USE OF GEOGRAPHICAL INFORMATION SYSTEMS IN ANALYZING VEHICLE EMISSIONS: ISTANBUL AS A CASE STUDY

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ABSTRACT:

Air pollution is defined as the presence in the outdoor atmosphere of one or more contaminants (pollutants) in quantities and duration that can injure human, plant, or animal life or property (materials) or which unreasonably interferes with the enjoyment of life or the conduct of business. Examples of traditional contaminants include sulfur dioxide, nitrogen oxides, carbon monoxide, hydrocarbons, volatile organic compounds (VOCs), hydrogen sulfide, particulate matter, smoke, and haze. This list of air pollutants can be subdivided into pollutants that are gases or particulates. Mobile source emissions are the largest contributor to urban emission inventories in many locations. Ambient air quality standards have become increasingly stringent, and it is important to understand the role of mobile source emissions on air quality through well-designed studies. High air pollution load in Turkey metropolitan cities like İstanbul, İzmir, Ankara, *etc.* has been a major leading to factor towards lowering the ambient air quality day by day. The lowering of air quality is a main environmental problem that affects many urban and industrial sites and the surrounding regions. On-road vehicles are responsible for a significant and rapidly increasing portion of the air pollution in the urban areas of developing nations.Second by second emissions of CO, CO2, HC, and NOx were measured in case study. Geographical Information System (GIS) is a computer based information system that enables capturing, modeling, manipulation, retrieval, analysis, and presentation of geographically referenced data. In this study, In order to compare measurements from the different vehicles, second by second vehicle speed and road altitude data was collected using GPS technology simultaneous with the emissions measurement. It is possible to analyze that increasing emission which various of vehicles sent out environment with GIS. The analysis of the amount of emission depending on the changes of the slopes, calculation of gases spread into air depending on traffic jam, the analysis of the amount of emission depending on the route selected in the city were applied.

1. INTRODUCTION

Current estimates revealed that a quarter of the world's population is exposed to unhealthy ambient air pollution levels, and more than 2 million premature deaths each year can be attributed the effects of urban outdoor air pollution and indoor air pollution, more than half occurring in developing countries (World Health Organization, WHO, 2005). A recent study by WHO concluded that, "One of the trends predicted to lead to increasing air pollution levels is the high rate of urbanization in countries where most of the population is on low income. It is expected that the rapid growth in urban populations will lead to a dramatic increase in vehicle numbers combined with inexpensive solutions for daily commuting, more frequent use of older and two-wheeled vehicles, poor car maintenance and other developments that increase air pollution" (WHO, 2005).

Air pollutant sources can be categorized according to the type of source, their number and spatial distribution, and the type of emissions. Categorization by type includes natural and manmade sources. Natural air pollutant sources include plant pollens, wind-blown dust, volcanic eruptions, and lightning-generated forest fires. Manmade sources include transportation vehicles, industrial processes, power plants, municipal incinerators, and others.

Transportation makes at least 30 % of criteria pollutant (ie, CO, NO_x, SO_2 , PM, NH_3,).

Area	Carbon monoxide		Nitrogen oxide		NM VOC		Sulfur dioxide		PM 10		$PM_{2.5}$		PM_1	
	RT	OT	RT	OT	RT	OT	RT	OT	RT	OT	RT	OT	RT	OT
United Kingdom	69	11	42	11	24	4	1	3	18	6	24	5	30	7
EU15	57	7	45	18	31	6	3	4	28[a]	11[a]		6,1[b]		
AC9			37	12	37	5	2	1						
United States	51	26	34	22	29	18	2	5	1,4[b]	2,2[b]	3,4[b]			
Austria	24,2		40,8		9,9		7,1		12,8					
Belgium	53,3		48,8		30,3		3,3		12,2					
Denmark	56		36,8		34,2	2,6	1,9	0,9	13					
Germany	53		50,9	11,9	20,4		3,1		16,1					
Finland	48,6		45,9		31,7	5			11,7					
France	41,5		51,4		25,5		4,9		11,3					
Italy	68,1		50,3		43,6		1		14,7					
Luxembourg	64		43,8	9-19	37,5		25		8,8					
Netherlands	60,5		41,8	6,5	36	5-12	4,9	1-3	14,7					
Spain	53,8		39,9	15	15,2		1,5		16,1					
Sweden	57,5		44,9		21,8	1,6	1,9	2,6	13,9					
Delhi, India	85,5		82,4		84,1		39		15,6[c]					

[a] Emission of particulates assigned as primary and secondary fine particulates, of which 12% are considered primary PM10.
[b] Direct emissions (i.e does not include fugitive dust)
[c] Based on inventory for total suspended particulates.

Table 1. Contribution of Transportation to Emission in Different Countries

GIS is an important tool for evaluating neighborhood level community health air pollution impacts. GIS allow us to more effectively display our results to the public and help them understand the types and sources of air pollution around them.

Transportation is a major source of greenhouse gas emissions (GHGs) related to global climate change. The sector currently accounts for one-quarter of the world's energy-related carbon dioxide (CO2) emissions and is expected to be the most rapidly growing source over the next 30 years, increasing at an annual rate of 2% to 3% (Price, et al., 2006). The largest share of this growth is expected to come from developing countries, with forecasted growth rates between 3.5% and 5.3% per year (as compared to 1.2% to 1.4% in the OECD). Given these forecasts, the developing world will shift from accounting for roughly 35% of world transportation GHG emissions in 2000 to 52% to 63% by the year 2030 (Price et al., 2006).

On-road vehicles give off poison gases such as CO, CO2, HC, NOx to the environment. Factors which effects to quantities of tailpipe emissions, are type of vehicle, model of vehicle, behaviors of drivers and slope of road.

Variables that affect vehicle emission: New methods can measure all variables that have impact on emissions.

This study is using the data collected in "Emissions Inventory Development" campaign in 2006 in Istanbul. That work has been conducted by EMBARQ and Istanbul Metropolitan Municipality and to quantify emissions from on-road vehicle in Istanbul. [EMBARQ, 2008].

The main objective of this paper is:

- to visualize emissions collected on map using ArcGIS
- to do spatial analysis on vehicle emissions, focus on the impact of road grade
- to do preliminary comparison on emission collected many different models.

2. METHODOLOGY

2.1 Geographic Location

Figure 1. Plot Project Area

It was selected first testing route in which is approximately 1800 meter, on D-100 highway, Golden horn Bridge to Mecidiyeköy, no traffic light and slope of road 4%. The second testing route is too a place which is approximately 1800 meter, on Vatan Street that has 2% slope and traffic lights. Figure 1

Figure 2. Study Area

2.2 Data Collection

Emission data for each vehicle were collected second by second using SEMTECH devices, as the vehicle were driven under real-world conditions. Road grade and coordinates were recorded using Laipac Tech GD30L, GPS at the same time more information on data collection can be found elsewhere [EMBARQ, 2008]. It was possible to transfer GIS data which was measured by GPS instrument. Output emission data was joined to GPS data. ArcGIS interfaces were used to transfer data.

2.3 Data Analysis

The emission of were measured for 1996, 1997, and 2004 model year vehicles A portable instrument, GPS was used to measure Latitude Longitude, Altitude.

Analysis of the data included the impact of road grade, fuel type as well as vehicle type on emissions values.

2.4 Emission Transfer to GIS

Geographic information system (GIS) technology can provide significant enhancements in estimating and analyzing of vehicle emissions. The application of GIS for emission of vehicles analysis is still relatively new and it requires a significant ongoing commitment to implement.

Simply put, a geographic information system is a means of electronically storing, analyzing, and displaying data that innately includes a spatial component; it includes actual location information (and often much more). GIS data systems easily store and manipulate spatial objects such as areas, polygons, boundaries, lines, and points. Each of these objects relate to real-world features such as census tracts, facility locations, roads, rivers, elevation, spatial demographic information, and political boundaries, all of which can be combined, interrelated, and analyzed using GIS tools.(U.S. EPA Annual Emission Inventory Conference Atlanta, Georgia April 2002). In this study, emission measured data were transferred GIS as point data.

2.5 Using Hardware and Software

ArcGIS 9.2, Microsoft Access and Microsoft Excel were used in this project.

Personal Computer that has 1 GB Ram, 150 GB hard disc was used.

2.6 Data Transfer

Geodatabases were created for data transfer in ArcCatalog. Created Geodatabase was opened with Microsoft Access Program. Data which is in Excel Format, was imported to access form as table data. Table data which was created, was imported to ArcMap. In the data, there are Latitude and Longitude data which are collected with GPS. With helps of these data, when X Field Longitude, Y Field Latitude and WGS 84 were selected as coordination system were created a drawing from the windows which opens when “Add XY data” is selected “Add XY data”, in Tools menu of ArcMap. Then exporting to the drawing which was formed from table data, feature class was created. The created feature class was transformed into ED 50 Datum from WGS 84 with “Project” interface in ArcToolBox. The analyses which will be made later, was performed with ED 50 Datum data.

Attributes of GasolineTest43

No	Time	Speed mph	Altitude	Flow sfpm	HC	CO	Nox	CO2	Latitude	Longitude	Date	Shape *
856	10:19:13	37,5	27,3	13,38	0,040006	0,162251	0	0,426167	41,043207	28,941073	08.11.2006	Point
857	10:19:14	35,6	26,6	17,48	0,052804	0,152858	0	0,435899	41,043083	28,940975	08.11.2006	Point
858	10:19:15	34,2	26,2	22,41	0,060255	0,130253	0	0,436009	41,042967	28,940881	08.11.2006	Point
859	10:19:16	32,9	25,9	27,97	0,08573	0,122449	0	0,430535	41,042854	28,940709	08.11.2006	Point
860	10:19:17	31,8	25,7	28,66	0,088277	0,089358	0	0,349144	41,042746	28,9407	08.11.2006	Point
861	10:19:18	30,9	25,3	30,32	0,093721	0,095183	0	0,712498	41,042641	28,940614	08.11.2006	Point
862	10:19:19	30,1	25	29,8	0,092292	0,277525	0	1,529219	41,042537	28,940532	08.11.2006	Point
863	10:19:20	29,7	24,7	26	0,079529	0,327987	0	2,192744	41,042435	28,94045	08.11.2006	Point
864	10:19:21	29,9	24,4	23,98	0,071911	0,305786	0	2,555873	41,042335	28,940369	08.11.2006	Point

Record: 0 Show: All Selected Records (0 out of 1890 Selected) Options

Table 2. Attribute of Gasoline Test43

2.7 Analysis of Measured Emissions in GIS

For analyses, vehicles which have two different technical features and collect data in traffic when they were on the move, were used. One of the vehicles, 2004 model (gasoline Test45), has 2000 engine capacity catalytic convector. One of the others is 1996 (gasoline Test43) model and other one is 1997 (gasoline Test51) model both of them has 1600 cc engine capacity. Test45 collected test data in midday; the others collected them when traffic was heavy. 2004 model vehicle uses unleaded gas, others use normal petrol. Each vehicle was driven by same driver during test process.

Result of analyses CO, CO_2, HC, NO_x which carried out in the pilot project area showed Figure 3, Figure 4, Figure 5, Figure 6.

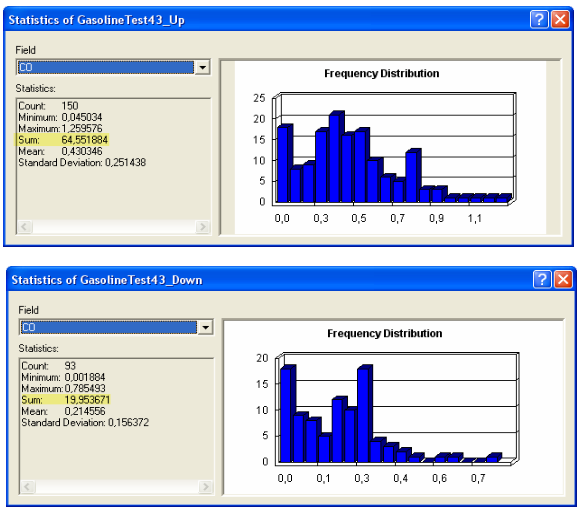

Figure 3.

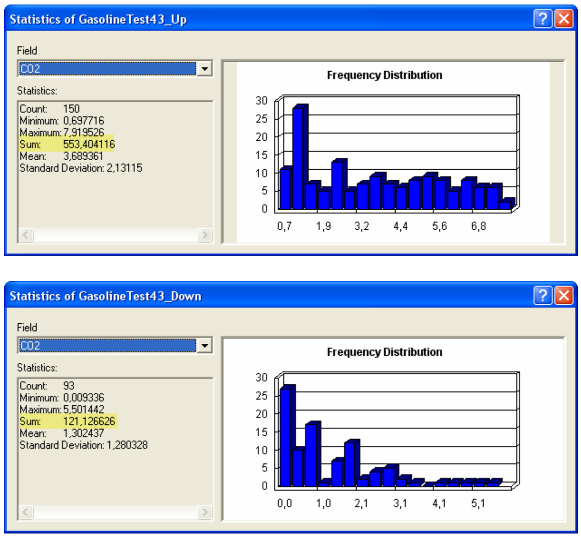

Figure 4.

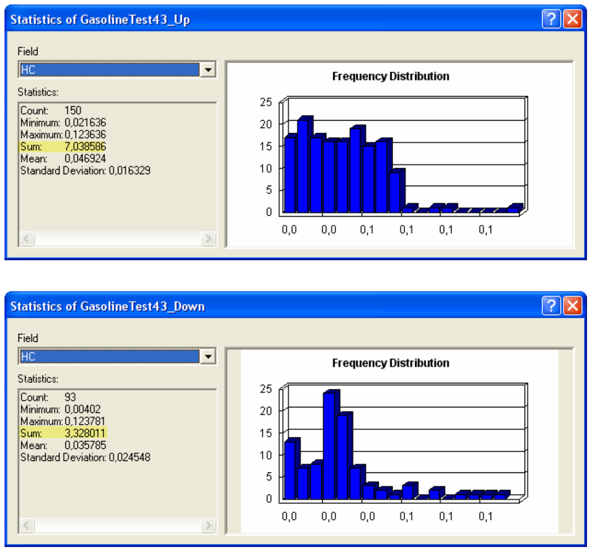

Figure 5.

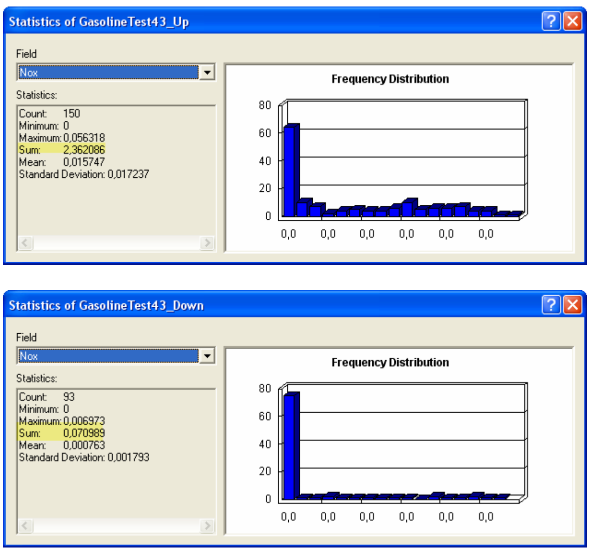

Figure 6.

3. RESULT

The analysis revealed that:

- Working catalytic converter is essential in reducing emissions
- Driving behavior is critical for emission lowering non aggressive driving while going uphill would reduce emission significantly (via-GIS)
- Spatial analysis should be part of emissions inventory to find, sources of emission identify mitigation measures.
- On-road emissions measurements inventory development.

Summary of emissions measured, for CO, CO2, HC, and NOX, for 3 vehicles are given in Table 3.

Tests	CO			CO2			HC			Nox			Models
	Uphill	Dowhill	VatanStreet	Uphill	Dowhill	VatanStreet	Uphill	Dowhill	VatanStreet	Uphill	Dowhill	VatanStreet	
GasolineTest45	2,256296	0,296506	0,509999	55,847906	61,498931	105,460285	0,830235	0,40769	0,605967	0,684373	0,446479	0,417081	2004
GasolineTest51	43,14991	16,166597	43,085252	654,932158	87,127569	352,990576	7,72498	3,188828	6,001051	4,930879	0,599535	2,965889	1997
GasolineTest43	64,551884	19,953671	103,208012	553,404116	121,126626	568,612636	7,038586	3,328011	13,363448	2,362086	0,070989	1,223555	1996

Table3. Emission Result of 3 vehicles

As seen in Table 3, emissions tend to increase in the uphill case compared to the downhill case. For example, for Gasoline Test 45, CO emissions are 0.29 grams in the downhill case as compared to 2.26 grams for the uphill In all cases going uphill increases emission significantly.

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