



A GIS-based Air Pollution Modeling in Tehran

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Abstract

Population growth, development of the mega cities and their impacts on urban traffic are the most important problems of the mega cities. Increasing traffic volume and air pollution lead to population health problem. In this research a prediction model has been developed for air pollution in 2004 using the data of 2002 and 2003. Additionally by using the method of local contribution to concentration in canyon streets, the concentration of both CO and NO₂ at each month and for six highways of Tehran and for each vehicle is calculated. The prediction model is a GIS-based model that takes geometry of the streets and vehicle numbers.

Keywords: GIS, Air Pollution, Traffic, Climate, Canyon Streets, Modeling, Prediction Model

1. Introduction

Air pollution is one of the most important problems of cities. Unfortunately in Tehran a few researchers focus on this problem so far. In this paper the emission model of two gases including CO and NO₂ is discussed. Air pollution from motor vehicles is one of the most serious and rapidly growing problem in Tehran. The modelling provides the ability to assess the current and future air quality in order to enable informed policy decision making. Thus, air quality models play an important role in providing sufficient information for better and more efficient air quality management planning.

Among various techniques for simulating dispersion of pollutants due to road vehicles in street canyons, the semi-empirical approach appears to be the most convenient one for practical use (Gualtieri and Tartaglia, 1998). Street canyon model is usually focused on pollutants, whose dispersion processes do not involve chemical or photochemical reactions. The main objective of this paper is modelling CO and NO₂ in 2002, 2003 and 2004 and predicting CO and NO₂ pollution in 2004 according to 2002 and 2003 data and comparing the prediction values with the actual data. The simulation model presented in this paper for evaluation of local air pollution consists of an air quality prediction.

A geospatial information system (GIS) is a computer-based tool related to mapping and analyzing spatially distributed phenomena related to the earth. GIS technology integrates common database operations with the unique visualization. The advantage of GIS compared to other information systems is the high power of analysing of spatial data and handling large spatial databases. In air pollution there are a large amount of data that GIS can be used for their handling. Data that is used for modeling air pollution is wind direction, wind speed, traffic flow, solar radiation, air temperature and mixing height. The highways that are studied in this research are Hemmat, Hakim, Jenah, Modarres, Zeinaldin and Basij which are among the main highways in Tehran. The program and software used are Matlab and ArcGIS.

2.Methodology

In this research, GIS has been set up according to diagram presented in Figure 1.

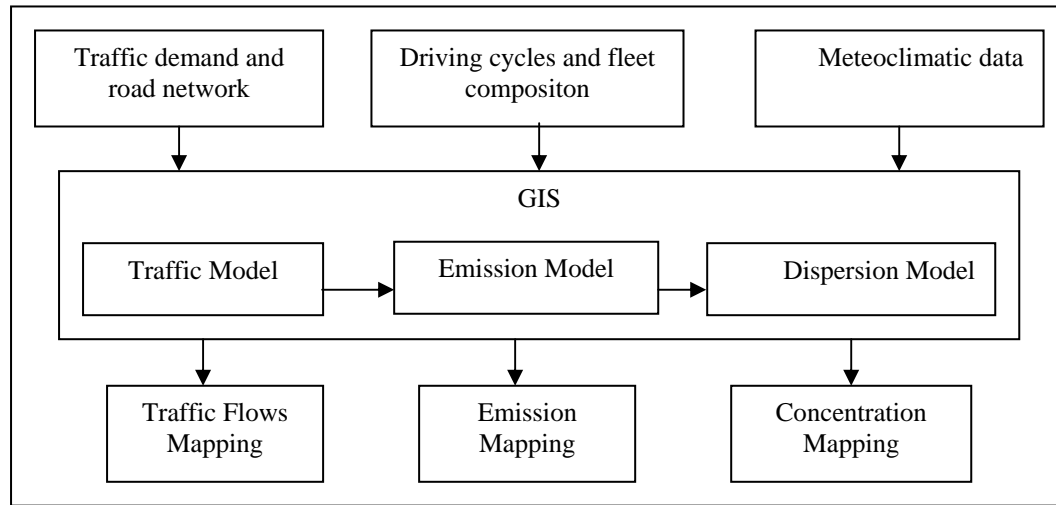


Figure 1:GIS Structure for Vehicular Pollution Modelling (Gualtieri and Tartaglia,1998)

The steps of the the modeling process is as follows:

The first step is to calculate the stack's volumetric gas flow rate (\dot{V}) using Formula 1. (Gualtieri and Tartaglia,1998)

$$\dot{V}(\text{m}^3/\text{min}) = \text{Mean speed of vehicle}(\text{m/s}) * \left[\pi * (\text{diameter of dispersion}(\text{m}))^2 / 4 \right] * 60(\text{Sec} / \text{min}) \quad (1)$$

where $\pi = 3.1416$

Formula 1 is then modified to correct the stack gas flow rate for the moisture content and standard conditions using Formula 2 (Gualtieri and Tartaglia, 1998) :

$$\text{Dry } \dot{V} (\text{m}^3/\text{min}) = \dot{V}(\text{m}^3/\text{min}) * \frac{273.15 \text{ K}}{T_{\text{actual}}} * \frac{P_{\text{actual}}}{1 \text{ atm}} * (1 - \text{humidity}) \quad (2)$$

where P_{Actual} : Actual Pressure and T_{Actual} : Actual Temperature.

The next step is to convert PPM (volume) to mass emission rate (kg/h) as follows:

$$\text{kg/h} = \text{ppm} * \text{density of air at standard condition} * \text{Dry } \dot{V} * 60(\text{min}/\text{h}) * \frac{MW_{\text{substance}}}{MW_{\text{air}}} \quad (3)$$

where $MW_{\text{substance}}$: Mass volume of Substance and MW_{air} : Mass volume of Air

The emission factor is calculated using Formula 3 (Gualtieri and Tartaglia, 1998):

$$E_g = \text{Emission factor} = \frac{\text{Emission rate} \left(\frac{\text{g}}{\text{hour}} \right)}{\text{Fuel feed rate} \left(\frac{\text{kg}}{\text{hour}} \right)} \quad (4)$$

$$Q_s = \text{Mean Emission Rate} = \text{Emission factor} / \text{Length of the road} \quad (5)$$

The emission factor E_g due to road vehicles belonging to group g is expressed as the mass of pollutant per unit length as a function of the average travel speed, V_m . Total pollutant emission, Q , produced by the traffic flow, f , of N vehicular groups is computed using Formula 6 (Gualtieri and Tartaglia, 1998):

$$Q = \sum_{g=1}^N \frac{c_g}{100} * E_g (V_m) * f \quad (6)$$

where c_g is the percentage of vehicular group g with respect to the vehicle fleet. Concentration is calculated by adding local and areal concentration. In this paper our objective is modeling the local concentration which is more effective than areal concentration. Local Contribution to concentration is calculated by different approaches (i.e. Zannetti (1990); DePaul and Sheih (1986)). The model developed by Gualtieri and Tartaglia is more useful for calculating the local contribution to concentration because of considering more elements of meteo climatic variables. The climatic data employed was related to July 2002 and December 2004 for both CO and NO₂. This model is based on the calibration process. The street canyon model used is based on Formula 7:

$$C_l = a \left[\frac{Q_s}{U + 0.5} \right] * F + bT + cH + \sum_i d_i Rad_i + k_0 \quad (7)$$

where: C_l ($\mu\text{g}/\text{m}^3$): modeled CO or NO₂ concentration;

Q_s (g/ms): mean emission rate;

F (m^{-1}): shape factor (F_W, F_L, F_I), depending on the specific sector (Table 1);

U (m/s): air wind speed;

T (C): air temperature;

H (m): mixing height;

$\sum Rad_i$ (W/m^2): solar radiation;

a, b, c, d, k_0 : model linear coefficients to be calibrated.

Q_s is calculated according to Formula 5. F is calculated with respect to Table 1.

$U, T, H, \sum Rad_i$ have been obtained from Iran Meteorological Organization.

a, b, c, d, k_0 are the calibration coefficients that are discussed in conclusion section.

Table 1: Shape factors values, F , as a function of sector geometrical features

Sector	Shape factor	Value(m^{-1})
Windward	F_W	$7 * \frac{h - z}{h * w}$
Leeward	F_L	$7 * \frac{1}{\sqrt{x^2 + z^2} + L_0}$
Intermediate	F_I	$(F_W + F_L) / 2$

where h: buildings mean height;
w: street canyon width;
x: distance of the receptor from street axis;
z: height of the receptor;
L₀: Vehicles mean width, generally assumed to be 2 (Meters);
The flowchart of the modeling process is shown in Figure 2.

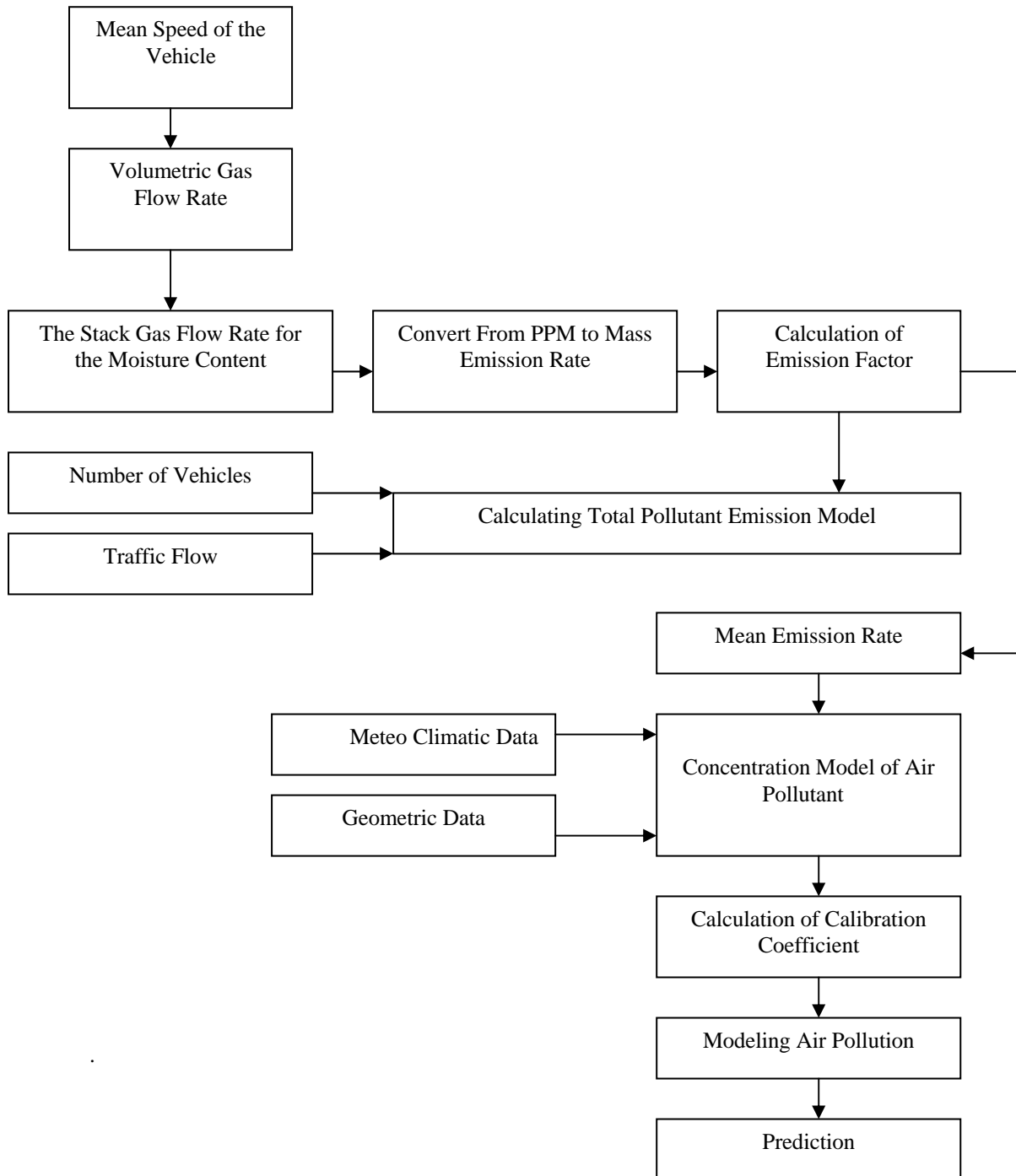


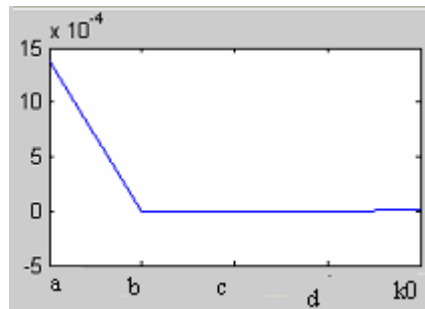
Figure 2: Flowchart of the modeling process

3. Conclusion

The available data for 2002 was related to the second half of the year, so the results of the calibration coefficients for CO in 2002 are different from the results in 2003 and 2004. It is concluded that the canyon model is efficient when complete data throughout year is used. The diagrams of changes of the calibration coefficients for taxi vehicles in 2002, 2003 and 2004 are depicted below.

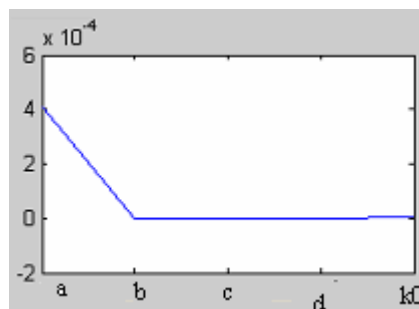
Calibration coefficients for taxi in 2002 with the windward direction

- a: 1.374948671739869e-003
- b: 3.853513032343572e-007
- c: 2.286940181094655e-009
- d: -1.180659878183390e-006
- k₀: 4.891150151774462e-006



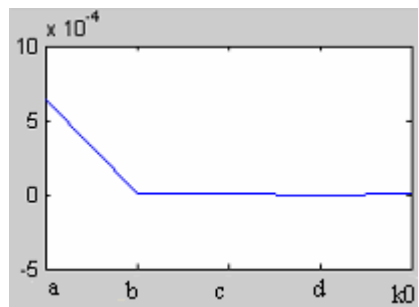
Calibration coefficients for taxi in 2002 with the leeward direction

- a: 4.103235064784254e-004
- b: 3.853513032343580e-007
- c: 2.286940181094613e-009
- d: -1.180659878183392e-006
- k₀: 4.891150151774506e-006



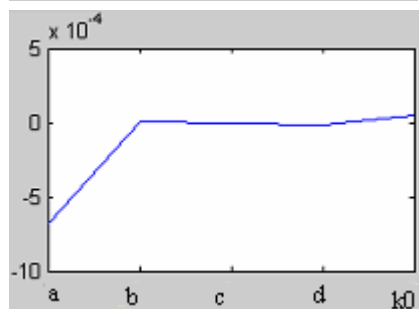
Calibration coefficients for taxi in 2002 with the intermediate direction

- a: 6.320310898243167e-004
- b: 3.853513032343602e-007
- c: 2.286940181094652e-009
- d: -1.180659878183414e-006
- k₀: 4.891150151774374e-006



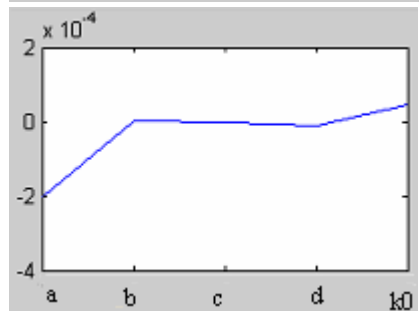
Calibration coefficients for taxi in 2003 with the windward direction

- a: -6.797655989864877e-004
- b: 2.193610982541772e-006
- c: -1.509709889915393e-008
- d: -1.125186204598263e-005
- k₀: 4.528171643662279e-005



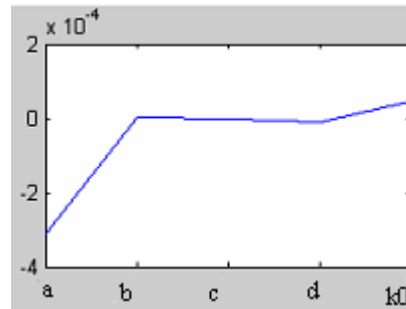
Calibration coefficients for taxi in 2003 with the leeward direction

- a: -2.028612484900796e-004
- b: 2.193610982542941e-006
- c: -1.509709889916437e-008
- d: -1.125186204598840e-005
- k₀: 4.528171643664303e-005



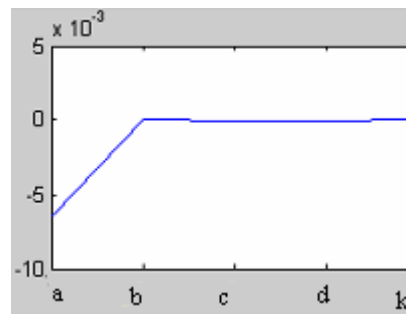
Calibration coefficients for taxi in 2003 with the intermediate direction

- a: $-3.124720225439167e-004$
- b: $2.193610982543523e-006$
- c: $-1.509709889916942e-008$
- d: $-1.125186204599109e-005$
- k_0 : $4.528171643665154e-005$



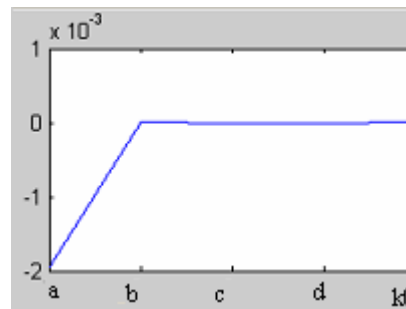
Calibration coefficients for taxi in 2004 with the windward direction

- a: $-6.508818108029970e-003$
- b: $1.265673002072326e-006$
- c: $-2.189049007255713e-009$
- d: $-5.702979908174779e-006$
- k_0 : $1.759312630374989e-005$



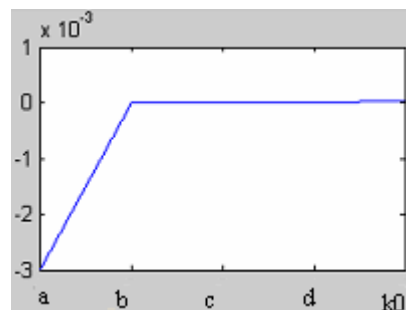
Calibration coefficients for taxi in 2004 with the leeward direction

- a: $-1.942415105385212e-003$
- b: $1.265673002072297e-006$
- c: $-2.189049007255620e-009$
- d: $-5.702979908174546e-006$
- k_0 : $1.759312630374937e-005$



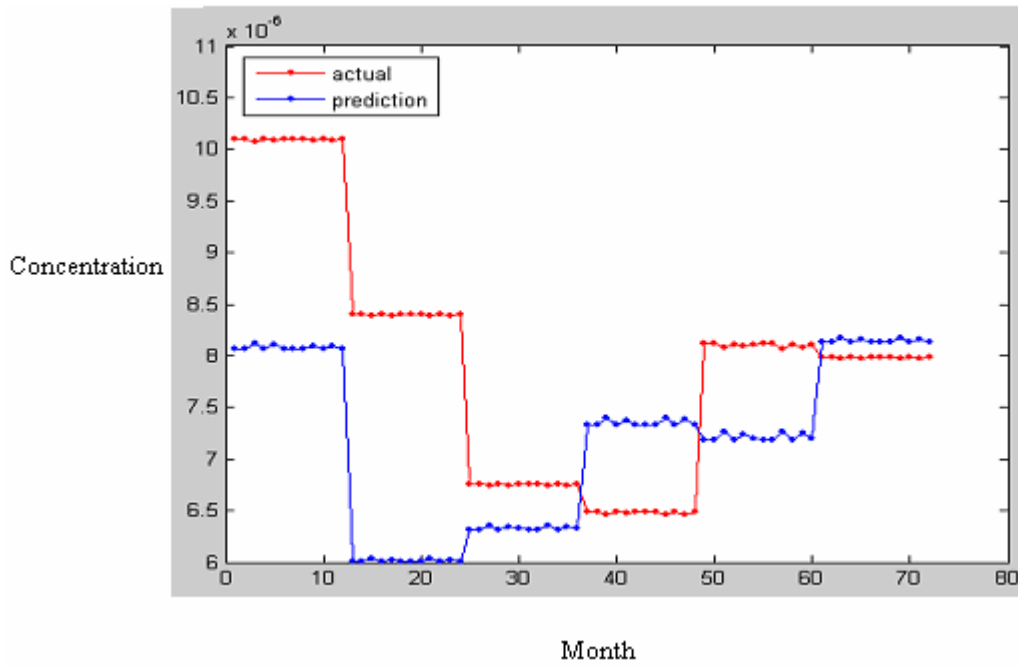
Calibration coefficients for taxi in 2004 with the intermediate direction

- a: $-2.991948344573258e-003$
- b: $1.265673002072326e-006$
- c: $-2.189049007255594e-009$
- d: $-5.702979908174774e-006$
- k_0 : $1.759312630374975e-005$



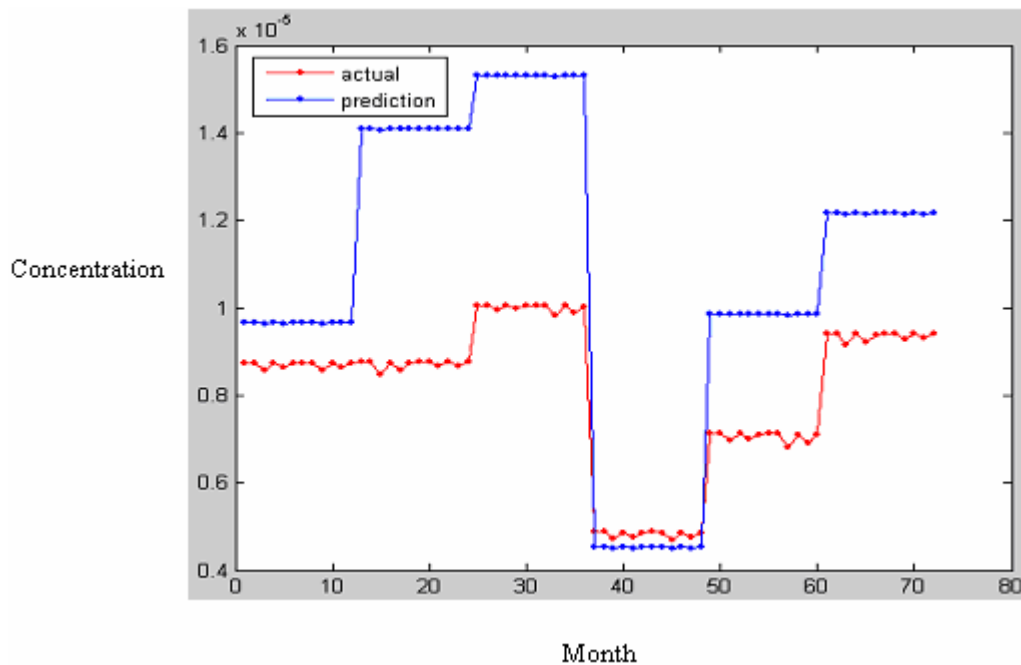
Considering the results, the differences between the wind sector in 2003 and 2004 coefficients are negligible, of course if data of previous years added, results may improve. For example the calibration coefficients for taxi in year 2004 and 2003 in windward direction approximately are the same.

In the following the results of using 2002 and 2003 data for prediction of pollutant in 2004 are discussed. The following graph shows the actual data of 2003 and the predicted values of 2003 using 2002 data. The horizontal axis is depicting twelve months for the six highways in Tehran and the vertical axis depicts the concentration of CO for each month and for each highway.

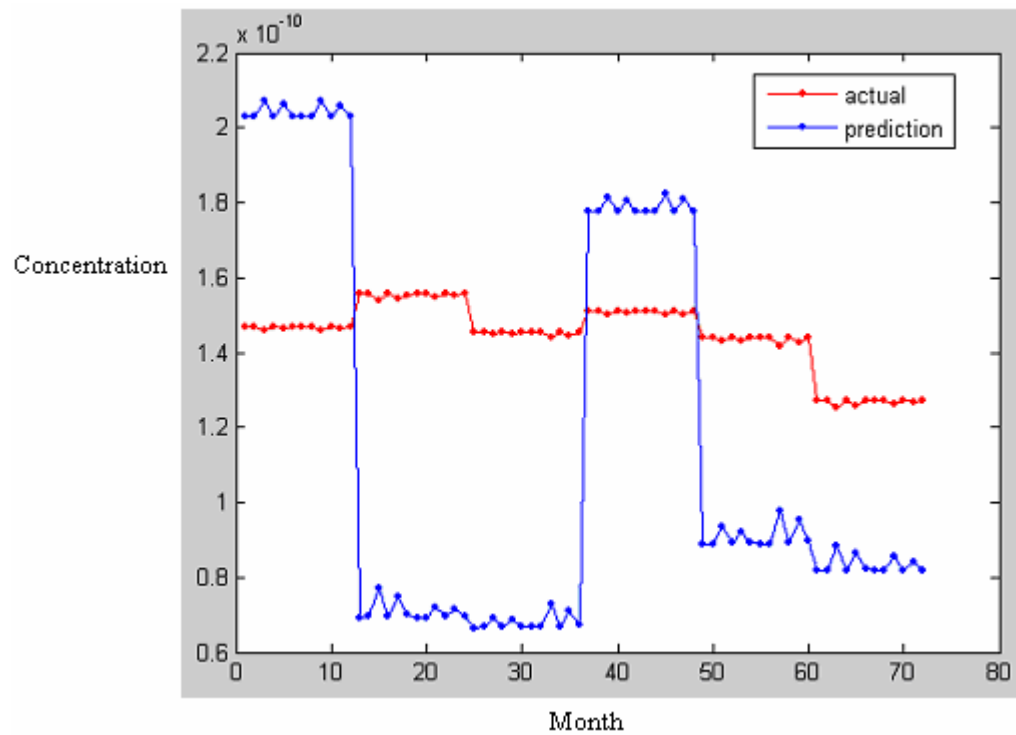
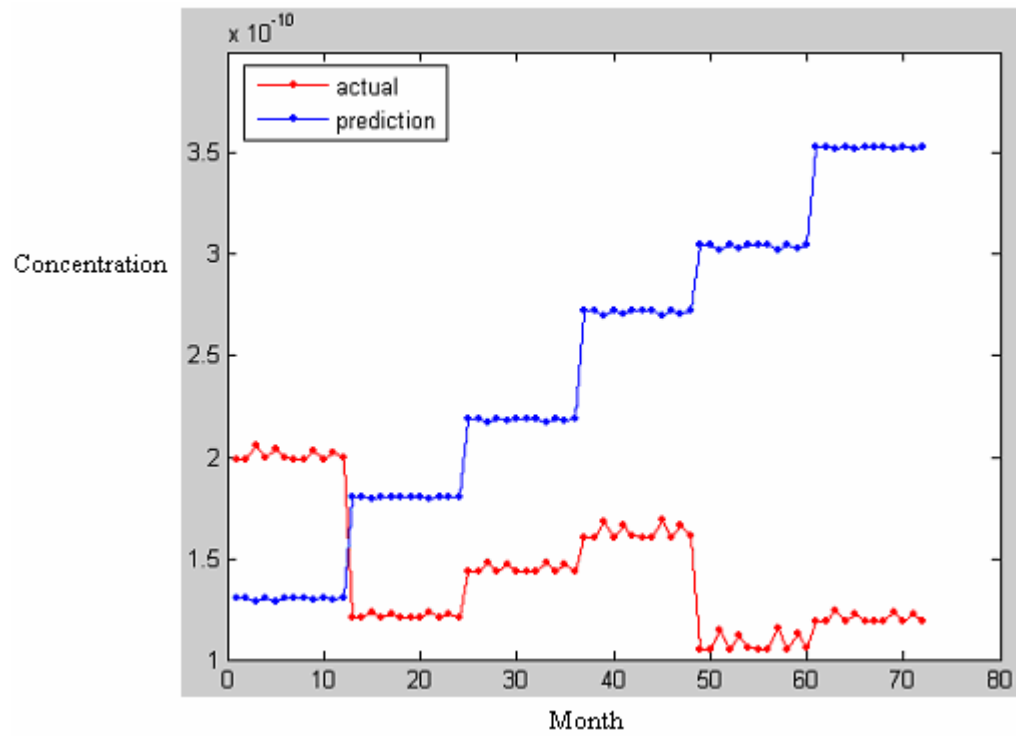


As can be seen the results is not acceptable and the reason is using only data of the second half of the year 2002 is implemented.

After using 2002 data for prediction of 2003 air pollution, in this section we use 2003 actual data which is for all of twelve months, for predicting 2004 concentration. As the following figures depict, the results are acceptable and the difference is negligible in some parts.

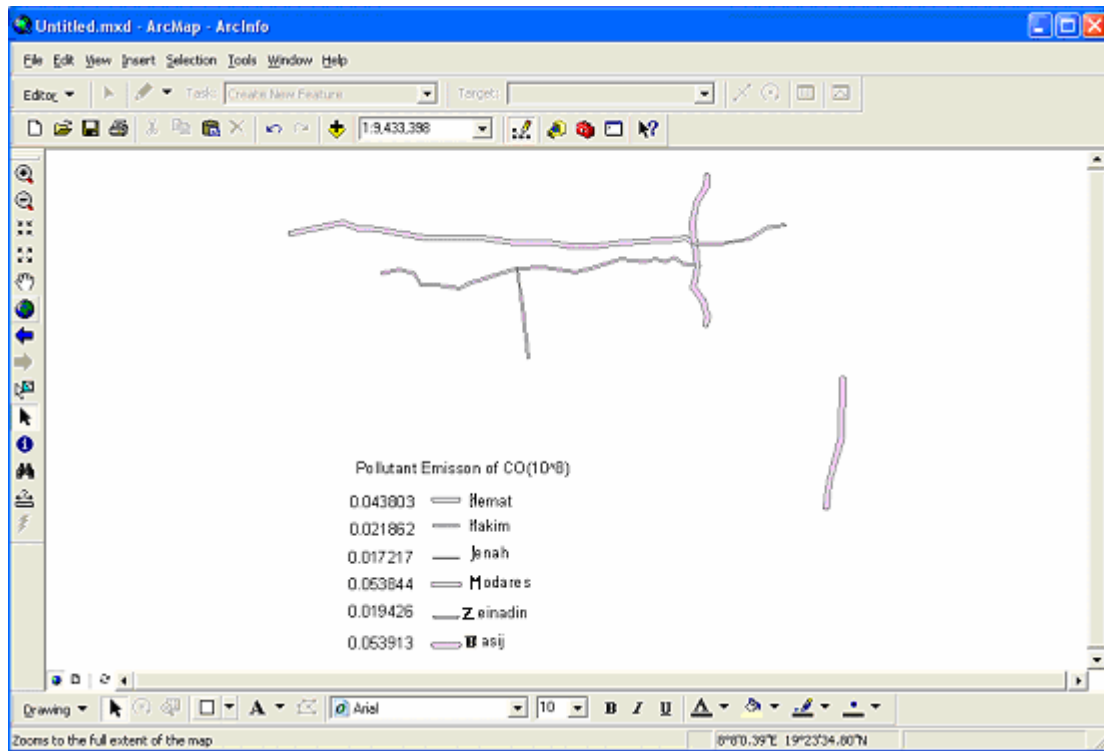


Similar to CO concentration, the scenario are repeated for NO₂ as follows.

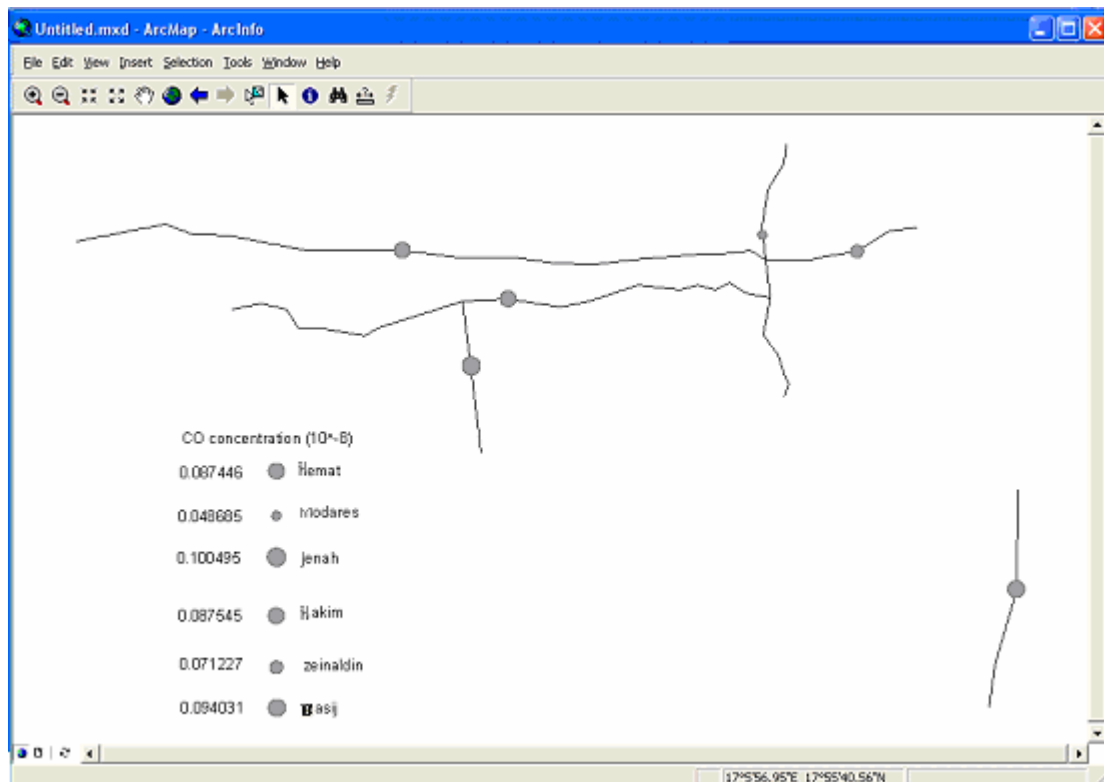


GIS has been used in this research to analyze and depict emission and dispersion model of CO in the six highways in Tehran.

An example of pollutant emission mapping due to all traffic volumes in Tehran, case study, CO for January 2004 emission rate is shown below.



An example of pollutant dispersion mapping in Tehran concerning CO concentration in January 2004 is illustrated below.



References

- Bellasio, R., G. Lanzani, M. Tamponi and T. Tirabassi (1994). Boundary layer parametrization for atmospheric diffusion models by meteorological measurements at ground level. *Il Nuovo Cimento*, 2, 163-174.
- DePaul, F.T. and C.M. Sheih (1986). Measurements of wind velocities in a street canyon. *Atmospheric Environment*, 3, 455-459.
- Florian, M. and S. Nguyen (1976). An application and validation of equilibrium trip assignment methods. *Transportation Science*, 10, 374-389.
- Gualtieri G., & Tartaglia M., 1998, Predicting urban traffic air pollution: a GIS framework, *Transportation Research - D*, 3(5), pp. 329-336, Elsevier Science.
- Van Mierlo J., 2000, Simulation software for comparison and design of electric, hybrid electric and internal combustion vehicles with respect to energy, emissions and performances, PhD thesis, Vrije Universiteit Brussel.
- Zannetti, P. Air pollution modeling, 1990, Computational Mechanism Publications, Southampon.