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Air Quality Governance in the ENPI East Countries

"Draft Report on air quality monitoring network for Tbilisi"

Activity 3 Report

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Summary

PROJECT TITLE:	Draft Report on air quality monitoring network for Tbilisi
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COUNTRY:	Georgia

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NAME OF KEY EXPERT MONITOR AIGAKĀLA

CONTENTS

1. LIST OF ABBREVIATIONS AND ACRONYMS

Atmospheric Dispersion Modelling System	ADMS
Degrees by centigrade	^{0}C
Carbon Monoxide	CO
Methane	CH_4
Caucasus Environmental NGO Network	CENN
European Union	EU
European Neighbourhood Partnership Initiative	ENPI
Megajoule	MJ
Gigajoule	GJ
Grams per second	g/s
Lead	Pb
Maximum Allowable Concentration	MAC
Metre	m
Cubic metre	M^3
Millimetre	mm
Micrograms per cubic metre	$\mu g/m^3$
Milligrams per cubic metre	mg/m^3
Manganese dioxide	MnO_2
Ministry of Environmental and Natural Resources Protection	MoENRP
National Environmental Agency	NEA
Nitrogen dioxide	NO_2
Nitrogen oxides	NO_x
National Environment Agency	NEA
Non-methane volatile organic compounds	NMVOC
Ozone	O_3
Particulate Matters	PM
SEAP	Sustainable Energy Action Plan
Square kilometre	km^2
Sulphur dioxide	SO_2
Tonnes per year	t/y
Total Suspended Particulates	TSP
Volatile organic compounds	VOC

2. SUMMARY

The report outlines the approach, method, guidance, tools and data used in designing the air quality monitoring network for Tbilisi.

The design is based upon the population density, detail emissions inventory for the city, historic ambient monitoring data and on the application of an ADMS-Urban model.

A preliminary assessment of air quality across Georgia identified that pollutants regulated by the CAFE Directive on ambient air quality are likely to be exceed LAT, UAT and LV’s throughout areas of Georgia. This report has been a focused study on the likelihood and location of such exceedances in the city of Tbilisi in order to best identity the most sensitive receptors and relevant sampling locations.

The data used in this study were as follows:

- National Network monitoring measurement data 2008 to 2013
- National Emission Inventory Data for Georgia 2012
- Dispersion modelling of point sources, area sources and mobile sources of air pollutants.
- Short term diffusion tube data

Following specific monitoring requirements are recommended: 5 fixed monitoring locations are established, monitoring NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$, lead, O_3, benzene.

The monitoring sites will include urban background location in Tbilisi, roadside location, industrial/ traffic sampling point of road transport emissions in Agmashenebeli Street, suburban location and maximum point of ground concentrations in the city.

3. INTRODUCTION

BACKGROUND AND SCOPE OF THE REPORT

The Air Quality Governance project in (ENPI) East Countries is currently assisting Georgia with the preparation and implementation of a national pilot project to perform a feasibility study on the introduction of a national air quality monitoring system. The intention is that the pilot project will allow Georgia to develop a national monitoring network and set relevant guidelines in compliance with EU standards.

The objective of the feasibility study is to seek to improve Georgia’s current air quality legislation, ambient air quality monitoring network as well as the assessment and reporting of ambient air quality so that it converges with European legislation and regulations thereby contributing to the improved air quality, whilst strengthening implementation and compliance.

This report is the third deliverable under the project and serves to elaborate recommendation for designing air quality monitoring network in Tbilisi, based on the application of ADMS-Urban model, population factor and emission inventory analysis and analysis of existing ambient air quality data. The report will provide recommendation for urban air quality monitoring network design for Tbilisi, describing minimum and maximum number of sampling points and their recommended spatial distribution.

4. METHODOLOGY FOR AIR QUALITY ASSESSMENT FOR TBILISI

DATA USED

This assessment is based on the desk study of ambient air quality in Tbilisi. Following data were used, while developing the report: i) air quality monitoring data collected by the National Environment Agency (NEA) for 2008-2012,; 2013ii) stationary diffused source pollution data for 2013 provided by the Air Protection Service of the Ministry of Environmental and Natural Resources Protection of Georgia (MoENRP)and emission inventories using ADMS-URBAN and EMIT software; iii) desk study and analysis of existing data on transport and municipal gas consumption patterns contained in Sustainable Energy Action Plans for Tbilisi and Emission Inventory and Preliminary Modelling Study for Tbilisi; iv) output data of preliminary urban air quality assessment for Tbilisi conducted in 2012-2013 and output data of URBAN-ADMS modelling of pollutants concentrations conducted under this study.

DESCRIPTION OF ADMS-URBAN DISPERSION MODEL

ADMS-Urban software used for modelling Tbilisi urban air quality is a joint product of CERC and UK Meteorological Office. It combines the basic model, containing point, line, area and volume source modules, with fully integrated street canyon, complex terrain and buildings modules, a dry deposition module, a chemistry module for predicting nitrogen, sulphur and ozone, and emissions database. It is based on three-dimensional quasi-Gaussian dispersion model. ADMS-Urban can describe in detail what happens from the street scale to the city-wide scale, taking into account the whole range of relevant emission sources: traffic, industrial, commercial, domestic and other less well-defined sources. By inputting emission source parameters, meteorological data, including diurnal patterns, terrain features, traffic flows, pollutants' background concentrations and background emissions, the model can generate annual average concentrations of pollutants, exceedances of limit values, percentiles, may compare actual values with air quality standards and monitoring data, may make future predictions and define low emission zones for traffic management (more detailed description of the model is given in report 1).

5. AIR QUALITY DISPERSION MODEL INPUT AND OUTPUT DATA FORTBILISI

RESULTS OF PRELIMINARY AIR QUALITY MODELLING

Under the on-going Dutch government-funded project: "Air Quality Monitoring in Tbilisi" (PSOM10/GE/11) aiming at building capacities for improved air quality monitoring in Tbilisi, CERC has compiled preliminary emission inventories using EMIT-software and conducted preliminary emissions dispersion and air quality modelling for NO_2, SO_2 and PM_{10} using ADMS – Urban for 2009. First step was collection, processing and aggregation of activity and emissions data for various sources. This was followed by the calculation of emission rates for all major emission sources, including road transport, airport, industrial sources, and commercial and domestic gas use. Preliminarily air modelling was conducted by using emission inventories, meteorological data received from Tbilisi airport and terrain data, retrieved from Shuttle Radar Topography Mission (SRTM) dataset, providing relief elevations on a 90-m resolution, and processed to receive suitable resolution for ADMS-urban.

For major roads a network of 240 roads was modelled, using peak hour vehicle counts at 78 junctions, converting them to two-way annual average daily flow and linking each junction with assumed vehicle counts. Following this, total vehicle mileage was calculated for different types of vehicles based on transport statistics of Tbilisi SEAP and London case for goods vehicles. Below is given the break-down of vehicle mileage by vehicle types:

Table 1. Total distance travelled by different types of vehicles

Vehicle type	Estimate annual mileage (million vehicle-km)	Tbilisi fleet breakdown (%)
Cars	2984	79.4
Mini-buses	210	5.6
Buses	58	1.6
Good vehicles	505	13.5

Traffic exhaust emissions were calculated based on speed-dependant emission factors of UK Transport Department expressed as g/kg per each vehicle type, fuel type, engine size and EURO category. The speed was assumed to be 15 km/hr. Non-exhaust emissions were calculated using 2009 EMEP/EEA emissions factors. Diurnal patterns were based on London example.

For minor roads, it was assumed that 65% of total distance travelled accounted for minor roads. Thus, this 65% were distributed on 1 square km grids, based on the density of road network in each square. Exhaust and non-exhaust emissions were calculated based on emission factors used for major roads.

Figure 1.Modelled Major Roads in Tbilisi

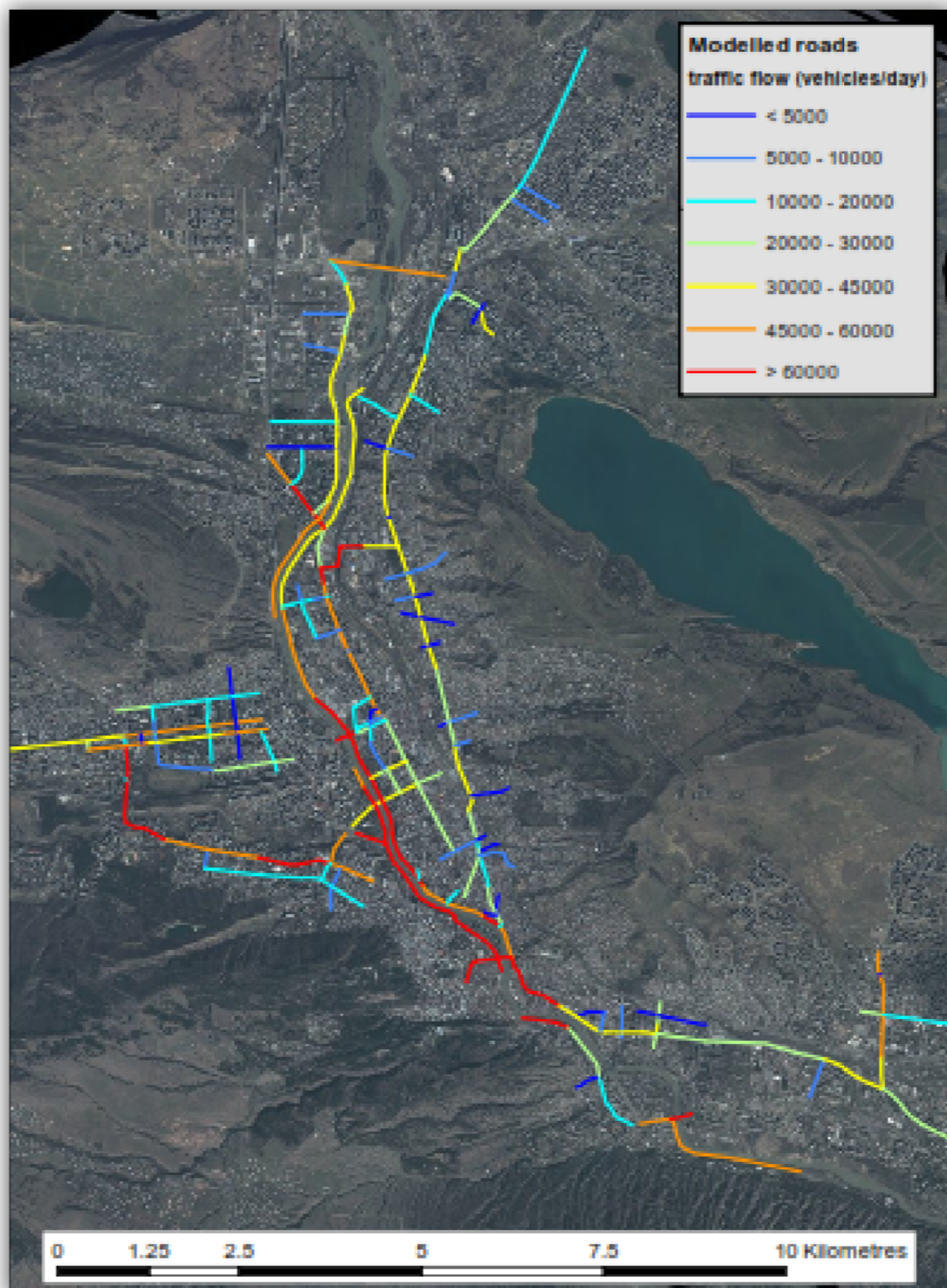
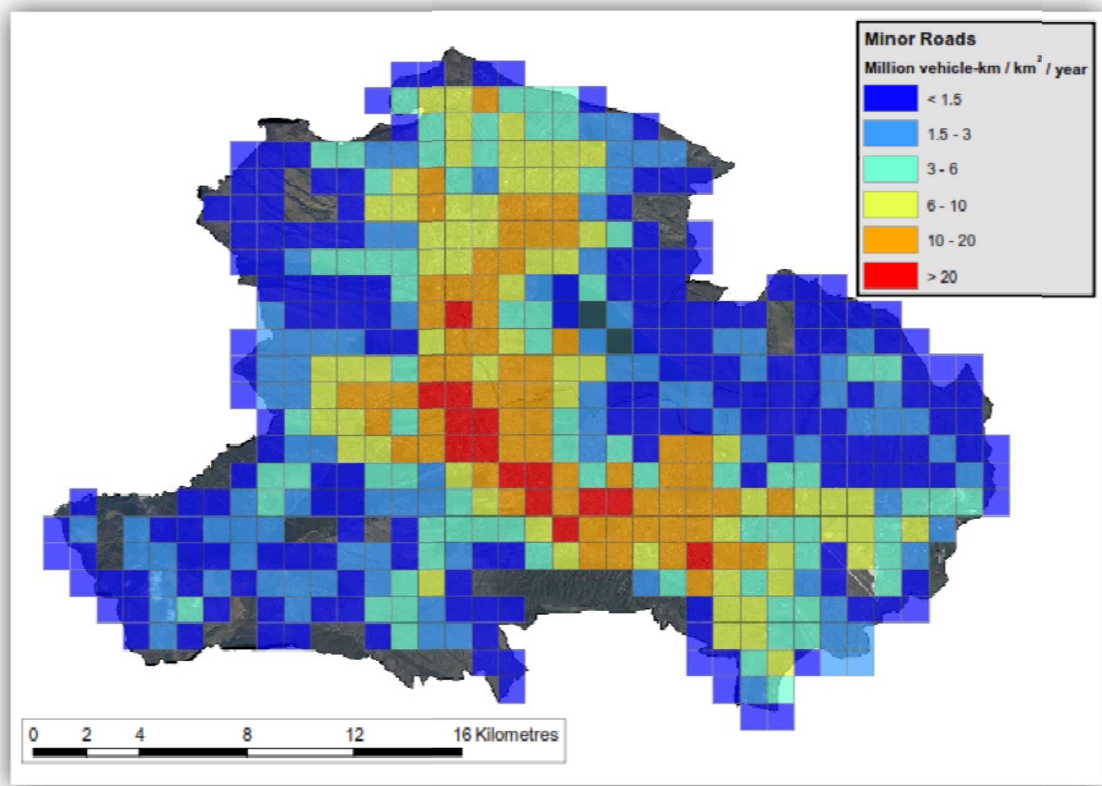


Figure 2.*Distance Travelled on Minor Roads*



Emissions, predominantly, NO_x emissions for domestic and commercial heating, were calculated using total gas consumption data for Tbilisi in 2009 SEAP reported as 273.8 million m^3, US EPA emission factors, assigning emissions to each district relative to population density and aggregating these values on 1 square km grids. This methodology is outlined in Chapter 5.2.1.2.

Industrial sources with emission rates greater than 0.5 g/s, including the mill, plasterboard production, steel works and asphalt/concrete production plants were modelled explicitly by using ADMS-Urban. Emissions from smaller sources, for which stack height were not known, were aggregated and included in the model as 1 km resolution grid sources. Diffuse sources were included as 50 square metre area sources.

In addition to emissions from mobile, industrial and area sources, emissions from aircraft sources were calculated based on 2010-2011 flight information and using emission factors of International Civil Aviation Organization (ICAO).

Figure 5.Airport Sources

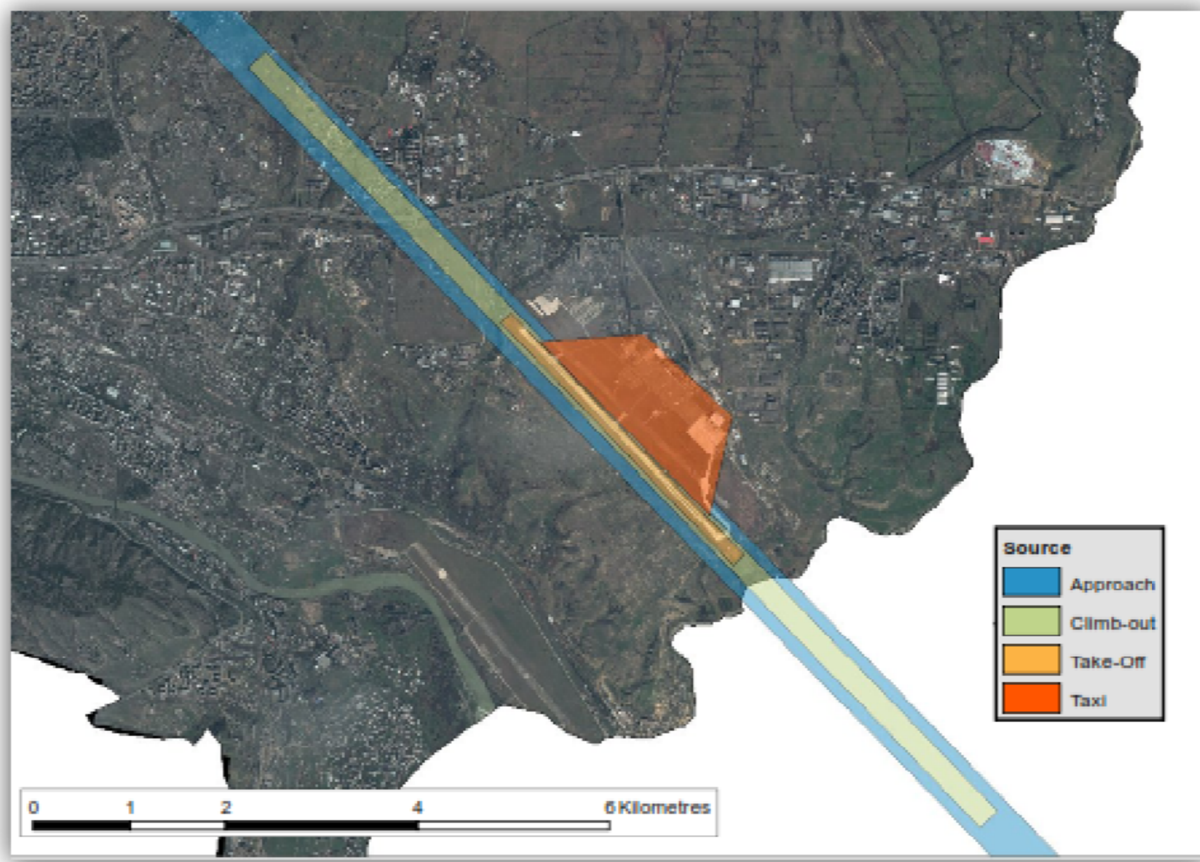


Table 2. Total emissions (Tons/Year)by different pollutants and source categories

Emission source category	*NO_x Tons/year*	*NO_2Tons/year*	*PM_{10}Tons/year*	*SO_2Tons/year*	*VOC Tons/year*	*CO Tons/year*
Airport	*92*	*10*	*0*	*7*	*9*	*86*
Gas use	*438*	*44*	*33*	*2*	*24*	*0*
Industrial diffuse sources	*0*	*0*	*5*	*0*	*0*	*0*
Industrial point sources	*31*	*3*	*287*	*192*	*292*	*346*
Major roads	*4147*	*319*	*245*	*350*	*4220*	*28740*
Minor roads	*7352*	*565*	*435*	*621*	*7481*	*50950*
Total	**12060**	**941**	**1007**	**1172**	**12030**	**80120**

Under the modelling exercise, contour maps of NO_x, SO_2 and PM_{10} concentrations were calculated for the Tbilisi built-up area with a size of 20 km x 25km. Annual average concentrations of pollutants were calculated on regular grids of output points with 200 m resolution for large-scale maps and with 50m resolution for detailed maps, with additional points added near major roads where the concentration gradients are the highest.

The modelling results showed exceedances of EU NO_x average limit value of 40 µg/m3across the majority of central area of the city. Likewise, PM10 concentrations exceeded average limit value of 40 µg/m3 along the major roads; SO2 concentrations were likely to exceed 24-hour mean Georgian MAC of 50 µg/m3 along major roads.

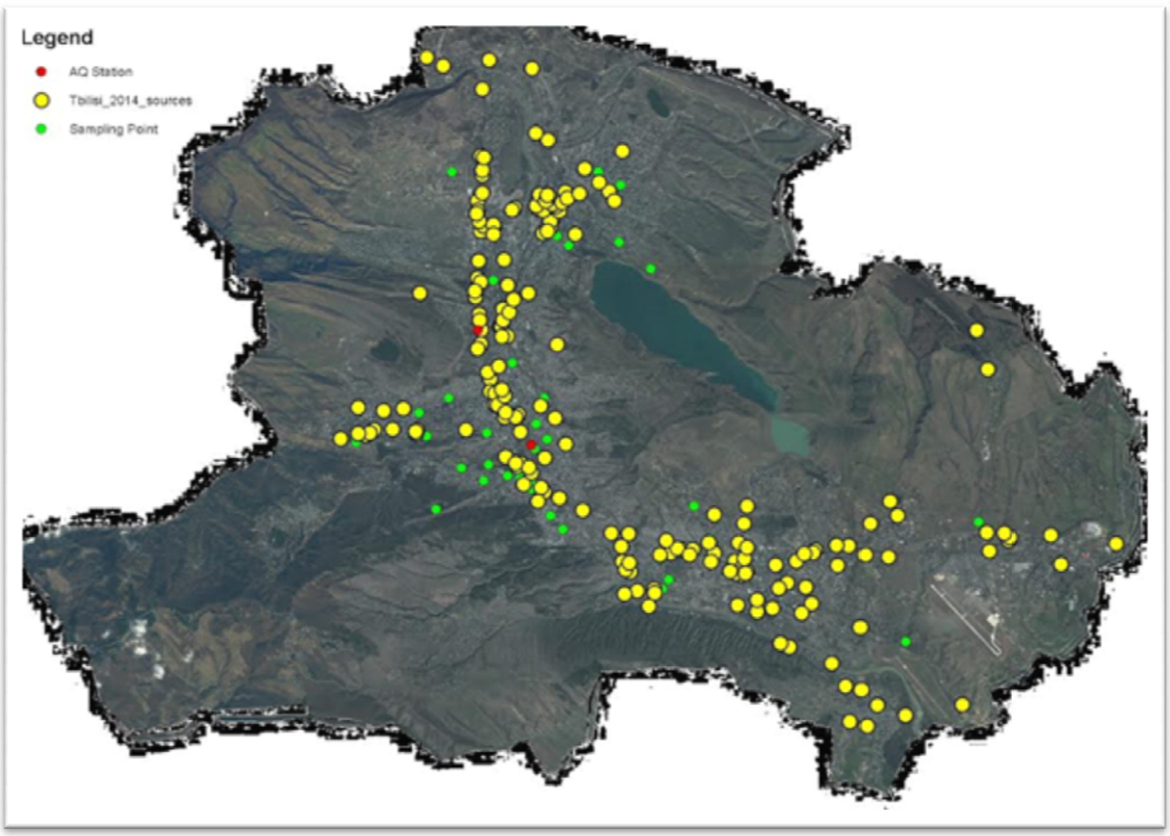
Air Quality Dispersion Model Input Data for Tbilisi under Current Study

5.2 1Emission Inventory Data

5.2.1.1 Emissions from Stationary and Diffuse Sources

2013 data on stationary and diffuse pollution sources were provided by the Air Protection Service of the Ministry of Environmental and Natural Resources Protection with indication of major stack parameters and geographic coordinates. In total, there were 210 operating sources in 2013.

Figure 13.2013pollutant releases to air from a facility



Emissions from the abovemap were calculated using EMIT software. Of all sources, only 12 had emission rates greater than 0.3g/s (See table 3 below). Only 6 stationarysources had emission rates greater than 0.5 g/s for any of the following substances: NO_x, TSP and SO_2.These were explicitly modelled in ADMS-Urban. Others were modelled as grid sources.

Table 3. 2013 Industrial Sources with total emission rates over 0.5 g/s

#	Owner/operator	Address	Activity type	Emission rate, total g/s	Total, t/y	Dust	SO2	Nox	CO	VOCs	Other

1	JSC, #1 Road company Tbilisi	KvemoPhonichala	Asphalt-concrete production	12.72	95.651	75.947	1.531	5.234	12.939	0	0
2	JSC, #2 Road company Tbilisi	10 Shusha str.	Asphalt-concrete production	9.88	74.291	62.097	0.947	3.239	8.008	0	0
3	Gzamsheni, Ltd	Sadguri valley	Asphalt-concrete production	3.52	26.436	14.941	0	2.68	6.625	2.19	0
4	Kargi, Ltd	Orkhevi industrial zone	Chalk powder production	2.42	18.204	17.593	0	0.176	0.435	0	0
5	KhisSakhli (Wood house), ltd	Orkhevi industrial zone	Wood processing	2.21	16.601	16.601	0	0	0	0	0
6	Georgian building group, ltd	#29 L. Andronikashvili street	Cement production	2.12	15.905	15.905	0	0	0	0	0
7	Mshenebeli, ltd	SadguriVeli settlement	Chalk powder production	1.33	9.976	9.336	0	0.195	0.445	0	0
8	AA Plasti, ltd	KvemoAlekseevka settlement 7/25	Plaster-board production	1.26	9.466	0.157	0	0	3.41	0	5.899
9	Reinforced-concrete tiles plants, ltd	Cairo 6	Tile production	1.13	8.477	0.64	0	2.257	5.58	0	0
10	Tbilaviamsheni TAM, JSC	181 B. Khmenitsky street	Machinery manufac-turing	1.04	7.844	0.426	0	1.425	1.832	3.796	0.365
11	Hydelberg Concrete Georgia, ltd	Phonichala	Concrete production	1.02	7.63	7.63	0	0	0	0	0
12	Caucasus Concrete 2007, ltd	SadguriVeli	Concrete production	0.88	6.626	6.626	0	0	0	0	0
13	Kazbegi 1881, ltd	68a D. Uznadzestr	Beer production	0.82	6.151	2.205	0.074	1.113	2.758	0	0
14	Zanduri, ltd	#16 Moscow Avenue	Mill production	0.74	5.6	5.6	0	0	0	0	0
15	Hydelberg Concrete Georgia, ltd	Gldani-Nadzaladevi district	Concrete production	0.68	5.102	5.102	0	0	0	0	0
16	Alkana, ltd	Orkhevi Industrial Zone	Cement production	0.63	4.73	4.73	0	0	0	0	0
17	Skhmuli, ltd	37 Kindzmaraulistr	Aluminum tiles production	0.56	4.212	2.26	1.339	0.144	0.468	0.001	0

#	EXITVEL	EXITTEMP	HEIGHT	Opwks	Ophrs	D	Production type	X	Y	TSP(t/yr)	C(t/yr)	SO2(t/yr)	NOX(t/yr)	CO(t/yr)	VOC(t/yr)	TSP g/s	CH g/s	SO2 g/s	NOX g/s	CO g/s	VOC
1	15	100	50	52	168	1	Gypsum board production	492943	4614973	2.096	0.000	0.000	17.705	43.771	9836.114	0.060	0.000	0.000	0.509	1.258	282.
2	15	100	50	52	168	1	Oil processing, gas transportation	488225	4615022	0.000	0.000	0.000	1.332	3.293	1883.970	0.000	0.000	0.000	0.038	0.095	54.1
3	4.626	30	4	52	168	0.5	Lime production	482050	4617750	87.166	9.951	43.552	1.806	73.295	0.065	2.506	0.286	1.252	0.052	2.107	0.00
4	15	100	50	52	168	1	Asphalt and concrete production	492105	4614648	81.356	0.047	0.997	3.407	8.424	0.000	2.339	0.001	0.029	0.098	0.242	0.00
5	15	100	50	52	168	1	Asphalt and concrete production	482623	4628229	66.684	0.038	1.128	3.856	9.532	0.000	1.917	0.001	0.032	0.111	0.274	0.00
6	15	100	50	52	168	1	Oil storage and retail sale	489250	4615202	0.000	0.000	0.000	0.000	0.000	60.139	0.000	0.000	0.000	0.000	0.000	1.72
7	15	100	50	52	168	1	Locomotive manufacturer factory	482856	4625083	21.393	0.000	0.198	0.283	17.182	5.315	0.615	0.000	0.006	0.008	0.494	0.15
8	15	100	50	52	168	0.5	Oil storage and retail sale	483002	4626271	0.000	0.002	0.005	0.027	0.017	32.417	0.000	0.000	0.000	0.001	0.000	0.93
9	15	100	50	52	168	1	Liquified gas retail service	482652	4625951	0.000	0.000	0.000	1.113	19.580	3.560	0.000	0.000	0.000	0.032	0.563	0.10
11	15	100	50	52	168	1	Commercial center	481461	4620900	19.079	0.001	0.000	0.000	0.000	0.000	0.548	0.000	0.000	0.000	0.000	0.00
12	15	100	50	52	168	1	Chalk powder production	491052	4615004	10.4495	0	0	0.1965	0.4859	0	0.30039125	0	0	0.005648776	0.013968143	

5.2.1.2Emissions from Commercial and Domestic Gas Burners

Gas Use For domestic and commercial heating loads to NO_x emission as, as well as minor emissions of Other Pollutant. Data received From Kaz trans gaz Tbilisi gives that in 2013 total gas consumption in Tbilisi was 286,289,300 m^3/y. This was used with emission Factors from US EPA AP42 documentation [1]to calculate total emissions from gas use in the city. Emissions were assigned to Each District Relative to the population density and were then aggregated onto a 1-km Grid.

Table 4. Tbilisi population size and density by districts in 2013

In2013 total gas consumption in Tbilisi was 286,289,300 m^3/y. This figure was normalized by dividing it to the total population size of the city (1,094,723)that gave per capita gas consumption value at 261.517m^3/y. Then per capita emissions were calculated by multiplying per capita gas consumption values and emission factors. Below is given the data on per capita emissions.

District	Population	Nox_t_yr	PM10_t_yr	SO2_t_yr	VOC_t_yr
Vake-Saburtalo	250920	104.99	7.98	0.63	5.77
Gldani-Nadzaladevi	327217	136.92	10.41	0.82	7.53
Isani-Samgori	310470	129.91	9.87	0.78	7.15
Old Tbilisi	97229	40.68	3.09	0.24	2.24
Didube-Chugureti	83578	34.97	2.66	0.21	1.92

[1] AP42 : Compilation of air pollutant emission factors Volume 1: Stationary point and area source, US Environmen Protection Agency, January 1995 http://www.epa.gov/ttn/chief/ap42/index.html#toc

Didgori	***10247***	***4.29***	***0.33***	***0.03***	***0.24***
Tskneti	***8324***	***3.48***	***0.26***	***0.02***	***0.19***
Tabakhmela	***4494***	***1.88***	***0.14***	***0.01***	***0.10***
Kojori	***2244***	***0.94***	***0.07***	***0.01***	***0.05***

5.2.1.3Emissions from Transport

For road transport emission inventories and emissions spatial modelling , the same road network and car fleet profile data are used as an input for 2009 ATMS-URBAN model, as the project was only able to receive 5-day vehicle counting data from Tbilisi Mayor’s Office that was not sufficient for an update of the model. However, comparing these 5-day data with 2009 data, it was concluded that they are more or less similar and accordingly, 2009 data can be used to characterize road transport intensity in 2013. Modelled road data are considered in detail in chapter 5.1 above.

Tbilisi car fleet is composed of public ground transport and private vehicles. Public ground transport is divided into busses and micro-busses. Detailed study of Tbilisi transport, conducted in 2009 under the Covenant of Mayors’ SEAP initiative[2] showed that the city commuters travelled 7,544 million passenger-kilometres in total, with 73% travelled by private cars and 27% - by public transport. Of the mobility provided by public transport, 50.3% was accounted for minibuses, 25.1% for busses and 24.6% for subway.

According to the SEAP Baseline Emission Inventoryfor2009, the bus fleet was composed of three different types of diesel-running busses including240 vehicles with fuel consumption of 55 litres per100km, 150 vehicles with fuel consumption of 38litres per100km and 544 vehicles with fuel consumption of 24 litres per100km. In total the busses have covered 58.4 million vehicle-km and served 56.9millionpeople.

The minibus fleet was composed of 2,621 vehicles in 2009. Tbilisi mini-buses have diesel-fuel engines with average fuel consumption of 12 litres per 100 km. On average minibuses travel 220 km daily and the passenger turnover is approximately twice as much as for bus network. Total distance travelled by minibuses is 210 million vehicle-km annually. The vehicles used by minibus companies are more than 20 year-old obsolete cars.

In 2009, the passenger car fleet of Tbilisi, including taxis consisted of 233,187 cars. There is no official statistics on the mobility of passenger cars. A survey conducted under the SEAP showed that average car occupancy is about 1.85 people per car. Average distance travelled is 35 km per day (12775 km per annum). Annual average distance travelled by private cars is 2978 million vehicle-km. There is also a

[2] Source: Sustainable Energy Action Plan. City of Tbilisi. 2011-2020. http://mycovenant.eumayors.eu/docs/seap/1537_1520_1303144302.pdf

municipal service car fleet, composed of about 176 vehicles travelling about 33600 km/y distance or 6 million vehicle-km. Altogether, private and municipal passenger cars travel 2984 million vehicle-km.[3]

Since there are no restrictions on the age of vehicles on the road, the number of second-hand European cars is gradually increasing. By 2009, 41% of vehicles were 20 years old or older. The catalytic converters are often destroyed or removed from imported cars. The share of Soviet-made cars is still high but it is gradually decreasing.

In accordance with SEAP and emission inventory and preliminary modelling studies, there were 15,170 commercial goods vehicles in Tbilisi in 2009, with an average fuel consumption rate of 24 l per 100 km and annual travel distance of 504 million vehicle-km.

[3] Source: Compilation of Emissions Inventory and Preliminary Air Quality Modelling for Tbilisi. Cambridge Environmental Research Consultants. 2013. Air Quality Monitoring in Tbilisi. Georgia. PSOM10/GE/11/

Total emissions from transport were calculated using emission factors for each type of car and annual mileage calculated under preliminary emission inventory and modelling study described in chapter 5.1.

Table 8.Distance Travelled by Different Types of Vehicles

Vehicle type	Estimated annual mileage (million vehicle-km)	Tbilisi fleet breakdown (%)
Cars	2984	79.4
Mini-buses	210	5.6
Buses	58	1.6
Light goods vehicles	338	9.0
Rigid heavy goods vehicles	112	3.0
Articulated heavy goods vehicles	55	1.5

5.2.1.4 Airport Sources

Emissions from aircraft sources were taken from URBAN-ADMS 2009 modelled data since the project does not have ADMS-airport extension for aircraft emission modelling. The previous study used 2010-2011 flight information at Tbilisi airport as model input data. Detailed description of airport sources isgiven in chapter 5.1 above.

5.2.1.5 Total emissions

Below is given total emissions from various sources based on emission inventories compiled through EMIT software.

Spatial distribution of NO_x, SO_2 and PM_{10} emissions necessary for modelling pollutants concentrations was assessed through ADMS-Urban. Below are given the maps of pollutants’ emissions spatial distribution.

Table 9.Total Emissions from Various Types of Pollution Sources, t/yr

Group	BENZENE (T/Y)	BUTADIENE (t/Y)	CO(t/y)	NO2 (t/y)	NOx (t/y)	PM10 (t/y)	PM2.5 (t/y)	SO2 (t/y)	VOC (t/y)	CO2(t/y)	METHANE(t/y)	N2O	NH3	TSP	B[a]P
Airport	0.00	0.00	85.57	9.79	91.66	0.50	0.50	6.69	9.12	0.00	0.00	0.00	0.00	0.00	0.00
Gas use	0.00	0.00	0.00	21.90	438.10	33.31	0.00	2.59	24.06	0.00	0.00	0.00	0.00	0.00	0.00
Industrial_Difuse_Sources	0.00	0.00	0.00	0.00	0.00	5.31	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00
Industrial_Point_Sources	0.00	0.00	235.10	2.44	48.87	0.00	0.00	47.08	12090.00	15010.00	0.00	0.00	0.00	326.10	0.00
MajorRds	3.19	1.48	153	188.	952	92.	54.	27	190.	4408	10.17	9.	48.	0.0	0.

			5.0 0	80	.00	02	93	2.1 0	10	00.00		25	97	0	00
MinorRds	5.66	2.62	272 1.0 0	334. 80	168 8.0 0	16 3.1 0	97. 38	48 2.3 0	337. 10	7814 00.00	18.02	16 .3 9	86. 82	0.0 0	0. 00
TOTAL	8.85	4.10	457 6.0 0	557. 70	321 8.0 0	29 4.3 0	15 2.8 0	81 0.7 0	126 50.0 0	1237 000.0 0	28.19	25 .6 4	13 5.8 0	32 6.1 0	0. 01

Figure 14.Map of the Total SO2Emissions (t/yr) Distribution

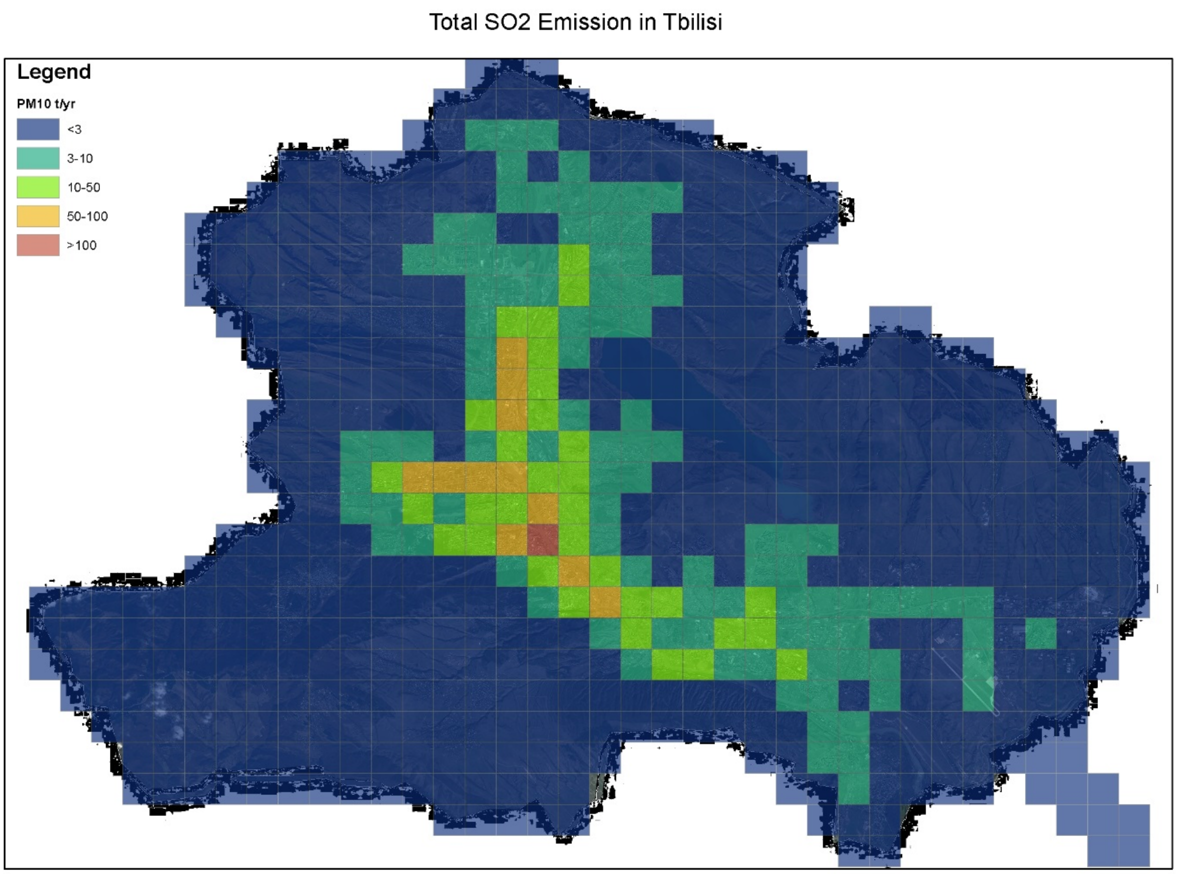


Figure 15.Map of the Total PM10Emissions (t/yr) Distribution

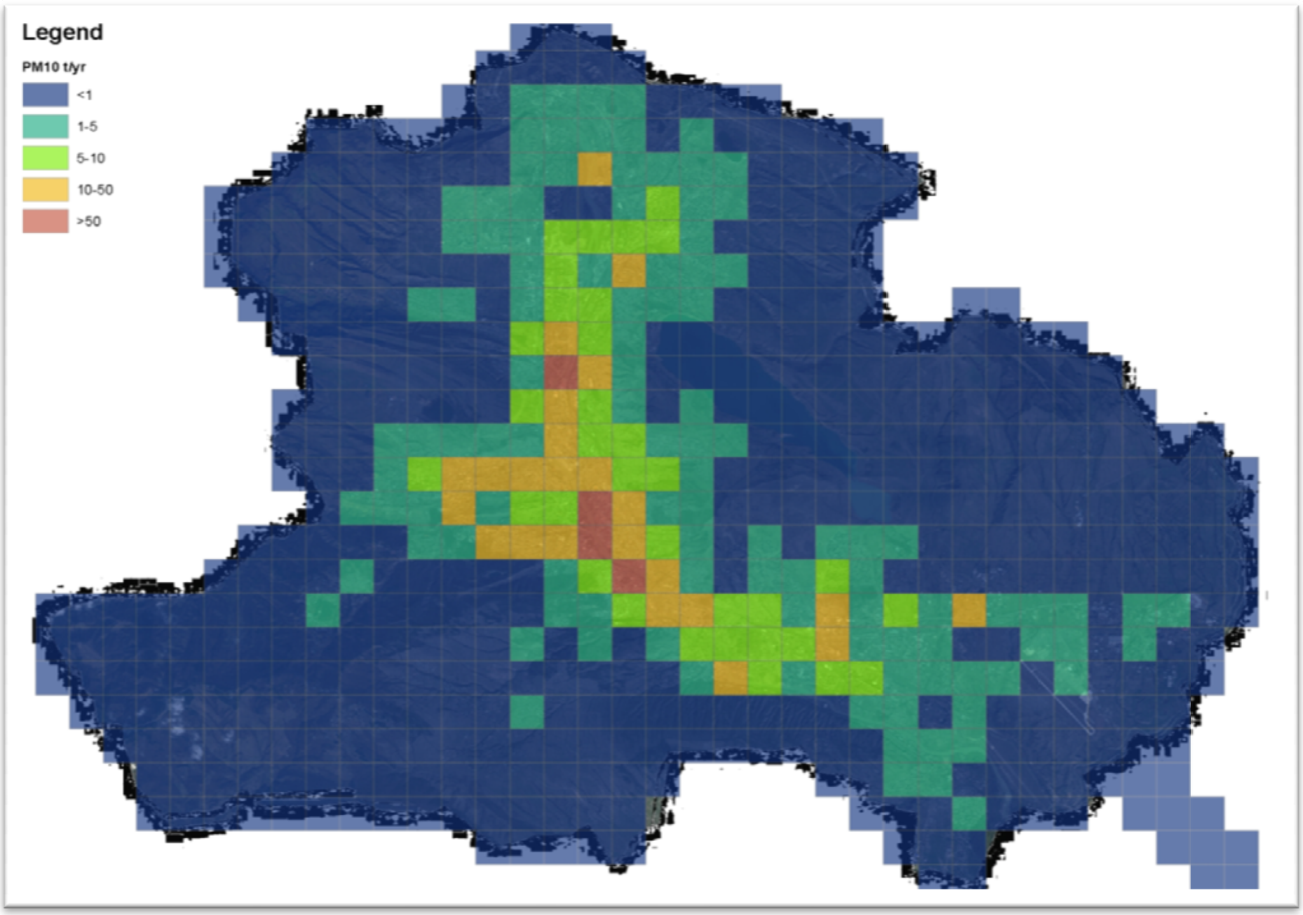
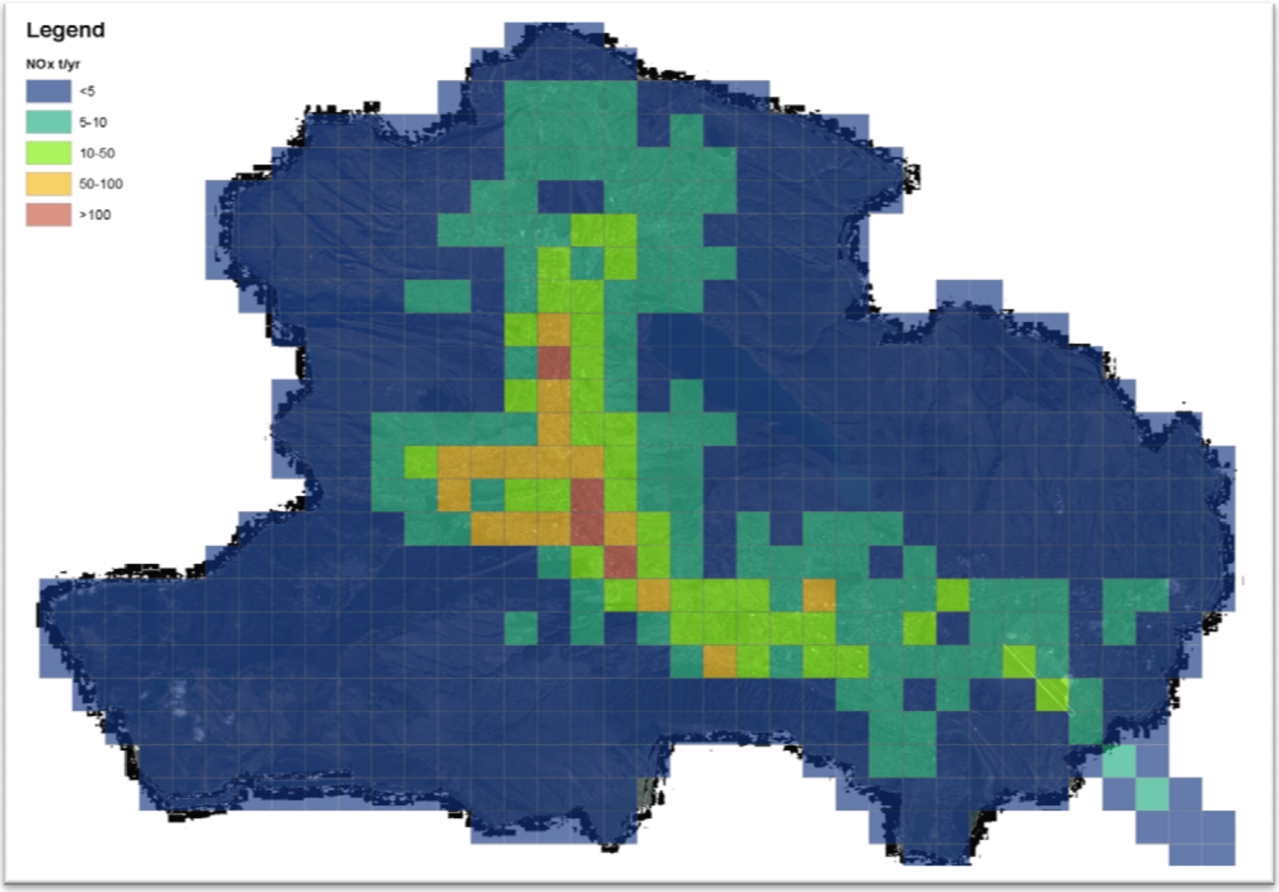


Figure 16.Map of the Total NOx Emissions (t/yr) Distribution



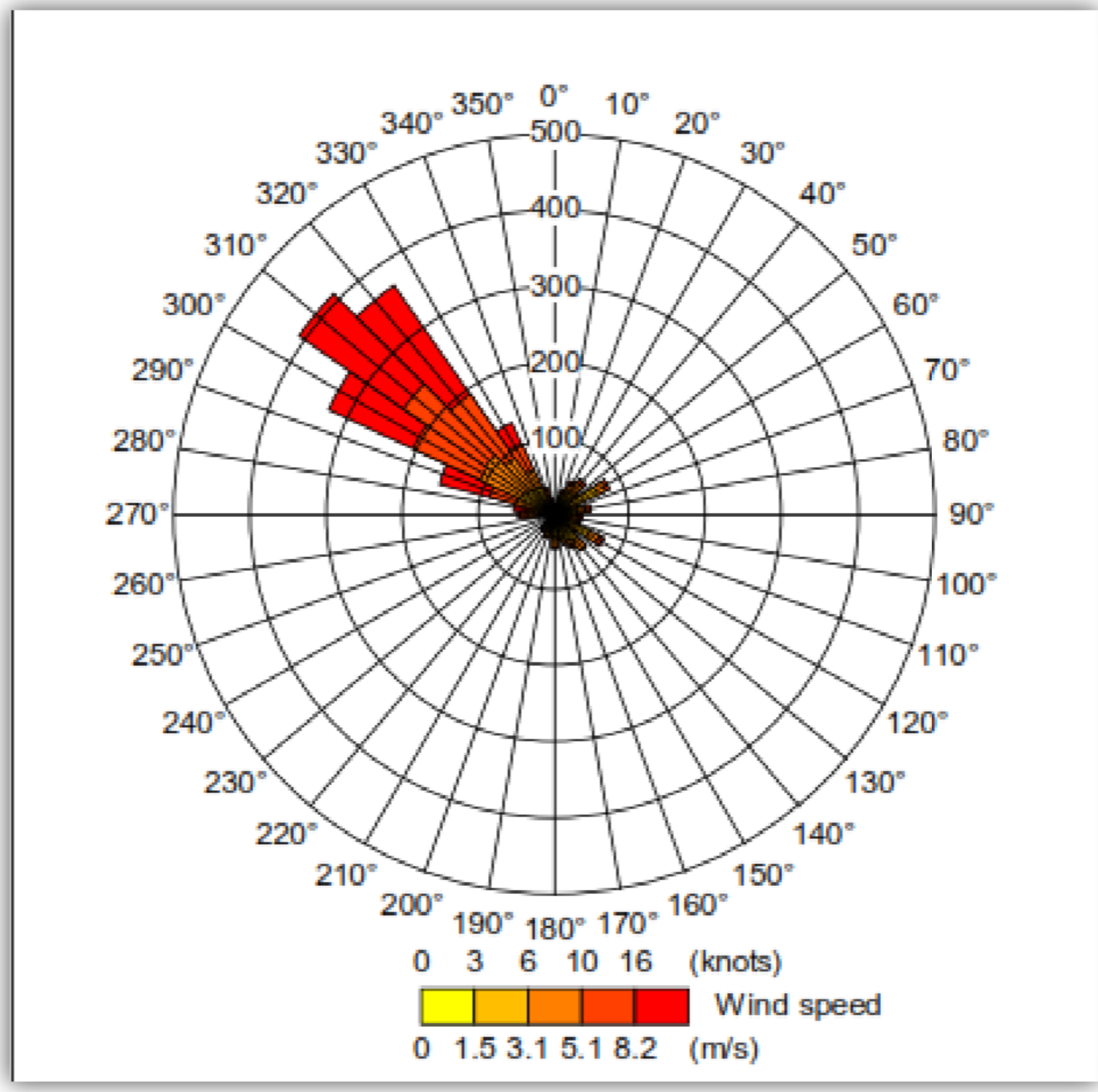
5.2.2 Meteorological Data

Meteorological data were taken from 3-hour measurements recorded at Tbilisi International Airport and used during preliminary assessment. ADMS-URBAN can generate hourly data for dispersion modelling. Below is given a summary of 2009 meteorological data.

Table 10. Major meteorological parameters

Parameter	Minimum value	Mean value	Maximum value
Wind speed (m/s)	0	5.4	23.0
Temperature (0C)	-7.7	13.4	36.4
Cloud cover	0	5.0	8.0

Figure 17. Wind speed and rose for 2009



5.2.3 Background Air Quality Data

Background concentrations of pollutants blown to the city outside the modelled area were taken from preliminary ADMS-URBAN air quality modelling study. Below the summary of background concentrations of pollutants is given for which the model was run.

Table 11. Modelled values of background concentrations

Substance	Annual average concentration (μg/m^3)
NOx	3.46
NO2	2.43
O3	40
SO2	0.7
PM10	10.8

6. AIR QUALITY ASSESSMENT IN THE AGGLOMERATION

AIR POLLUTION FIELD ANALYSIS

6.1.1 Long term Monitoring

Air quality in Tbilisi has been monitored at three air quality monitoring stations across the city, one of which is a continuous monitoring station.

The sampling stations are located at

- Kvinitadze St.
- Moscow Ave.
- Tsereteli Ave

Pollutants monitored at the three stations are listed in Table 12 below.

Table 12. Ambient air pollutants monitored in Tbilisi

Tbilisi Sample Station	Pollutant
Kvinitadze St.	Dust
	SO_2
	O_3
	Lead
	NO_2
	CO
Moscow Ave.	NO_2
	CO
Tsereteli Ave	CO

The site classification of these stations is currently unknown. Sampling and detection techniques methods used are non-reference methods and therefore do not comply with the requirement of the data quality objectives set by CAFE directive.

6.1.2PassiveMonitoring

For a limited period (14 days) in 2014, air quality in Tbilisi was monitored using diffusion tube passive sampling methods at 34 locations across the city.

Table 11 Passive Samples distributed across Tbilisi 2014

Sample Specis	Pollutant
NO2 Tube Monitors	34
SO2 Tube Monitors	4
O3 Tube Monitors	2

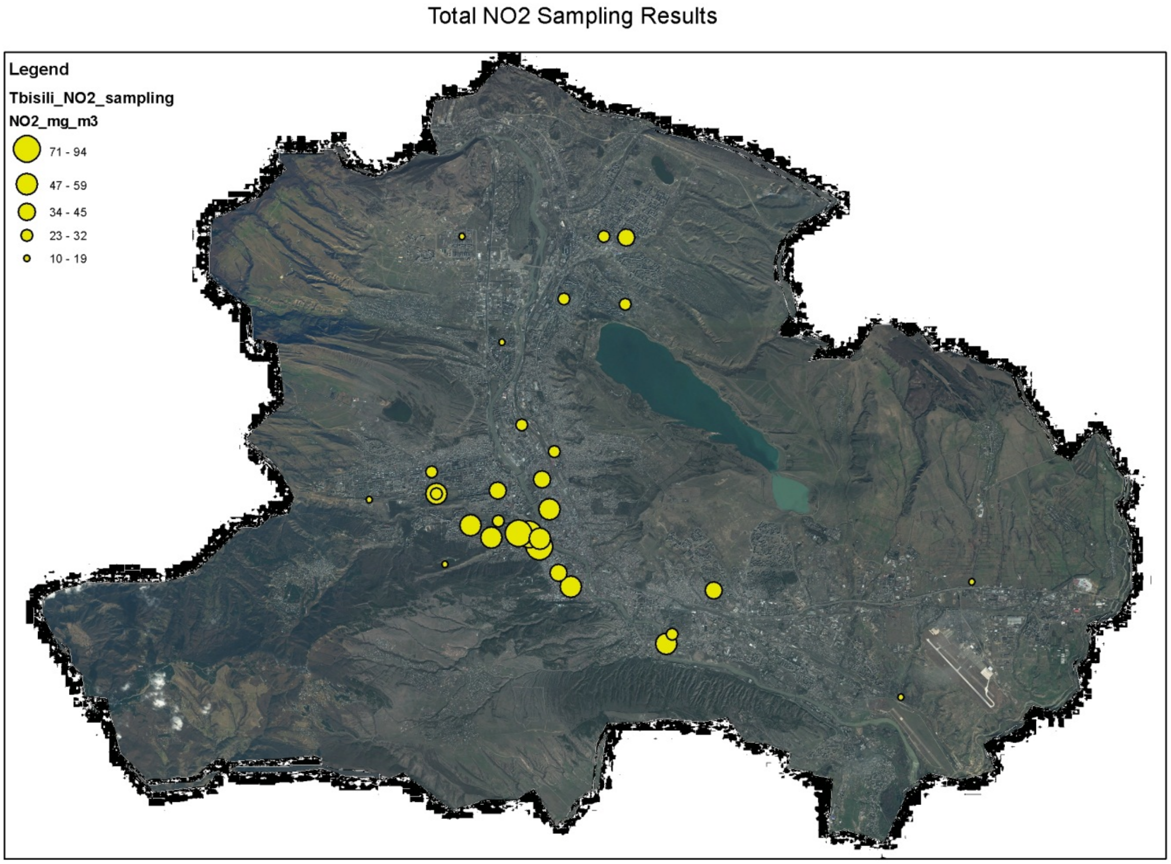


Figure 18.Location of Passive Sampling NO_2 across Tbilisi for 2013

Monitoring Data Results

Long-term air quality monitoring results are summarised as annual averages below for the years 2008 to 2013.

Where dust was monitored as TSP, the measured concentration was used for assessment of PM_{10} concentration at that location, assuming TSP/PM_{10}ratio of 1.35[4].

Table12 Air quality monitoring results for Tbilisi stations as annual averages for 2008 to 2013

Species	Location	2008	2009	2010	2011	2012	2013
		Concentration μg/m³					
Dust	Kvinitadze St.	780	500	430	500	500	693
PM_{10}(assuming a ratio of 1.35 dust to PM_{10})	Kvinitadze St.	578	370	319	370	370	513

[4] Source: A report on Guidance to Member States on PM10 monitoring and intercomparisons with the reference method. EC working group on particulate matter, 2002

SO_2	Kvinitadze St.	130	120	98	90	90	119
CO	Kvinitadze St.	5,100	4,000	3,600	2,800	2,970	3,333
	Moscow Ave.					2,600	2,557
	Tsereteli Ave					4,200	4,884
NO_2	Kvinitadze St.	60	70	92	88	89	100
	Moscow Ave.					87	87
O_3	Kvinitadze St.			13.6	34	13	26
Lead	Kvinitadze St.	0.33	0.22	0.2	0.21	0.13	0.1

6.1.3 Preliminary passive sampling results (Appendix B, Table B1) illustrate that NO_2 concentrations appear to vary widely across the city ranging from 9.57 $\mu g/m^3$ at the Tbilisi - Turtle Lake sample site (suburban) to 94.03 $\mu g/m^3$at the Tbilisi - Rustaveli Avenue site (Roadside).

At 4 sites average NO_2concentrations over a 14 day sampling period exceeded 60 $\mu g/m^3$ (the exceedance of hourly limit hourly limit value 200 $\mu g/m^3$might be at risk), over the same period concentrations at 10 sites were between 40 and 60$\mu g/m^3$, at 4 sites for the same period NO_2 concentrations were between 36 and 40 $\mu g/m^3$, and at 18 sites NO_2concentrations were below36$\mu g/m^3$.

Modelling Data Analysis

Results from preliminary ambient air quality modelling undertaken both as a city wide Tbilisi model and in detail for Agmashenebeli Road has been previously discussed in chapter 5 of this report. This section looks at the representativeness of the data against two sets of monitoring data – fixed sampling and passive sampling

Comparison Against Fixed Monitoring Data

Two monitoring stations - one at Kvinitadze Street and another long term station in Moscow Avenue- were used as initial receptor stations. The raw (unverified) modelling data generated for these locations was compared against the for the 12 month monitoring data obtained from each station between period February 2013 to January 2014 (Table 13). It can be seen that the magnitude of the monitoring data was far in excess of the raw model data outputs for NO2, PM_{10} and SO_2. This comparative approach would have required a bias factor of between 2.81 to 34.55 to be applied across the whole of the Tbilisi raw model output data set. An alternative approach was adopted.

Table 13 Comparison between measured and modelled NO2, PM10, SO2 at the two fixed monitoring Stations in Tbilisi

Monitoring Site	Monitoring period	Measured	Monitored Concentration	Raw Modelled Concentration*	Bias Factor
Kvinitadze Street	12 month	NO_2	100.3 $\mu g/m^3$	35.7 $\mu g/m^3$	2.81

	Period Feb - 13 to Jan 14	PM_{10}	473.6 μg/m^3	13.71 μg/m^3	34.54
		SO_2	118.6 μg/m^3	5.26 μg/m^3	22.55
Moscow Avenue		NO_2	86.8 μg/m^3	[illegible]μg/m^3	[illegible]

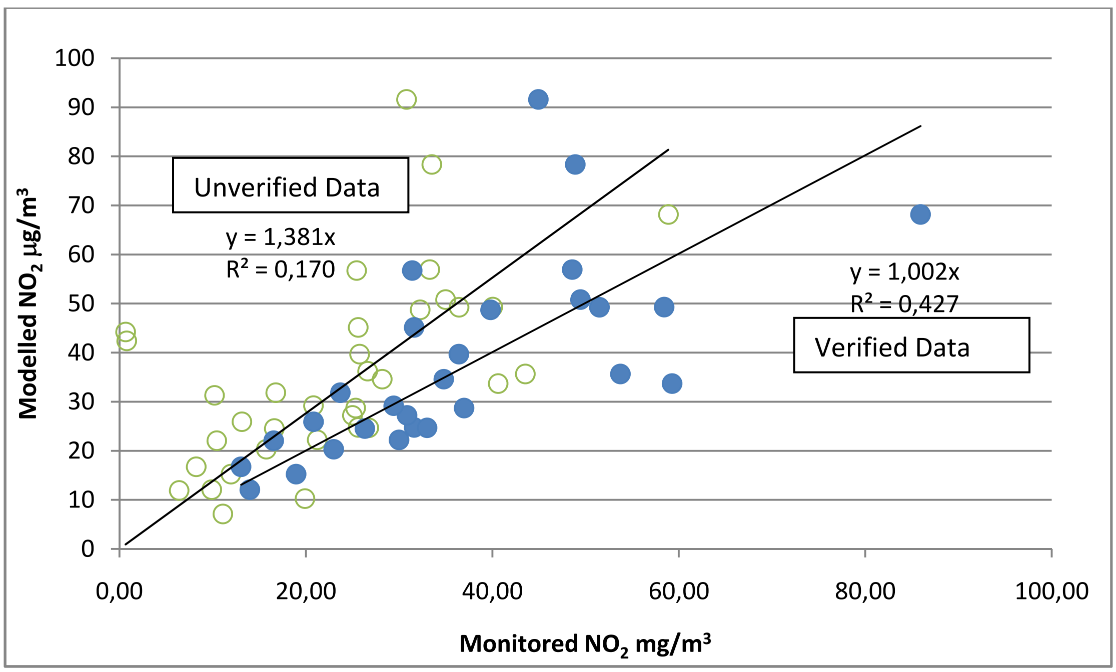
*Modelled output included background concentrations

Comparison against Diffusion Tube Data

All 35 passive sample locations were represented as receptors within the Tbilisi ambient air model. Raw model NO_2 results were compared against the passive diffusion tube results for all 35 receptors.

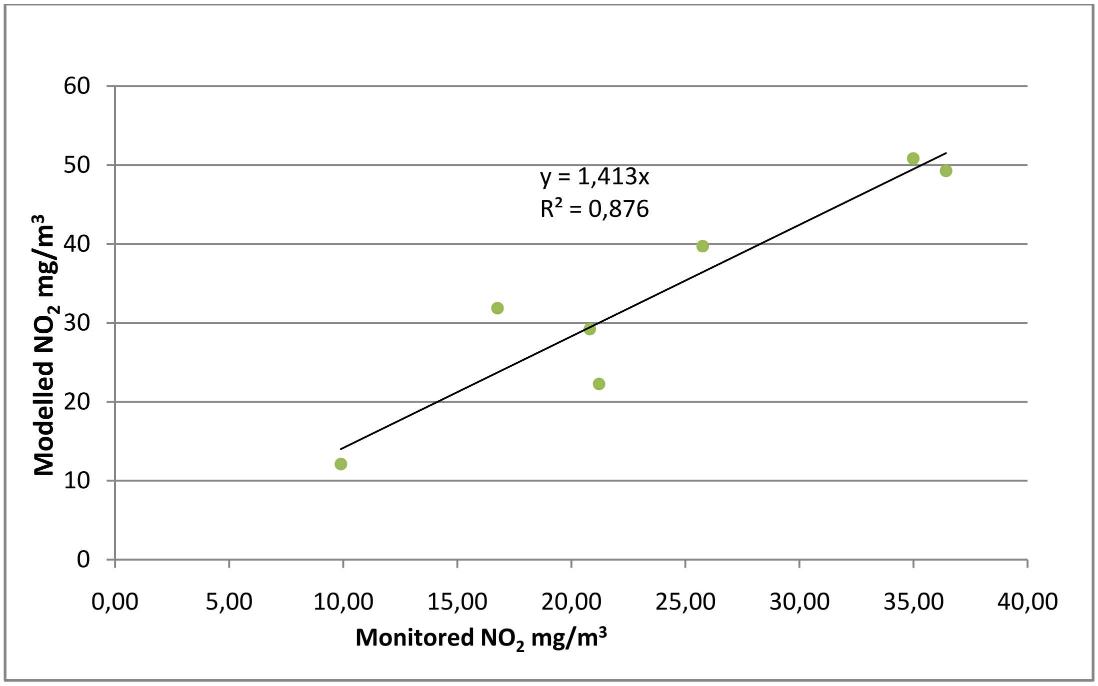
The initial relationship between the whole raw modelling data and the passive sampling data was good (graph slope of 1.3813), though there was a great deal of data scattering between the unverified model and passive date sets (R^2=0.1703).

Figure 18.Verification of NO_2Modelling Data against June 2014 Tbilisi Passive Sampling concentrations



The relationship between selected passive monitoring data set based upon site classification (e.g urban, suburban, urban background) was explored, and it was found that a similar slope exited for all data sets. However a stronger relationship was observed to exist for the urban background sub-set (Figure 19) between modelled and passive sample NO_2 data, with an R^2= 0.8761 (which is closer to 1the ideal value of R^2 = 1.000)

Figure 19.Comparison between NO_2Modelling Data against June 2014 Tbilisi Passive Sampling concentrations for Urban Background locations only



Verification Factor

A final verification factor of 1.38 was applied to the whole Tbilisi NO2 data set, in order to improve the relationship between modelled NO_2 concentrations and passive sample results across the city as a whole.

Both current and previous model outputs predicted small areas where exceedances of both the annual average limit value for NO_2, and PM_{10} would occur.

Sulphur dioxide was modelled for both hourly (99.79 percentile of annual mean) and daily concentrations (99.18 percentile of daily concentrations). It was predicted that the hourly and daily SO_2 concentrations were at risk of exceeding the LAT for SO_2 at one receptor location. Elsewhere in Tbilisi the SO_2 concentrations were predicted as being sufficiently low to remain below UAT value for hourly and daily SO_2.

6.1.3.1 Identification of the areas of pollution concentration above or under the LV, UAT and LAT

Monitoring Data: Ambient air quality data was analysed for potential exceedances against the EU Air quality limit values (LV), lower assessment threshold (LAT) and upper assessment thresholds (UAT) as outlined within the CAFE Directive. The outcome is illustrated in Table 13 below, where there are blank cells then no exceedance was determined. In the absence of daily averages, the annual average from monitoring data was used to assess exceedences of daily limit LAT's, UAT's or LV's for both SO_2 and PM_{10}. In the case of SO_2 annual average monitored concentrations implied that SO_2 concentrations in ambient air exceeded the daily UAT. This was a direct contradiction of the predictions from modelling data and implies that there may well be some missing emission inventory inputs in to the model data.

Table 13Exceedance of lower assessment thresholds (LAT), upper assessment thresholds (UAT) and limit values (LVs) within Tbilisi air quality monitoring data.

Species	Location	2008	2009	2010	2011	2012	2013
		Concentration $\mu g/m^3$					
PM_{10}(Dust)	Kvinitadze St.	Annual LV	Annual LV	Annual LV	Annual LV	Annual LV	Annual LV
SO2	Kvinitadze St.	Daily UAT	Daily UAT	Daily UAT	Daily UAT	Daily UAT	Daily UAT
CO	Kvinitadze St.	LAT					
	Moscow Ave.						
	Tsereteli Ave						
NO_2	Kvinitadze St.	Annual LV	Annual LV	Annual LV	Annual LV	Annual LV	Annual LV
	Moscow Ave.					Annual LV	Annual LV
O_3	Kvinitadze St.						
Lead	Kvinitadze St.	LAT					

Though air quality monitoring data was only available as annual averages, the data was not wholly appropriate to employ to access short period limit values. However it can be observed that where annual limit values exist then relevant pollutants have exceeded the LV at some or all sample locations. In the case of CO, the LAT was deemed to be exceeded based on annual average value, even though the limit value is expressed as a short –term 8 hours mean concentration.

Modelling Data: Modelling data have predicted exceedences of the daily air quality LAT at 25 , UAT at 9 and LV's at 11 receptor location across Tbilisi and 32 LAT's for the 24 hourly LV for NO_2. In addition to the predicted exceedance of the LV's at monitoring sites, widespread exceedances of both LATs and UATs were predicted by the model. The extent of these exceedances is presented in the following table.

Table14 Area and type of Exceedances within the Tbilisi Air Quality ADMS-Urban Model

Model Type	Area of Exceedance					
	NO_2 Annual	NO_2 Annual	NO_2 Annual	PM_{10}AnnualLimit Value	PM_{10}AnnualLimit Value LAT	PM_{10}AnnualLimit Value UAT

	Limit Value	Limit Value LAT	Limit Value UAT			
City Wide Tbilisi	10% of the whole city	30% of the whole city	15% of the whole city	5% of the whole city	100% of the whole city	50% of the whole city
Agmashenebeli Road	With 150 m of main traffic routes	Within 250 m of main traffic routes	Within 200 m of busy roads	Within 75 m of main traffic routes	Within 50 m of main traffic routes	Within 75 m of main traffic routes

Monitoring data from air quality stations within Tbilisi have confirmed that the LAT and UAT for annual average NO_2 LV are routinely exceeded within the city. Modelling data has predicted where these exceedances are likely to occur throughout the city and to what extent.

Explicitly busy road, junctions and those areas close to busy road and junctions in central Tbilisi were predicted to experience elevated concentrations of air pollutants, particularly NO_2, and PM_{10}, likely to exceed LAT, UAT's and LV for the annual mean NO_2 and PM_{10} species. This is compounded by the alignment of NO_x point sources along the major roads throughout Tbilisi (Figure 18).

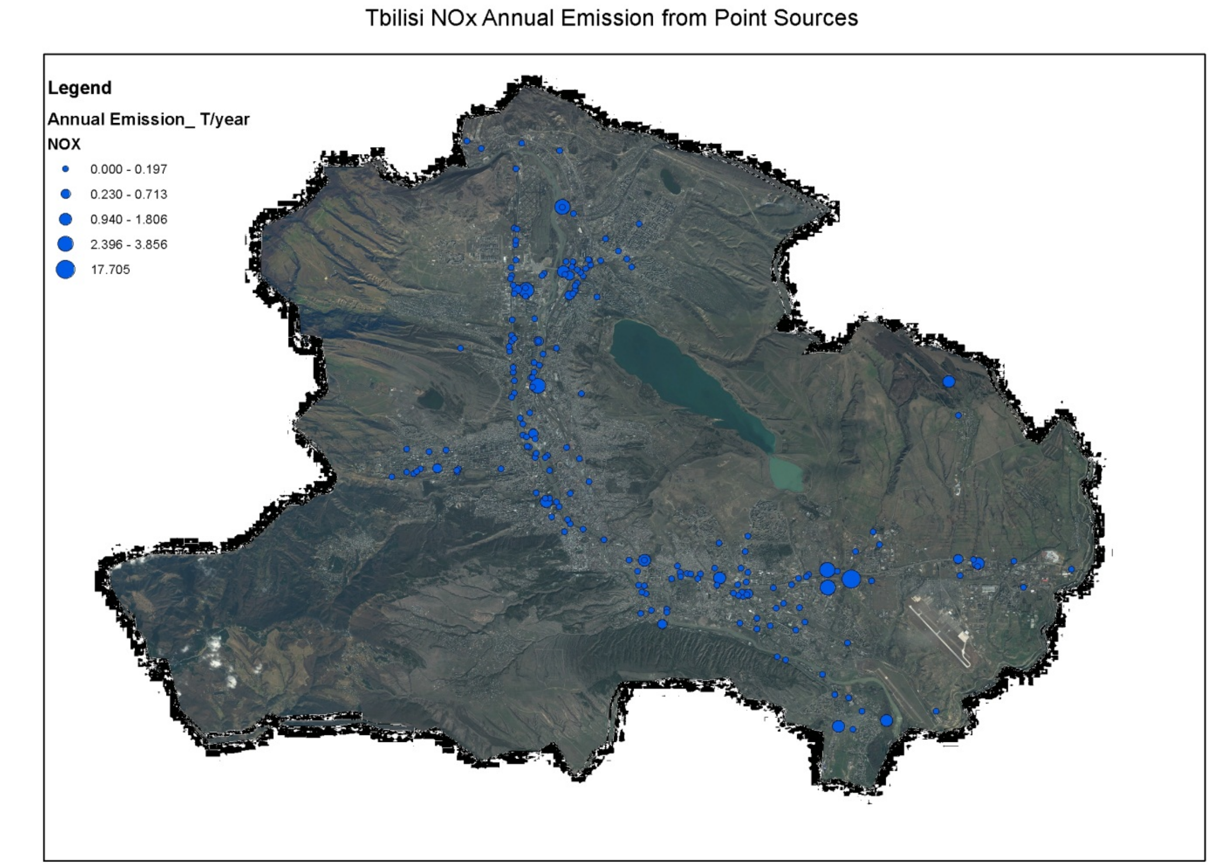


Figure 18.Annual Point Source Emissions of NO_x across Tbilisi for 2009

Estimated annual average concentrations of SO_2 for Tbilisi indicated that large areas of Tbilisi experience very low levels of SO_2, less than 5 μg/m^3. According to the modelling results the city's central area is free from SO2, with no significant concentrations at any of the receptors locations, with annual average concentrations exceeding 45 μg/m^3.

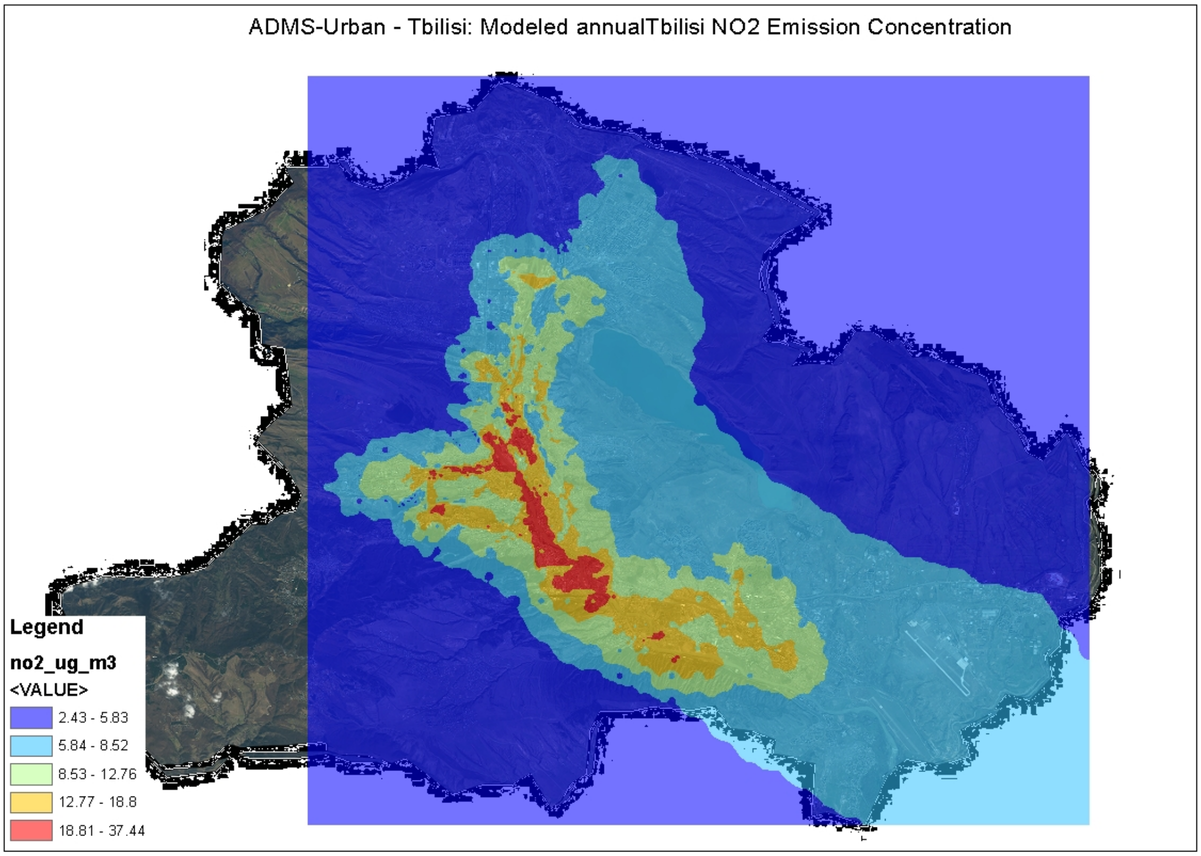


Figure 18.Estimated Annual Mean Concentrations of NO2 across Tbilisi for 2013

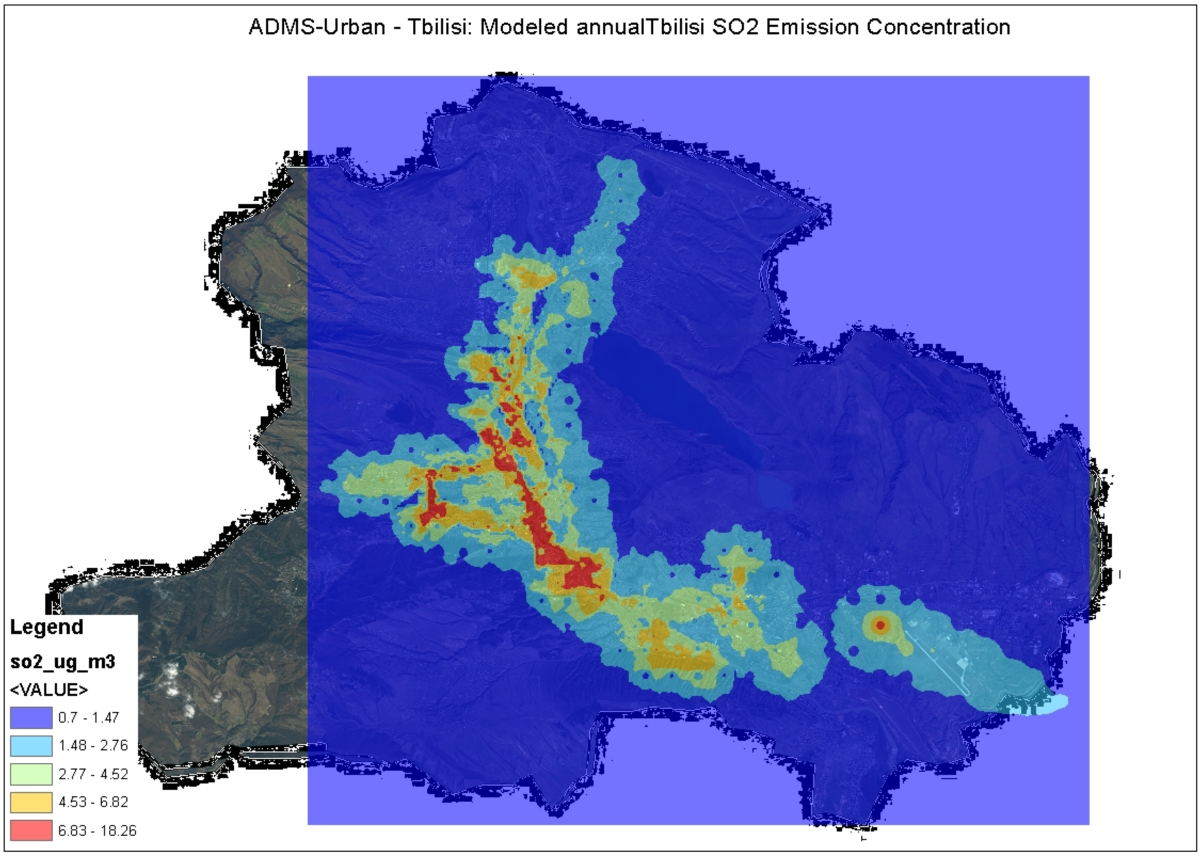


Figure 19.Estimated Annual Mean Concentration of SO2 (μg/m3) across Tbilisi for 2013.

The pattern of SO2 concentrations follows the principal roads into the city centre. As greater level of road traffic information was readily available for the city of Tbilisi, including vehicle category and fuel, which has a high sulphur content. This is reflected in the predicted SO2 annual average concentrations for Tbilisi, which imply that the dominant source of SO2 in Tbilisi are vehicle emissions. This may not be the case and that a significant proportion of point source emissions may well need to be accounted in the emission inventory.

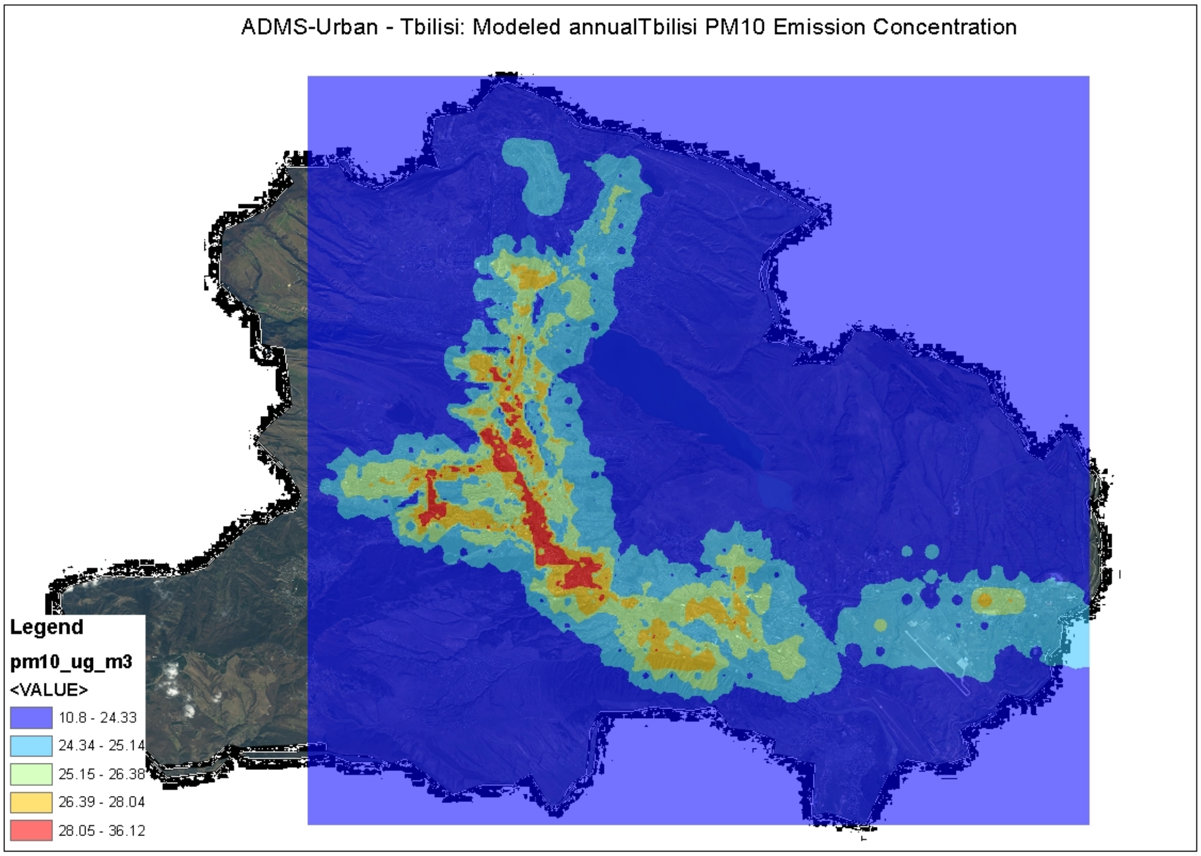


Figure 20. Estimated Annual Mean Concentration of PM_{10} (μg/m3) across Tbilisi for 2013

6.1.4 Zones and Agglomerations

The pattern of elevated concentrations of PM10follow the principal roads into the city centre. As detailed road traffic information was readily available for the city of Tbilisi, including vehicle category and fuel type. This is reflected in the predicted PM10 annual average concentrations for Tbilisi, which indicate that the dominant source of PM10 in Tbilisi are vehicle emissions.

Lower assessment thresholds (LATs), upper assessment thresholds (UATs) and limit values are used to define where the maximum exposure to air pollutants may occur and where air pollution may be present in lower concentrations. Such information is used for understanding the spatial distribution of pollutants and helps in designating zones and agglomerations.

Whether a LAT is not reached the number of monitoring stations required within a zone can be low, where a UAT is exceeded the number of monitoring stations has to be higher. Therefore LATs and UATs allow us to determine an optimised cost-effective and compliant air quality network and are an essential part of the overall strategy within the EU CAFE Directive. Zoning is initially determined at the Preliminary Assessment stage and updated periodically.

In terms of the limit values, where the exceedances of pollution limit values occur, a member state is required to prepare an action plan to document that limit values will be met.

6.1.5 Zones and assessment Regime

In agglomerations and in zones where pollutant concentrations exceed the upper assessment threshold (Table 15) monitoring is mandatory.

Table 15 Limit Values, lower assessment thresholds (LAT), upper assessment thresholds (UAT) and limit values

Pollutant	Limit Value (LV) $\mu g/m^3$	Lower Assessment Threshold (LAT) % of LV	Upper Assessment Threshold (UAT) % of LV	Averaging Period	Statistics	Protection of
NO_2	200	50%	70%	1 hour	18 times per year	Human health
	40	50%	65%	Calendar year	Annual Mean	Human health
NOx	30	65	80	Calendar year	Annual Mean	Vegetation
SO_2	125	40	60	24 hrs	3 times per year	Human health
	20	40	60		Mean annual and Winter	Ecosystems
Particles (PM_{10})	50			24 hr	35 times per year	Human health
	40			Calendar year	Annual mean	Human health
Particles ($PM_{2.5}$)	25	50	70	Calendar year	Annual Mean	Human health
Lead	0.5	50	70	Calendar year	Annual Mean	Human health
Benzene	5	40	70	Calendar year	Annual Mean	Human health
CO	10,000	50	70	8 hrs (running)	Maximum	Human health

Where pollutant concentrations are below the upper assessment threshold monitoring can be reduced and supplemented by modelling. Where pollutant concentrations are below the lower assessment threshold assessment can be undertaken using modelling alone.

6.1.6 Source appointment

Within Tbilisi, the majority of stationary emissions to air have been identified as emanating from a small number of industries. In addition, the aggregated emissions resulting from domestic heating systems also provide a significant contribution to ambient air concentrations of NO_2. However road transport has already been highlighted in this report (Table 2) as being responsible for over 90% of the emissions to air of NOx, NO2, VOC and CO within Tbilisi. In addition road transport is responsible for 67% of all

PM_{10}emissions to air and 83% of all SO_2 emissions to air throughout the city. A large proportion of the emissions from road transport are likely to occur from the use of private vehicles rather than mini-buses, buses, or HGVs (Table 1). Therefore abatement and control of emissions to air from road transport is likely to be difficult to enforce, unlike a city-wide bus upgrade, which can be centrally administered and involves a limited number of stakeholders. Minor roads where predicted to be a greater source of road transport emissions than those from major roads (Table 2).

Emissions to air from domestic heating has been modelled as occurring largely within the north east of the city, where the city's population density is at its maximum. Therefore NO_x emissions from domestic heating are at a maximum in the north east of Tbilisi.

Table 16- Verified Modelling Data Tbilisi

Sample Site Name	X	Y	CO 8hrs mg/m3	NO2 ug/m3	P 99.79|ug/m3|NO2|<All sources>|-|1hr	PM10 ug/m3	P 90.41|ug/m3|PM10|<All sources>|-|24hrs	SO2 ug/m3	P 99.73|ug/m3|SO2|<All sources>|-| 1hr	P 99.18|ug/m3|SO2|<All sources>|-|24hrs
Tolstonokovistr	483058.00	468041.00	0.00	3.35	19.13	10.85	10.94	0.71	2.32	1.18
Chargalistr	43678.00	4624702.00	0.00	3.51	22.15	10.87	11.03	0.74	3.14	1.40
Tbilisi - Lilo settlement	496457.00	4615873.00	0.08	11.27	77.42	31.52	47.08	1.90	14.15	5.62
Tbilisi - BesarionChichinadzestr	494172.00	4612152.00	0.10	13.79	114.46	12.17	13.32	2.83	24.10	9.30
Conjunction of Tavdadebulistr and Petritsi str.	479985.00	4627009.00	0.14	16.09	120.74	12.39	14.42	2.40	18.64	8.45
Mosulishvili str. School #79 area	485298.00	4626981.00	0.14	16.51	112.37	12.38	13.58	2.40	17.23	7.42
Temqa district	485260.00	4624823.00	0.14	16.84	103.19	12.28	13.33	2.38	14.94	6.59
Temqa	485260.00	4624823.00	0.14	16.84	103.19	12.28	13.33	2.38	14.94	6.59
Tbilisi - Turtle lake	479447.00	4616434.00	0.14	17.74	124.15	12.28	14.02	2.47	20.24	9.83
University - Maglivi building	476986.00	4618521.00	0.16	18.94	126.65	13.82	17.10	2.71	20.92	9.33
Tbilisi - TeopaneDavitianistr	4876105.00	4616510.00	0.18	20.56	118.54	12.66	14.27	3.02	20.46	9.00
Shatili str. Nearby the Caucasus international University	483280.00	4624997.00	0.23	24.17	122.65	13.26	15.26	3.42	22.74	9.41
Gldani district. Mosulishvili str. Park	484569.00	4627018.00	0.31	25.35	119.81	13.94	16.27	4.44	20.69	12.33
Tbilisi - Dimitri Uznadzisstr	488119.00	4615605.00	0.24	25.57	122.17	13.35	15.44	3.78	22.78	11.28
G. Gogiberidze str. Park	481285.00	4623607.00	0.32	29.89	137.21	13.97	18.16	4.46	32.70	15.97
Tbilisi 29	486774.00	4614183.00	0.29	31.15	125.70	14.81	18.05	4.39	26.16	11.04
DadianiStr	482968.00	4620078.00	0.31	31.71	128.02	13.81	16.26	4.43	26.07	13.53
Tbilisi - Mziuri Park	481163.00	4617828.00	0.40	36.92	139.76	14.60	18.66	6.14	50.60	21.97
Stanislavski str	481914.00	4620935.00	0.40	37.40	135.60	14.56	17.19	5.53	34.15	17.85
Tbilisi - Freedom Sq	483497.00	4615710.00	0.44	37.55	145.54	14.86	19.07	6.16	40.30	18.77
Budapestistr	479171.00	4618706.00	0.38	37.77	130.93	14.43	17.39	5.35	27.73	14.82
Hippodrome	479171.00	4618706.00	0.38	37.77	130.93	14.43	17.39	5.35	27.73	14.82
Tbilisi - 1st School	483113.00	4616166.00	0.41	37.98	139.24	14.62	18.31	6.01	36.52	17.16
Surami str.	482982.00	46189529.00	0.42	39.16	137.25	14.80	17.52	5.73	42.72	18.16
VashaPshavela Av	479016.00	4619419.00	0.57	39.33	164.15	16.05	23.30	7.34	65.69	28.96
Bakhtrionistr	481150.00	4618825.00	0.46	41.33	134.10	15.87	20.06	6.40	39.24	20.08
Tbilisi - Rustaveli Av	482494.00	4617004.00	0.52	44.93	146.14	15.65	20.59	7.92	44.33	22.65
Tbilisi - ZurabArakishvilistr	480268.00	4617690.00	0.70	46.94	160.17	17.19	24.04	9.11	60.01	29.10
Agmashenebeli Av	482824.00	4618209.00	0.54	48.36	141.24	15.93	19.14	6.99	40.34	19.92
Tbilisi - Kostavastr	482161.00	4617409.00	0.61	48.67	148.33	16.41	21.32	12.57	118.71	41.11

Tbilisi - Leo Kiachelistr	482502.00	4617274.00	0.68	50.71	164.93	17.11	23.88	12.45	62.99	33.89
Tbilisi - Abashidzestr	480938.00	4617301.00	0.90	52.70	163.42	18.82	25.06	11.92	71.14	36.29
Tbilisi 14	486584.00	4613880.00	1.29	57.69	190.72	22.42	29.74	16.47	83.73	41.23
Tseretelistr	482582.00	4619181.00	1.14	58.50	166.78	21.22	30.70	14.11	66.26	38.24
Agmashenebeli Str.	482534.00	1618410.00	0.96	62.51	171.60	19.48	24.80	12.25	81.15	33.67
Tbilisi - Melikishviliav	481825.00	4617435.00	2.28	83.69	222.80	30.72	44.63	30.74	191.44	97.73

7. RECOMMENDATIONS FOR AIR QUALITY MONITORING NETWORK DESIGN

AIR QUALITY MONITORING DESIGN

Through applying current air quality measurements as well as surrogate information and guidance, it has been established that levels of particular air pollution species at selected locations within Tbilisi are above or, where measurements are not available, likely to be above thresholds which require fixed measurements to be made for compliance with the CAFE Directive.

SPATIAL REPRESENTATIVENESS

Classification and location criteria to identify suitable sampling points for the assessment of air quality have previously been described in detail within section 3.6 of the report entitled 'Comparison of the Air Quality Monitoring Systems of EU Members States and Georgia'.

It is clear therefore, that within the Tbilisi air quality monitoring network, stations should be carefully located to reflect both:

Difference exposure scenarios across the city, e.g. central city street canyons with high ambient concentrations of pollutants, and suburban areas with lower ambient background concentrations

Different source characteristics across the city, e.g. high proportion of traffic related pollutants, or an area with a concentration of industrial point source emissions.

At each sample location, the spatial representation of a particular sample site must reflect the wider character of the local area, beyond the immediate locality, i.e. a Tbilisi roadside sample site could be considered representative of other roadside locations in the city which have similar layout and traffic levels, speeds etc.

In actuality, the area of representativeness is not easily determined, as it requires extensive monitoring at several adjacent sites covering an area around the station, or rather detailed dispersion model calculations based upon detailed emission inventories, both for the area in question and the larger surrounding area. Therefore a qualitative assessment of spatial representation has been used in this instance.

SAMPLE SITE CHARACTERISTICS

Sample site criteria for the measurement of SO_2, NO_2, PM_{10} and $PM_{2.5}$, lead, benzene and CO require samples to be collected where the concentrations are at their highest, or where the population are likely to be exposed.

As a largely urban environment, a number of sample site characteristics can potentially be incorporated into the Tbilisi air quality monitoring network, these include:

<u>Urban centre:</u> Urban location representative of typical population exposure in towns or city centres, for example, pedestrian precincts and shopping areas

Urban background: Urban location distanced from sources and therefore broadly representative of city-wide background conditions, e.g. urban residential areas.

Suburban: Residential area on the outskirts of a town or city

Roadside: Sample site typically within one to five metres of the kerb of a busy road (although distance can be up to 15 m from the kerb in some cases).

Industrial: Industrial sources make an important contribution to the total pollution burden.

Other: Special source-orientated or location category covering monitoring undertaken in relation to specific emission sources such as power stations, car-parks, airports or tunnel.

SPECIFIC SAMPLING SITE SELECTION

Identification of the specific suitability of sample site locations selected on the basis of compliance with spatial representation and proximity to a known emission source, need to be tested for their practicality. Establishing where a sample site may be theoretically best suited does not necessarily equate to where it could most practically be best suited.

A series of site selection criteria can be used to test the practicality of a sample site location, these are:

1. Avoid being too close to interfering pollutant sources
2. Good security is required to avoid loss or damage
3. Good access is required, for site staff and vehicles
4. Continuous, reliable electrical power availability as well as telephone communications
5. Site need to be discretely positioned, so as to minimise the visibility of the site in relation to its surroundings
6. The site must be positioned where safety of the public and operators is maintained
7. All local planning requirements must be met, or where excessive, avoid using the site.

These criteria shall be applied when considering the specific site for each of the required monitoring sites within the Tbilisi air quality monitoring network.

MINIMUM NUMBER OF SAMPLING POINTS FOR EACH RELEVANT POLLUTANT SPECIFIED IN BOTH DIRECTIVES

The minimum number of sampling points within an agglomeration is specified in both Annex V Section A, Table 1and Annex IX, Table A of the CAFE-Directive and Annex III Section IV Table a) of the 4th DD.

Both the CAFE and 4th Daughter Directives have specific criteria for a minimum number of diffuse sources sampling points in zones and agglomerations, where fixed measurements are the sole source of information, in order to assess compliance with the following:

- Limit values for NO_2, CO, PM_{10}, Pb, SO_2, Benzene
- $PM_{2.5}$ exposure
- Target values for As, Cd, Ni & B(a)P
- Target values for Ozone

The minimum numbers of sampling points per agglomeration (0-249,000 population) is:

- 1 for pollutants NO_2, SO_2, CO, Pb, Benzene
- 2 for PM (sum of $PM_{10}$and $PM_{2.5}$)
- 1 for Cd, Ni, and As, and
- 1 for B(a)P

As the Tbilisi monitoring station located at Kvinitadze St, the annual mean concentrations of NO_2, SO_2 and PM_{10} (monitored as TSP) were all recorded as exceeding UATs (Table 13). PM_{10} exceeded UATs for both annual and daily LVs, NO_2exceeded UAT for Annual LV and SO_2 exceeded the UAT for daily limit value. Due to the UAT being exceeded for NO_2, SO_2 and PM_{10}, the Tbilisi air quality monitoring network will be required, as a minimum, to monitor at more than the minimum number of sampling points.

As SO_2 and NO_2 UAT thresholds were exceeded within Tbilisi between 2008 and 2013, the CAFE directive (Annex V, section A, Table 1) requires a minimum of 4 sampling points to be established within agglomerations of between 1,000,000 and 1,499,000 (population of Tbilisi is 1,095,000). And as the PM_{10} concentrations exceeded the UAT between 2008 and 2013, 6 sampling points for $PM_{(10\ \&\ 2.5)}$are required.

Concentrations of CO in ambient air across Tbilisi were detected below the LAT, therefore no routine monitoring for CO is required. The assessment of ambient concentrations of CO maybe undertaken through supplementary means, such as modelling or emissions inventories.

The minimum number of ozone sample points for Tbilisi will be1 sample site, as it is classed as a zone which have a population greater than 250,000 and is deemed to be a suburban area.

When monitoring for nitrogen dioxide, particulate matter, benzene and where upper assessment threshold have been exceeded, it is a requirement that at least one urban background monitoring station and one traffic-orientated station are in place. Though this is only a requirement when there are two or more fixed sampling points.

The total number of urban-background stations sampling diffuse sources and the total number of traffic oriented stations shall not differ by more than a factor of 2, for NO_2, particulate matter, benzene and carbon monoxide.

When monitoring for As, Cd, Ni and B(a)P at least one urban-background station should be included. When monitoring for B(a)P at two or more sample sites then one traffic-oriented station should be included.

Minimum number of sample sites within the Tbilisi air quality monitoring network

The above observations justify the designation of Tbilisi as an agglomeration according to the CAFE directive definition. Specific monitoring requirements are proposed in Table 16 below. On the basis of Tbilisi being determined an agglomeration, the following fixed monitoring activities are recommended for minimum compliance with both the CAFE and Fourth Daughter Directives:

Table 16 Fixed monitoring requirements for minimum compliance with the CAFE Directive within Tbilisi

Proposed Zone/agglomeration Number	Minimum Number of Sampling Points	Proposed Zone/agglomeration	Pollutants to be monitored	Category of Sampling Location required	Proposed Specific Sample Site
1	1	Tbilisi	NO_x, SO_2, PM_{10}, $PM_{2.5}$	Roadside location in Tbilisi	Corner of Baku Street with Agmashenebeli Avenue
	1		NO_x, SO_2, PM_{10}, $PM_{2.5}$	Urban Background location in Tbilisi	Teopane Davitaia Street
	1		NO_x, SO_2, PM_{10}, $PM_{2.5}$	Point of max. ground level concentration from Road transport emissions	Rustaveli Avenue
	1		NO_x,PM_{10}	Suburban Traffic	P. Melikishvili Street
	1		NO_x, PM_{10}, O_3	Suburban Background	Besarion Chichinadze Street

OPTIMUM NUMBER OF SAMPLE SITES WITHIN THE TBILISI AIR QUALITY MONITORING NETWORK.

As there exists some uncertainty over the historic ambient air quality monitoring records in Tbilisi, due to lack of compliance in monitoring methods used, the option to pursue an optimum air quality monitoring system design should be considered. It is proposed that the optimum air quality monitoring network would follow a similar approach and scale to the minimal network design, with the addition of CO, lead, ozone and benzene being monitored at selected locations. It is proposed that this designexists until such time that a preliminary assessment may justifiably discount the requirement to monitor on the basis of data collated using compliant quality assured monitoring data.

Such optimum monitoring network requirements are proposed in Table 17 below.

Table 17Number and type of fixed monitoring sites within Tbilisi to achieve optimum coverage of air quality species and achieve compliance with the CAFE Directive

Proposed Zone/agglomeration Number	Minimum Number of Sampling Points	Proposed Zone/agglomeration	Pollutants to be monitored	Category of Sampling Location required	Proposed Specific Sample Site
1	1	Tbilisi	NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$, benzene	Roadside location in Tbilisi	Corner of Baku Street with Agmashenebeli Avenue
	1		NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$, lead, O_3, benzene	Urban Background location in Tbilisi	Teopane Davitaia Street
	1		NO_x, SO_2, PM_{10}, $PM_{2.5}$	Point of max. ground level concentration from Road transport	Rustaveli Avenue

				emissions	
	1		NO_x, CO,PM_{10}, lead, benzene	Suburban Traffic	P. Melikishvili Street
	1		NO_x, PM_{10}, O_3	Suburban Background	BesarionChichinadzeStreet

Sampling in Agglomerations

When sampling in agglomerations at least 50% of the stations shall be located in suburban areas, and within suburban areas at least one station should be located where highest exposure of the population where likely to occur.

Minimum number of point source sampling points

In determining the number of fixed measurement sampling points for assessing the contribution of pollution in the vicinity of point sources, a number of factor were taken into account:

Table18 Factors in deciding whether to sample a point source

Factor	Query	Case for Tbilisi
Emission densities	Where is the pollution coming from and which are the areas with the greatest pollution emissions?	Domestic heating, limited number of industrial point sources across the city centre, road transportation
Likely distribution patterns of ambient air pollution	How dispersed is the pollution, where is it most and least concentrated?	Dispersed, though there are pockets of concentrations in the City centre
Potential exposure of the population	Where are members the public at greatest risk of being exposed to poor air quality.	Within their residences and places of work, in the city centre

Compliance with the PM2.5 Exposure Reduction Target

In order to assess compliance with the PM2.5 exposure reduction target for the protection of human health a minimum number of sampling points for fixed measurement has been set. Currently this has a maximum ceiling of one sampling point per million inhabitants. As these can be summed over agglomerations and additional urban areas in excess of 100,000 inhabitants, no more than one PM2.5 sampling point will be mandatory. This sampling point may coincide with sampling points required to assess impact upon human health.

Other Design Factors within the Air Quality Monitoring Network Design

A number of additional design features required within the Tbilisi air quality network, include:

- The minimum monitoring equipment requirements and additional laboratory facilities
- Lay out and Instrumentation of monitoring stations
- Data communication and data management
- Network organisation
- Quality Assurance and Quality Control

- Maintenance & Repairs.
- Equivalence Testing

Minimum monitoring equipment requirements and additional laboratory facilities

At all network monitoring sites where fixed continuous ambient air quality monitoring is required, sampling and detection methods are required to be used that produce results equivalent to any of the methods referred to in Section A. In general these methods should be compliant with the type approved reference methods for the measurement for air quality pollutants (specified in Annex vi of Directive 2008/50/EC) are based upon Standard Methods developed by CEN (Table 19):

Table 19 CEN Air Quality Standard Methods

Pollutants	Standard	Year
(NO_x)	EN14211:	2005
(SO_2)	EN14212:	2005
(O_3)	EN14625:	2005
(CO)	EN14626:	2005
(PM_{10})	EN12341:	1999
($PM_{2.5}$).	EN14907:	2005
(Benzene)	EN14662	2005

These standards describe in detail how analysers are to be tested, approved for use, calibrated and their ongoing performance determined. These harmonised procedures allow Member States to reliably and consistently quantify the uncertainties associated with their measurements of air pollution. CEN, through the various Working Groups, continue to revise and improve the Standards as new information becomes available.

Gas analysers are required to be regularly calibrated against specific gas calibration standards. In order to maintain traceability (EN 17025) of these calibration standards, a national reference laboratory is required to be used. Such a facility should have the ability to either validate or approve gas standards to an international reference equivalent. Where such a facility is not available, national reference laboratories from neighbouring states may be used.

Whereparticulate samples are required to be determined using the gravimetric method, then this must be done so at a suitable laboratory which complies with the requirements within both EN 12341 and EN14902. Once again, such a facility may be accessed outside of Georgia if necessary.

Lay out and Instrumentation of monitoring stations

Monitoring stations are required to be weatherproof, secure, robust, safe organized places of work for site engineers to work and site staff to inspect. Typically a monitoring station will consist of a steel framed enclosure, which is sufficient in size that more than one staff member can enter the work space and comfortably work around the instruments. Monitoring instruments are usually rack mounted in the centre of the enclosure and sample lines are drawn down from the roof mounted manifolds. The monitoring stations with the air quality network will require instruments which employ the following detection methods to be at applied for specific pollutants, which are required to test the contribution from a range of source types (Table 20).

Table 20Instrumentation Methodology Required Across Tbilisi Air Quality Monitoring Stations

Pollutant	Sources	Methodology
Nitrogen Dioxide (NO_2)	Road transport and industry	Chemiluminescence
Ozone (O_3)	Sunlight and heat, acting on road transport and industrial emissions	UV absorption
Sulphur Dioxide (SO_2)	Industry and fuel combustion	UV fluorescence
Carbon Monoxide (CO)	Road transport	IR Absorption
Particles (PM_{10}, $PM_{2.5}$)	Road transport, industry, construction, soil and natural sources	Gravimetric filter method/ Tapered Element Oscillating Microbalance/ Beta Attenuation Monitor
Benzene	Road transport and industry	Gas Chromatography Photo-Ionisation Detection

<u>Data communication and data management</u>

Collecting the data from the monitoring sites: Air quality data and air station operating conditions (e.g. meteorological and station status, alarms, etc) should be continuously broadcast via either a GPRS or 3G communication system from the air quality stations to a centralized computer database.

Data should then be immediately available as provisional data, and updated as provisional data to a centralised Air Quality Archive and where available a dedicated website. Data ratification can be undertaken at a later date. As this data can be screened and validated, but not fully ratified, it can be described as provisional data. The process for collecting, validating and disseminating the provisional data is described below.

Validation of Air Quality Data: Station concentration data can be stored as small durations (typically 15 minute averages) upon a central data management system database. Raw and provisional data will be kept as the original database in order to retain a complete record of all air quality station concentrations.

A manual raw data screening is undertaken every three months periods in order to validate the scaled data.

Dissemination of Ratified Data: Provisional data should be fully ratified every 3-month blocks. As part of the ratification process, any suspect data may be reinstated if deemed to be genuine. Following ratification process, the fully ratified dataset can then be disseminated as validated.

Network organisation

The Tbilisi air quality monitoring network organisation is inherently linked to the development of the Georgian National Quality Plan as outlined in section 6.12 of the previous report entitled ‘Comparison of the Air Quality Monitoring Systems of EU Members States and Georgia’. The roles and responsibilities of the proposed national quality programme is outlined in Figure 15 below. The Environmental Pollution Department within the National Environmental Agency provide the central key role in the network operation, supported by several other bodies, including suppliers and technical service providers, such as a maintenance and repair engineer as well calibration gas/ reference test suppliers. It is proposed that the maintenance and repair engineer role should be provided by an external contractor with sufficient experience, specialists skills and staff resources to provide continuous technical coverage.

Figure 15 National Air Quality Monitoring Network Quality Plan Participants

Quality Assurance and Quality Control

The primary objective of QA/QC within the air quality network is to maintain high quality of measurement standard and traceability to ensure that data made available is robust and that data reported to the European Commission meets the legal obligations of the relevant Directives.

Quality Control: Air quality data generated by the Tbilisi air quality network is subject to the following quality assurance and quality measures to be undertaken for the respective purposes:

Table 21 Quality Control procedures for the Tbilisi air quality network

Quality Control Procedure	Data Quality Property

Data is regularly validated and ratified	Ensures final air quality data set is of a known and documented quality
Standard methodologies for sampling, calibration, auditing, and collection of data	Comparable sampling and detection methods used network to be either CEN reference or equivalent to a CEN reference method
Data is representative of the parameters being measured.	Use of Standard operating procedures

Individual Quality Control procedures for the air quality data should include;

- screening raw data,
- maintaining instrument performance,
- calibration checks using approved standards and
- flow-rate checks.

Quality Assurance: Quality Assurance is a review which assesses effectiveness of the QC program quality, completeness, accuracy, precision, and representativeness of data.

Analyzer Zero and Span Verifications: Bi-weekly zero and span verifications should be used for assessing gas analyzer performance and calibration stability.

Calibrations: Six monthly multipoint calibrations should be conducted, and used in combination with zero and span data to evaluating analyzer performance and establishing data validity.

<u>Equipment Service and Repairs</u>

In order to maximize data capture rates and achieve the Directives data quality objectives a routine maintenance and repair programme is required for all monitoring and ancillary equipment.

Routine servicing should be carried out on a 6-monthly basis

In the event of an instrument malfunction, the maintenance and repair engineer should attend site to carry out emergency repairs or fit a replacement analyser.

<u>Equivalence Testing PM10 and PM2.5</u>

In order for non-reference method continuous particulate monitoring to be verified within Georgia, it must first be performance validated against a reference particulate sampling device. This requires that an extensive series of equivalence tests must be undertaken compliant with EN 12341.

8. RECOMMENDATIONS

RECOMMENDATIONS

These recommendations recognize that:

- Fixed, long-term measurements of the pollutants regulated by the CAFE and 4th Daughter Directives have been monitored in part since 2008 in Tbilisi, though not to the required standards;
- Road transport appears to represent the main emissions source of pollution effecting the majority of the population of Tbilisi;
- There are potential impacts upon resident populations resulting from exposure to pollutants arising from the emissions of point sources to the south east of Tbilisi;
- Short-term passive monitoring has indicated that the spatial distribution of NO_2 concentrations across the city vary widely;
- Historic monitoring of SO_2at the Kvinitadze Street monitoring station in Tbilisi has indicated that annual average SO_2 concentrations currently exceed the EU daily Limit value;
- Preliminary measurements of airborne benzene levels are as yet inconclusive;
- In order to achieve minimal compliance with the CAFE Directive, a total of 5 monitoring sites are required across Tbilisi, with only routine monitoring required for NO_x, SO_2, PM_{10}, $PM_{2.5}$, 03;
- Given the limited temporal measurement data and lack of surrogate information from emissions inventories, pursuing an air quality monitoring network which has minimum compliance with air quality directives risks missing exceedances of the remaining pollutant species such as lead and benzene; and
- It is recommended that sampling of both lead and benzene are undertaken at selected locations until such time that a preliminary assessment may justifiably discount the requirement to monitor on the basis of data collated using compliant quality assured monitoring data.

APPENDIXA MINIMUM NUMBER SAMPLING POINTS

Table A-1 Minimum Number of Sample Points for Diffuse Sources within an agglomeration or zone required under both 1999/30/EC (Annex IX), 2000/69/EC (Annex VII) and 2004/107/EC (Annex V)

Minimum Number of Sample Points for Diffuse Sources within an agglomeration or zone								
Population of agglomeration or zone (thousands)	If maximum concentrations exceed the upper assessment threshold				If maximum concentrations are between the Upper and lower assessment thresholds			
	Pollutants except PM	PM (2) (sum of PM_{10} and $PM_{2.5}$)	As, Cd, Ni	B(a)P	Pollutants except PM	PM (2) (sum of PM_{10} and $PM_{2.5}$)	As, Cd, Ni	B(a)P
0 – 249	1	2	1	1	1	2	1	1
250 – 499	2	3			1	2		
500 – 749	2	3			1	2		
750 – 999	3	4	2	2	1	2	1	1
1,000 –1,499	4	6			2	3		
1,500 – 1,999	5	7			2	3		
2,000 – 2,749	6	8	2	3	3	4	1	1
2,750 – 3,749	7	10			3	4		
3,750 – 4,749	8	11	3	4	3	6	2	2
4,750 – 5,999	9	13	4	5	4	6	2	2
> 6,000	10	15	5	5	4	7	2	2

Table A-2 Minimum Number of Sample Points for fixed measurements for zones and agglomeration attaining the long-term objectives required under both 1999/30/EC (Annex IX), 2000/69/EC (Annex VII) and 2004/107/EC (Annex V)

Minimum Number of Sample Points for fixed measurements for zones and agglomeration attaining the long-term objectives			
Population of agglomeration or zone (thousands)	Agglomerations (urban and suburban) or zone (thousands)	Other zones (suburban and rural)	Rural background
< 250		1	1 station/ 50,000km^2 as an average density overall zones per country
< 500	1	2	
< 1,000	2	2	
< 1,500	3	3	
< 2,000	3	4	
< 2,750	4	5	
< 3,750	5	6	
> 3,750	One additional station per 2 million inhabitants	One additional station per 2 million inhabitants	

APPENDIX B PASSIVE SAMPLING RESULTS

City	X and Y Coordinates	Address	Area Description	NO_2 µg/m^3	Ozone µg/m^3	Benzene
Tbilisi	486584; 4613880	Tbilisi 14	Kerbside	51.72		
Tbilisi	486774 ; 4614183	Tbilisi 29	Kerbside	31.63		
Tbilisi	0482534;1618410	Agmashenebeli St.	Kerbside	38.10		
Tbilisi	0482582;4619181	Tseretelist.	Kerbside	36.15		
Tbilisi	0482982;4618952	Suramist.	Urban background	38.66		
Tbilisi	0482968;4620078	Dadiani St.	Urban background	24.68		
Tbilisi	0481914;4620935	Stanislavski st.	Urban background	31.16		
Tbilisi	0479171;4618706	Budapestist.	Urban background	47.58		
Tbilisi	0481150;4618825	Bakhtrionist.	Urban background	37.04		
Tbilisi	0479171;4618706	Hippodrome	Road side	27.21		
Tbilisi	0479016 ;4619419	VashaPshavela Av.	Road side	27.13		
Tbilisi	0482824;4618209	Agmashenebeli Av.	Road side	59.36		
Tbilisi	0483058; 468041	Tolstonokovist.	Urban background	46.65		

Tbilisi	0481285;4623607	G. Gogiberidzest. Park	Urban background	12.70		
Tbilisi	0479985;4627009	Tavdadebulistr and Petritsist.	Road side	14.53		
Tbilisi	0484569 ;4627018	Gldani district. Mosulishvilist. Park	Kerbside	26.98		
Tbilisi	0485298;4626981	Mosulishvilist. School #79 area	Suburban	33.74		
Tbilisi	0485260;4624823	Temqa district	Urban background	24.50	70.46	
Tbilisi	043678; 4624702	Chargalist.	Urban background	44.84		
Tbilisi	0483280;4624997	Shatilist.	Urban background	22.76		
Tbilisi	0476986;4618521	University - Maglivi building	Urban background	17.69		
Tbilisi	483497; 4615710	Freedom Sq.	Kerbside	59.17		
Tbilisi	483113; 4616166	1st School	Kerbside	42.14		
Tbilisi	482494; 4617004	Rustaveli Av.	Kerbside	94.03		
Tbilisi	482502; 4617274	Leo Kiachelist.	Road side	53.25		
Tbilisi	482161; 4617409	Kostavast.	Road side	80.78		
Tbilisi	480938; 4617301	Abashidzest.	Suburban	51.68		
Tbilisi	480268; 4617690	ZurabArakishvilist.	Urban background	51.16		
Tbilisi	479447; 4616434	Turtle lake	Suburban	9.57		

Tbilisi	481163; 4617828	Mziuri Park	Roadside	29.67		
Tbilisi	481825; 4617435	Melikishvili av.	Urban	70.60		
Tbilisi	494172; 4612152	BesarionChichinadzest.	Suburban	19.19		
Tbilisi	496457; 4615873	Lilo settlement	Suburban	14.37		
Tbilisi	488119; 4615605	DimitriUznadzisst.	Urban background	34.28		
Tbilisi	4876105;4616510	TeopaneDavitianist.	Suburban	28.37		