanization, there are positive returns to manufacturing in terms of increasing the level of total factor productivity. For an initial urbanization of 10%, the elasticity of total factor productivity relative to urbanization is 6.4%-8.2%. This elasticity reduces to 1.9%-4.2% as urbanization surges from 20% to 30%. The elasticity further declines to 0.9%, as urbanization increases to about 37%-50%. Agarwalla mentions that at a lower level of urbanization, other supporting services do not develop much to help in cost reduction. Additionally, the local labor market is not adequately concentrated to provide benefits of competition to firms. This suggests that manufacturing units benefit by locating in very large urban areas, and not in small cities.

pppp) However, the trade sector shows a continuous decline in the level of total factor productivity with increase in urbanization. This suggests that there are negative externalities arising from concentration in the trade sector due to either industry concentration or urbanization. The study suggest that the elasticity of total factor productivity with respect to the level of urbanization declines as the level of urbanization increases. A 10% level of urbanization leads to an elasticity range of 2.9%-3.1%. As the level of urbanization increases from 30% to 40%, the elasticity declines and ranges between 2.3% to 2.5%.

qqqq) Graham (2006) studies the links between returns to urban density, productivity and road traffic congestion. He utilized a generalized translog production-inverse input demand function to estimate and test for the existence of variable returns to agglomeration in manufacturing, construction and service industries. To identify the impact of urban transport congestion he continues to construct measures of agglomeration that contain an implicit transport dimension and that allow the consideration of the implications of constraints on the efficiency of travel. Also, he incorporated the relative ease of accessing urban activity in the estimation of agglomeration. Consequently, Graham (2006) based his analysis on effective densities. According to Graham, an effective density measures the amount of 'activity' that is accessible from some given location.

rrrr) To model the proximity of activity, or the nearness of one ward/city to the next, he uses a measure based on straight line distance calculated using Pythagoras and the ward centroid x and y coordinates. Alternatively, he uses information on the ward/city to ward/city generalized costs of travelling by road. Consequently, the author developed two effective densities based on proximity (UDio) and travel cost (UGio). He hypothesizes that in large cities, where congestion is present, the ratio of UD to UG will tend to be relatively large because while there is a lot of activity concentrated in space, road traffic speeds are low and so the generalized cost of travelling small distances is high. In smaller towns and cities where there is less congestion and consequently higher road speeds the ratio of UD to UG will be less. In rural areas where traffic moves at free flowing speeds the ratio of UD to UG is to be at a minimum.

ssss) He estimates positive agglomeration externalities for manufacturing, construction and for each of the seven service industries. The lowest agglomeration elasticity shown in Table H.2 is for manufacturing and it is estimated to be 0.041.

Table H.2 Estimated Elasticities of Productivity with Respect to Agglomeration in the UK

Industry	Elasticity
Primary	-0.042
Food manufacturing	0.0084**
Manufacture of textiles	0.121
Manufacture of wood & wood products	0.069*
Manufacture of paper & paper products	0.121
Publishing & printing	0.105**
Manufacture of chemicals	-0.008
Manufacture of rubber & plastics	(0.155)**
Manufacture of metals & metal products	0.03

Manufacture of office machinery & equipment	0.168
Manufacture of radio, TV & communications	0.382**
Manufacture of medical & precision equipment	(0.191)**
Manufacture of motor vehicles	0.121
Electricity, gas and water	0.09
Construction	0.191**
Wholesale & retail	0.041**
Hotels and restaurants	0.224**
Transport services	0.325**
Post & telecommunications	(0.008)**
Finance & insurance	0.251**
Real estate	0.084**
IT services	0.034*
Business & management consultancy	0.298**
Architectural & engineering	0.066**
Advertising	0.137**
Labor recruitment/personnel	0.023
Public admin, education & health	0.292**
Media services	0.222**

- Note: ** - significant at 0.01, * - significant at 0.05

tttt) Ultimately, urbanization leads to increases in productivity due to clustering of firms, but at the same time, beyond a point, it also results in some diseconomies resulting from traffic congestion. Thus, from a policy perspective, the challenge is to maximize the economies of scale and scope resulting from the clustering of firms and minimize the diseconomies resulting from congestion. Land use policy, therefore, is an important tool in maximizing the positive and minimizing the negative externalities resulting from urbanization and clustering of firms.

uuuu) The EG index is defined as:

vvvv)

$$\gamma_j = \frac{\sum_k \left(S_{jk} - X_k\right)^2 - \left(1 - \sum_k X_k^2\right) \sum_i Z_{ij}^2}{\left(1 - \sum_k X_k^2\right)\left(1 - \sum_i Z_{ij}^2\right)} = \frac{G_j - \left(1 - \sum_k X_k^2\right) H_j}{\left(1 - \sum_k X_k^2\right)\left(1 - H_j\right)}$$

(1)

wwww) where:

xxxx) $G_i = Gini\ Index = \sum_{j=1}^{N} Z_j^2$ (2)

yyyy) Hi = Herfindahl Index

zzzz) γj = degree of the jth industry's agglomeration at the city/regional level.

aaaaa) Si = share of employment in industry i in a given city/region

bbbbb) Xi = share of total employment in industry i.

ccccc) Zj = sizes of plants in industry j.

ddddd) Graham (2006) studies the links between returns to urban density, productivity and road traffic congestion. To model the proximity of activity, or the nearness of one ward/city to the next, he uses a measure based on straight line distance calculated using Pythagoras and the ward centroid x and y coordinates. Alternatively, he uses information on the ward/city to ward/city generalized costs of travelling by road. The generalized cost (gij) of road travel by car from ward/city i to ward/city j is a measure of the total of all the costs faced:

eeeee) $$g_{ij} = p \times rd_{ij} + \tau_{\upsilon} \left(\frac{rd_{ij}}{s_{ij}} \right) + \sum_{c} U_c$$ (3)

fffff) where:

ggggg) p is the price or money cost per passenger kilometer and comprises the costs of operating the vehicle,

hhhhh) rd_{ij} *is the distance by road between i and j ,*

iiiii) τ_{υ} *is the value of in-vehicle time,*

jjjjj) s_{ij} *is the average speed between i and j , and*

kkkkk) U_c *is any other relevant user cost.*

lllll) The generalized cost data utilized is obtained from the UK Department for Transport (DfT). The cost data assumes constant money prices, user costs and values of time. Consequently, differences in the generalized cost of travelling from ward/city i to ward/city j , or from ward/city i to ward/city k, reflect only the differences in the relative distances and speeds of travel, not prices or values. Consequently, the author developed two effective densities based on proximity (UDio) and travel cost (UGio) shown in equations 4 and 5 respectively, for a firm in industry o located in ward i.

mmmmm) (4)

$$UD_{i0} = \frac{E_i}{r_i} + \sum_{j}^{i \neq j} \left(\frac{E_j}{d_{ij}} \right)$$

nnnnn) (5)

$$UG_{i0} = \frac{E_i}{g_i} + \sum_{j}^{i \neq j} \left(\frac{E_j}{g_{ij}} \right)$$

ooooo)

ppppp) where:

qqqqq) E is total employment,

rrrrr) r_i is an approximation of the radius of ward i and

sssss) d_{ij} is the Euclidean distance between i and j.

ttttt) The Balassa Index is defined and estimated as:

uuuuu) (6)

$$B_{ij} = \frac{e_{ij} / e_i}{e_j / E}$$

vvvvv) Where:

wwwww) eij = employment in industry i in city/governorate j

xxxxx) ei = total industry employment in city/governorate

yyyyy) ej = employment in industry i in GCMA

zzzzz) E = Total employment in GCMA

aaaaaa) The approach for doing so follows the model employed by Graham (2006). The effective density of measures is defined for proximity (UD) and travel cost (UG) for a firm in industry *'o'* and located in city *'i'* (Cairo). The departure from the Graham (2006) model stems from the transformation of Equation (7) to Equation (8) (UD*io* to UV*io*):

bbbbbb)

$$UD_{i,o} = \frac{E_i}{r_i} + \sum_{j}^{i \neq j} \left(\frac{E_j}{d_{i,j}} \right) \quad (7)$$

cccccc)

dddddd)

$$UV_{i,o} = \frac{E_i}{V_i} + \sum_{j}^{i \neq j} \left(\frac{E_j}{V_{ij}} \right) \quad (8)$$

eeeeee) where:

ffffff) r_i, is the radius of city/governorate. The radius is estimated based on Equation (9)

gggggg)

$$r = \left(\frac{Area}{\pi} \right)^{1/2} \quad (9)$$

hhhhhh) $d_{cairo,j}$ = The distance between Cairo and any reference city/governorate

iiiiii) E_{cairo} = Employment in a given industry (manufacturing, agriculture, etc.) in Cairo

jjjjjj) E_j = Total employment in the referenced city/governorate

kkkkkk) V_{ij} = difference between the free-flow travel speed and travel speed at congested periods along the road corridor between cities/governorates i and j. V is a measure of congestion and a proxy for measurement of generalized travel cost.

llllll)

mmmmmm)

$$GC = \frac{1}{S} xVoT \quad (10)$$

nnnnnn) Where,

oooooo) GC = Generalized cost of travel;

pppppp) S = Observed travel speed; and *qqqqqq) VoT = Value of Time*

rrrrrr)

ssssss) Delay Cost (DC) is estimated based on Equation 9.

tttttt) $$DC = \left(\frac{1}{S_{FF}} - \frac{1}{S_{cong}} \right) x\, VoT$$ (11)

uuuuuu) Where

vvvvvv) S_{FF} = *Free-flow speed*

wwwwww) S_{cong} = *Peak period speed*

xxxxxx) *VoT = Value of Time for Commute*

yyyyyy) For Corridor 1,

zzzzzz) $$DC = \left(\frac{1}{61.2} - \frac{1}{29.7} \right) x\, 9.4$$ = -0.16 LE/hr

1. Housing Demand

aaaaaaa) Expected congestion is sufficiently important to be a factor in one of a household's most important decisions, the selection of residential location. While the prospect of using housing prices to capture congestion as a locational amenity is not new, there appear to be relatively few studies to date that test hypotheses concerning the capitalization of traffic congestion into house prices.

bbbbbbb) Table H.3 summarizes four recent studies and highlights the inconsistencies in the results across the four studies. Hughes and Sirmans (1992) use an actual measure of traffic in close proximity to residential location. They test two models: the first relies on an actual traffic count as an indicator for congestion. The second tests the sign and significance of a high/low traffic dummy variable that replaced the actual traffic count.

ccccccc) The results provide evidence that high levels of traffic have a significant negative impact on property values. A vehicle count as a gauge of congestion may be misleading because there is no reflection of road capacity. Guild, Schwann, and Whitehead (1998) recognize that there are several components to the cost of transport, including trip distance, traffic volume, and the value of commuting time. Two hypotheses are tested. The first is that housing prices should be higher for properties closer to frequent travel destinations because this reflects increased accessibility. To measure this effect, the authors use the distance traveled by an individual from home to the central business district. The second hypothesis suggests that worsening congestion puts downward pressure on nearby property values. To test this hypothesis, the change in traffic volume over time is used as a proxy for worsened congestion. Their findings largely contradict their expectations; properties further away from the central business district were more valuable than were closer properties, rejecting their first hypothesis. In addition, property prices in this study area do not respond to worsening congestion.

ddddddd) Bateman et al (2001) test the effects of traffic congestion on housing values in Glasgow to determine the compensation that households would receive as a result from the noise, vibration, smell, fumes, smoke, artificial lighting and discharge onto the land of solid and liquid substances. Many variables are used to represent a measure of the property's exterior structural qualities. The primary focus of the paper is on the effects of specific variables considered as proxies for accessibility. These variables are defined as the ease with which local amenities could be reached from each property. Three separate accessibility measures are used: car travel time, walking distance, and straight-line distance. The coefficient on the car travel time variable to the city center, rail station and nearest local show are all positive, implying that property prices are higher for a house further away from the city than to a similar house closer to the city. The authors also find that at some point driving too long would be a disamenity.

Table H.3 Four Recent Studies

- A uthors	n) ongestion Variable	o) ongestion Coefficient	p) Interpretatio n	q) onsistency with Accessibility Hypothesis
Hughes and Sirman (1992)	Vehicle Count	-0.0771 (sig 5%)	7.7% decrease in housing values for each additional car	Yes
	Dummy Variable	-0.0848 (sig 5%)	8.82% decrease in housing values for high traffic properties	Yes
Guild, Schwann and Whitehead (1998)	Change in Traffic Volume	2.131 (not sig)	2.13% increase in housing values when traffic volumes increase by 1%	No
Bateman et al (2001)	Commute Time	0.078 (sig 5%)	For every additional minute added to the commute, housing values increase by 7.8%	No

Tse and Chan (2003)	Commute Cost	-92.56 (sig 5%)	A dollar reduction in the commuting cost would raise the property price by $11.96/ft^2	Yes
	Commute Time (linear)	18.29 (sig 10%)	A one minute reduction in the commuting time would raise property prices by $2.13/ft^2	Only when non-monotonicity was assumed
	Commute Time (negative square)	-0.219 (sig 5%)		

eeeeeee) To relax the assumption of constant speed, Brounen et al (2010) examines the effects of traffic congestion on local house prices around Utrecht, the fourth largest populated city and the second largest employer in the Netherlands. Therefore, Utrecht attracts labor from its environs. The authors combined data sets covering 125,159 housing transactions from the Dutch Association of Real Estate Agents and nine years of detailed traffic information for the study. The combined data sets helped the authors examine how travel time delay (arising from congestion) is factored into property value, especially during periods where congestion has increased in excess of three-fold. The authors controlled for two important variables in this study, accessibility and availability of public transport, that could potentially confound the relationship between congestion and housing prices. The authors found that people are willing to live more in congested areas. What this suggests is that people want to live close to their place of work, especially if getting to work requires spending time standing still on congested roads.

fffffff) Kockelman and Kalmanje (2004) explores the possible transportation and property value impacts of a new congestion management policy called credit-based congestion pricing (CBCP) for Austin, Texas. The trip-based welfare impacts of CBCP for three scenarios (full network pricing, major highway pricing only, and no pricing) modeled to identify households and neighborhoods that will benefit most and least from implementation of CBCP. The home sales price model was used to predict changes in average home values across Austin locations upon implementing congestion pricing. The study concluded that residential property prices are estimated to fall marginally, with some areas near the central business district (CBD) gaining if congestion pricing were implemented on major highways only.