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ORIGINAL PAPER

Investigation and sensitivity analysis of air pollution caused by road transportation at signalized intersections using IVE model in Iran

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Abstract

Introduction The development of urbanization has had many negative outcomes in different societies. Population growth and the increase in the transportation are the consequences of urban growth which has resulted into problems. Vehicles are responsible for 90% of air pollution in Iran and it is essential to use authentic models of traffic emissions in accordance with the current conditions to predict this and future emissions. Iran has a lot of different air pollution dispersion parameters compared with the developed countries.

Method In this paper air pollution emission parameters in signalized intersections have been modelled and results have been compared to measured concentrations of air pollution in intersections. For this purpose the use of IVE (International Vehicle Emission) model that is common air pollution modelling and besides, Sensitivity Analysis has been performed to show modeling accuracy in comparison with current emissions.

Result By modeling and measurement results, it's easily understood in warm seasons emission concentration is more than cold seasons. Minimum and maximum rate of Carbon-monoxide (CO) and Nitrogen-oxides (NO_X) has been evaluated.

Conclusion IVE model has shown a bit difference amount of pollutions by comparison with field measurement emission. It could be said it is appropriate for model vehicle emission in Iran.

Keywords Air pollution · Emission · Transportation · IVE · Pollutants

Highlights

?1. Emission factors have been measured in both cold and warm seasons.
2. The fleet technology has been considered in modelling.
3. The results of modelling have been compared with field data.
4. Both transportation and weather related parameters have been considered in model.

1 Introduction

The development of urbanization in different societies has had many negative outcomes. Population growth result increases in the transportation which has resulted into problems. Transportation causes lots of problems contrary to its benefits. Two major problems are noise and air pollution. Noise pollution in airports is more important. Lots of studies on noise pollution reduction of aircraft around airport have been done recently by introducing optimal model to decrease noise pollution and fuel use of commercial aircraft [1–3]. Another problems is the air pollution that significantly visible in metropolitan areas. It has been estimated that air pollution is responsible for the death of 3.1 million people in the world every year [4]. Among the sources of air pollution motor vehicles movement in transport network is known as the main cause of air pollution to such an extent that it has obtained a share of 60 to 90% of total emissions [5]. Environmental stress, fuel consumption and transport industry pollutions augment when the traffic flow is stopped

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and delayed and stop-motion phenomenon occurs frequently. These phenomena are often seen at intersections and road junctions, especially when the traffic signals are used. Thus, the highest concentration of pollutants produced by transportation occurs near the signalized intersections and squares and urban air quality near these areas is of lower condition compared to other areas which is due to the changes in vehicle speed when approaching and moving away from the intersection [6, 7]. In other words, there are high traffic dynamics near signalized intersections.

High dynamics for congestion, i.e. stop-and-go traffic and low dynamics for free-flowing traffic. Traffic with high dynamics has significantly higher emissions than traffic with low dynamics [8, 9]. Also Mustafa et al. (1993) revealed that the traffic signals at intersections generate about 50% more emissions than roundabouts and during heavy traffic, signals lead to larger emissions of HC, almost double of that at roundabouts [10]. Coelho et al. by modelling and laboratory studies displayed that existence of signalized intersections in urban areas increases pollution 15 to 40% [11].

Road vehicle emissions depend on many parameters like transportation and weather factors. Emission models are used to perform the measurments of road transport emissions [4]. Vafa-Arani et al. (2014) have studied on air pollution in Tehran metropolitan city and have shown two source of air pollution affect the weather of this city. They have examined transportation and industrial pollution effect [12]. Sivacoumar et al. (2001) investigated Jamshedpur region in India by using a mathematical programming method to anticipate the air pollution of this region. He illustrated the portion of NO_X concentration from vehicles, domestic and industrial [13]. Hong and Shen (2013) conveyed the residential density on CO_2 in comparison with vehicle using emission factors based on vehicle and trip characteristics [14]. Wang et al. (2008) used a system dynamic model to predict air pollution in Dalian. They utilized system dynamic model based on the cause-and-effect analysis and feedback loop structures. Their model comprises 7 submodels like population, economic development, number of vehicles, environmental influence, travel demand, transport supply, and traffic congestion. They suggest Dalian should have been restricted in quantity of vehicle in aim of reducing air pollution [15] and Anh (2003) by using a dynamic model showed air pollution is the main result of traffic congestion. He thinks development in public transportation system and road network expanding can help to reduce pollutant [16].

2 Defining the problem

The field study of the transportation related projects in the field of air pollution is not completely possible and would not provide satisfactory results because this can be performed by a specific devices or tool such as a portable spectrometer device connected to the exhaust which also create some drawbacks and limitations, such as:

- These devices are associated with errors.
- Using this device a few parameters such as instantaneous velocity can be measured with limits and it is not possible to consider factors, as well as the entire fleet of transportation.
- Preparation and maintenance of these tools is very expensive and not applicable in this country [4].

Hence it is necessary to use authentic models of traffic emissions in accordance with the current conditions. On the other hand, despite the traffic emissions models used to evalute pollution from mobile sources, no steps have been taken to examine their suitability in the countries' conditions. In this study IVE model have been chosen because of its ability in covering lots kind of vehicle (about 1372) and estimating emission factors based on spot speed instead of average speed. In this research IVE model is evaluated and validated using field studies and measurements to introduce a reliable and convenient model for its eligibility. In this study the IVE model is evaluated based on the sensitivity to changing parameters. To examine this model all conditions of the intersection of the municipality of Najafabad - Esfahan have been applied. Accordingly, to enter the input parameters needed by the model the data collected on some winter and spring days of 2015 at a certain hour (11 to 12 AM) were used. One of the factors that cause changes in the calculated concentrations of pollutants causing an error in the calculations is wind. That's why among the days of study the selected days did not vary in terms of wind speed and direction.

Hui et al. (2007) implemented IVE model in Guangzhou China city streets in 2005 and observed correlation coefficients of 0.90 and 0.81 for CO and NO_X [17].

3 Research

3.1 Intersection profile

The area under study is a signalized intersection with a fixed schedule both sides of which end to a one-way path. Phasing of this intersection traffic signal is presented in the Fig. 1.

3.2 The volume of vehicles

In this study, video recording was used as a tool for counting the vehicles on the road at 11–12 within the mentioned days that the results of which are shown in Appendix Table 5. The counts are multiplied by 10 to be rounded. Also the left turn movements of east-west were 19–22% and right turn movements of north-south were 10–12%.

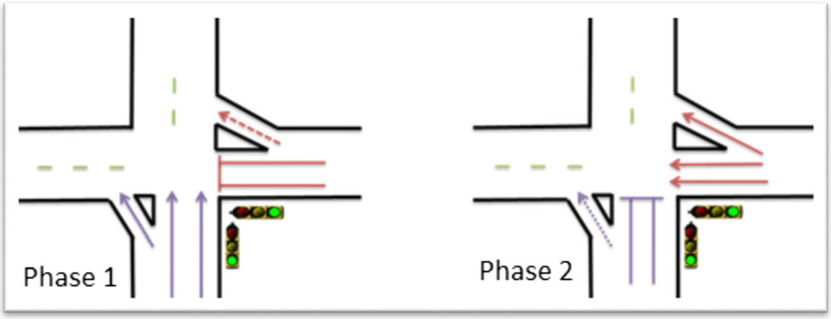


Fig. 1 Phases of the intersection

3.3 The average speed of the fleet

According to the software user manual of IVE, the speed of a fleet of vehicles that as an input parameter in this model, is movement speed not travel speed [18]. For this reason, the fleet velocity of this intersection, the stop time of the vehicles caused by the red lights was ignored. These numbers show the dominant speed of the cars 50 m before and after the intersections at two intersecting streets obtained by the distance and time (minus the red lights interval). The results of the average approximate speed of vehicles on research days are presented in Appendix Table 6.

3.4 Driving cycle

The driving style means the acceleration and vehicle speed during driving. The type of driving is the result of the driving culture and traffic conditions of the area. IVE model, in order to define the style of driving, uses a driving factor related to the type of driving associated with vehicle specific power (VSP) and engine stress. VSP is a function of instantaneous velocity, gradient, vehicle weight, air density and …, IVE uses the Eq. (1) which is valid for light vehicles with good accuracy.

$$\mathrm{VSP} = V^{*}\left[1.1a + 9.81\left(a^{*}\ \tan(\sin(grade))\right) + 0.132\right] + 0.000302\mathrm{V}^{3} \tag{1}$$

Where, V is the velocity (m/s) a stands for acceleration (m/s^2) and grade as the slope of the road. In IVE 60 modes (indices) are considered for specific power and engine stress. Specific power and engine stress parameters related to each of these 60 modes in the model has been shown in Appendix Table 7. By setting these parameters in a period, the percentage of time that the fleet exists in each index is determinded. Engine stress is also visible in minimum and maximum periods in Appendix Table 7 too. According to the instantaneous and average velocity as well as VSP, the engine stress of most vehicles is within (−1.6–3.1) and a very small number of them (some imported cars) has the engine stress of 7 or more.

As previously mentioned among the countries that use this model, China has highest similarity with Iran's cities driving style. In this study, first the urban cycle of China's Beijing has been used and it has been applied to the study area by repeatedly driving situations under the intended traffic and recording time, velocity and acceleration within continious and short intervals. Also the condition of those vehicles with right or left turns and not-stop before traffic signal have been included in this cycle. Figure 2 presents the cycle has been defined in the IVE related to this study.

3.5 Meteorological data

Among lots of meteorological factors, most important ones are air temperature, humidity, wind speed and wind direction [19]. Humidity and temperature are the most important meteorological variable that are effective in engine performance and emissions and have been performed in IVE model for this study. Appendix Table 8 shows the humidity and temperature in the area of this study.

3.6 Variables

3.6.1 Fleet technology

In IVE model, 1372 predefined technologies exist for vehicles and it is possible to define additional capabilities by the user. The classifications are based on engine size, fuel type, fuel system, pollution standards, pollution control of exhaust system, the engine operation and etc. In this study for specifying

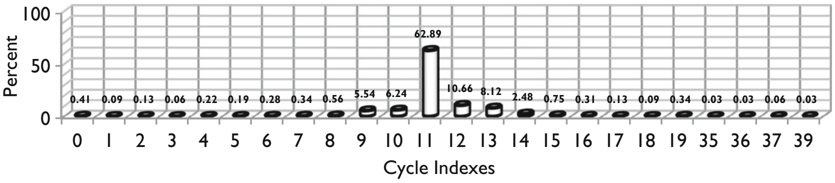


Fig. 2 Index values related to the cycle defined within the region in IVE

Table 1 The amount of emission factor of the IVE

Spring 2015			Winter 2015		
NO_X (G/Km)	CO (G/Km)	Day 2015	NO_X (G/Km)	CO (G/Km)	Day 2015
0.63	7.47	April 15	0.7	8.35	January 1
0.57	6.76	April 16	0.61	7.32	January 3
0.57	6.76	April 17	0.64	7.71	January 5
0.66	7.89	April 19	0.55	6.65	January 6
0.54	6.45	April 20	0.7	8.35	January 10
0.6	7.61	April 21	0.77	9.78	January 11
0.57	6.76	April 22	0.72	8.59	January 12
0.7	8.35	April 23	0.62	7.75	January 20
0.79	9.46	April 24	0.75	8.87	January 21
0.57	6.77	April 25	0.54	6.45	January 23
0.83	12.7	April 30	0.6	7.1	January 24
0.6	7.1	May 1	0.6	7.61	January 25
0.7	8.35	May 3	0.63	7.47	January 26
0.63	7.47	May 4	0.7	8.35	January 30
0.6	7.1	May 7	0.66	7.89	January 31
0.59	9.06	May 8	0.75	8.87	February 4
0.69	10.6	May 12	0.6	7.61	February 6
0.63	7.47	May 13	0.61	7.32	February 7
0.54	8.27	May 14	0.64	7.71	February 8
0.79	9.46	May 15	0.61	7.32	February 12
0.66	7.89	May 16	0.58	6.97	February 13
0.66	7.89	May 17	0.6	7.1	February 14
0.63	7.47	May 18	0.6	7.61	February 16
0.63	7.47	May 19	0.49	6.29	February 17
0.54	6.45	May 20	0.53	6.36	February 18
0.63	7.47	May 21	0.57	7.23	February 22
0.6	7.1	May 25	0.7	8.35	February 24
–	–	–	0.63	7.47	February 25
–	–	–	0.63	7.47	February 26
–	–	–	0.6	7.1	February 27
–	–	–	0.6	7.1	March 2
–	–	–	0.54	6.45	March 3

Table 2 The concentration of pollutants measured at 11 to 12

Spring 2015				Winter 2015			
NO [ppb]	NO_2 [ppb]	CO [ppm]	Day 2015	NO [ppb]	NO_2 [ppb]	CO [ppm]	Day 2015
32.6	53.4	3.05	April 15	72.22	48.42	3.6	January 1
53.46	36.15	2.35	April 16	34.74	41.57	3.22	January 3
47.09	36.4	2.38	April 17	31.73	53.5	3.45	January 5
49.4	43.41	2.92	April 19	20.78	59.96	2.89	January 6
52.69	31.5	2.03	April 20	31.8	73.82	4.1	January 10
39.86	51.57	2.86	April 21	32.2	79.69	4.3	January 11
42.54	42.72	2.55	April 22	55.41	64.61	3.77	January 12
11.2	68.6	3.64	April 23	44.9	63.4	3.63	January 20
24.78	71.45	3.99	April 24	51.25	75.5	4.4	January 21
37.72	41.71	2.37	April 25	25.81	38.91	2.87	January 23
19.8	70.12	4.65	April 30	38.21	38.3	3.3	January 24
37.8	39.81	2.4	May 1	53.07	34	3.33	January 25
27.13	59.7	3.59	May 3	63.9	46.72	3.1	January 26
22:25	56.5	3.32	May 4	42.7	51.1	3.79	January 30
19.7	57.41	2.85	May 7	22.3	65.69	3.49	January 31
25.97	43.5	2.53	May 8	54.4	76.85	3.78	February 4
29.74	60.03	3.2	May 12	11.6	57	3.38	February 6
38.1	53.17	2.78	May 13	57.81	33.75	3.39	February 7
55.35	33.3	2.15	May 14	16.93	53.4	3.74	February 8
17.98	77.51	3.54	May 15	36.69	51.1	3.57	February 12
32.6	52.12	2.41	May 16	28.8	53.1	2.9	February 13
27.7	63.4	2.75	May 17	33.2	57.1	3.05	February 14
21.2	64.4	3.33	May 18	34.3	61.1	3.22	February 16
37.5	45.2	2.88	May 19	39.1	35.5	2.81	February 17
29.1	47.3	1.92	May 20	37.1	32.1	2.78	February 18
21.1	64.3	3.08	May 21	41.1	51.2	3.51	February 22
25.2	57.7	2.1	May 25	58	66.6	4.01	February 24
–	–	–	–	55.3	42.1	3.7	February 25
–	–	–	–	59.1	38.7	3.61	February 26
–	–	–	–	42.2	35.5	3.2	February 27
–	–	–	–	18.9	49.8	3.5	March 2
–	–	–	–	49.1	32.2	2.67	March 3

the fleet technology, by analyzing of field video recorded during this period, all vehicle types have been determined and the technological features have been found by the manufacturer information and other authoritative sources and have been entered into the model. Also to determine the age and kilometers usage of vehicle the information on transport and energy performance of vehicles have been used [20]. Appendix Table 9 shows the fleet technology of this study.

3.6.2 Air conditioning systems

This defined parameter shows a percentage of time in which the fleet uses air conditioner at 27 °C or higher temperature. In designing this model, it is assumed that regardless of the user defined amount of parameters at 15° and below none of the fleet uses the parameter and at a temperature of 32 °C or above the whole fleet having an air conditioning system uses this system. Given the field studies and the fact that this study is done in winter and early spring, this parameter is considered to be 0.

3.6.3 Fuel parameters

Indicating to reliable sources and studies about the quality of gasoline and diesel in the country and the amount of material in them, corresponding parameters to fuel have been determined and entered into the model. Some of these parameters are as follows:

- The overall quality of fuel: Medium
- The amount of lead in fuel: zero (negligible)
- The amount of sulfur in the fuel: between 50 and 300 ppm
- The benzene in the fuel: between 5.0 and 5.1% (average)

Table 3 Comparison of CO emissions concentration of the model and Field data

Winter				Spring			
Day 2015	Modelling CO g/l	Field data CO g/l	Data difference of models (equal)	Day 2015	Modelling CO g/l	Field data CO g/l	Data difference of models (equal)
January 1	47.11	33.969	1.39	April 15	42.998	28.881	1.49
January 3	33.839	30.457	1.11	April 16	32.731	22.354	1.46
January 5	42.473	32.585	1.3	April 17	33.632	22.635	1.49
January 6	29.716	27.394	1.08	April 19	48.539	27.673	1.75
January 10	51.747	38.563	1.34	April 20	33.69	19:35	1.74
January 11	60.639	40.392	1.5	April 21	43.15	27.115	1.59
January 12	50.766	35.534	1.43	April 22	36.485	24.225	1.51
January 20	46.173	34.245	1.35	April 23	51.19	34.337	1.49
January 21	55.785	41.305	1.35	April 24	63.302	37.554	1.69
January 23	27.238	27.208	1	April 25	36.698	22.541	1.63
January 24	33.116	31.198	1.06	April 30	83.993	43.582	1.93
January 25	39.935	31.476	1.27	May 1	38.478	22.822	1.69
January 26	39.512	29.345	1.35	May 3	52.118	33.876	1.54
January 30	52.674	35.718	1.47	May 4	44.492	31.383	1.42
January 31	47.488	32.954	1.44	May 7	34.693	27.022	1.28
February 4	53.617	35.626	1.5	May 8	43.692	24.038	1.82
February 6	38.92	31.938	1.22	May 12	62.948	30.272	2.08
February 7	36.279	32.03	1.13	May 13	43.496	26.37	1.65
February 8	36.137	35.258	1.02	May 14	40.622	20.478	1.98
February 12	33.839	33.692	1	May 15	61.409	33.415	1.84
February 13	30.821	27.487	1.12	May 16	46.086	22.915	2.01
February 14	34.22	28.881	1.18	May 17	47.488	26.091	1.82
February 16	34.012	30.457	1.12	May 18	44.824	31.476	1.42
February 17	27.676	26.65	1.04	May 19	42.168	27.301	1.54
February 18	28.995	26.37	1.1	May 20	33.69	18.314	1.84
February 22	38.745	33.139	1.17	May 21	43.662	29.16	1.5
February 24	52.303	37.738	1.39	May 25	38.793	20.008	1.94
February 25	40.508	34.89	1.16	–	–	–	–
February 26	41.504	34.061	1.22	–	–	–	–
February 27	35.009	30.272	1.16	–	–	–	–
March 2	31.855	33.046	0.96	–	–	–	–
March 3	28.242	25.345	1.11	–	–	–	–
$r = 0.88$				$r = 0.86$			

- The oxygen content of gasoline (fuel additive that increases the oxygen content of fuel and improves pollution): zero

4 Results

4.1 The results of modelling

After entering all the parameters mentioned in the previous section, IVE has been run and the results are presented in Table 1.

4.2 The results of field measurement

In this study at the intersection, fixed air pollution monitoring device from "Signal group" is installed by Esfahan Organization of Environmental Protection at the height of 2.5 m ground above that the sensors of which are able to measure and record air pollution at the intersection at any moment. Therefore, in order to perform this study, the data provided by this device have been applied and among the urban emissions, NO_X and CO are more than any other emissions which are presented in Table 2.

Table 4 Comparison of NO_X emissions concentration of the model and Field data

Winter				Spring			
Day 2015	Modelling NO_X g/l	Field data NO_X g/l	Data difference of models (equal)	Day 2015	Modelling NO_X g/l	Field data NO_X g/l	Data difference of models (equal)
January 1	2.461	1.48	1.66	April 15	2.264	1.161	1.95
January 3	1.759	0.998	1.76	April 16	1.719	1.109	1.55
January 5	2.215	1.151	1.92	April 17	1.766	1.048	1.69
January 6	1.547	1.144	1.35	April 19	2.553	1.177	2.17
January 10	2.704	1.461	1.85	April 20	1.764	1.031	1.71
January 11	2.995	1.553	1.93	April 21	2.108	1.208	1.75
January 12	2.653	1.559	1.7	April 22	1.916	1099	1.74
January 20	2.291	1.436	1.6	April 23	2.674	1176	2.27
January 21	2.93	1.679	1.75	April 24	3.317	1.354	2.45
January 23	1.426	0.868	1.64	April 25	1.924	1.036	1.86
January 24	1.736	0.982	1.77	April 30	3.426	1.278	2.68
January 25	1.951	1.065	1.83	May 1	2.017	1.007	2
January 26	2.08	1.374	1.51	May 3	2.723	1199	2.27
January 30	2.752	1.222	2.25	May 4	2.342	1.102	2.12
January 31	2.497	1.244	2.01	May 7	1.818	1.094	1.66
February 4	2.817	1.739	1.62	May 8	1.773	0.943	1.88
February 6	1.901	1.002	1.9	May 12	2.571	1.234	2.08
February 7	1.885	1.109	1.7	May 13	2.29	1.215	1.88
February 8	1.884	0.998	1.89	May 14	1.659	1.085	1.53
February 12	1.759	1.163	1.51	May 15	3.218	1.383	2.33
February 13	1.607	1.119	1.44	May 16	2.424	1.146	2.11
February 14	1.794	1225	1.46	May 17	2.497	1.269	1.97
February 16	1.661	1.297	1.28	May 18	2.36	1.214	1.94
February 17	1.354	0.95	1.43	May 19	2.22	1.084	2.05
February 18	1.519	0.877	1.73	May 20	1.764	1.038	1.7
February 22	1.9	1.209	1.57	May 21	2.299	1.214	1.89
February 24	2.733	1.614	1.69	May 25	2.033	1.16	1.75
February 25	2.133	1.21	1.76	–	–	–	–
February 26	2.185	1.197	1.83	–	–	–	–
February 27	1.835	0.979	1.87	–	–	–	–
March 2	1.67	0.963	1.73	–	–	–	–
March 3	1.478	1.001	1.48	–	–	–	–
$r = 0.85$				$r = 0.84$			

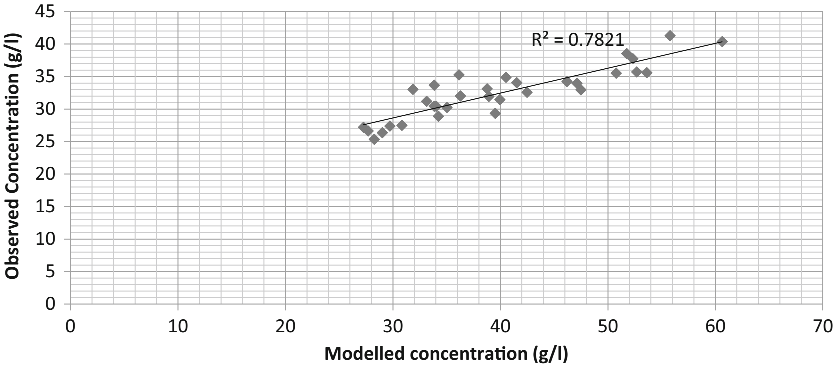


Fig. 3 The regression between CO concentration in modelling and field measurement- winter 2015

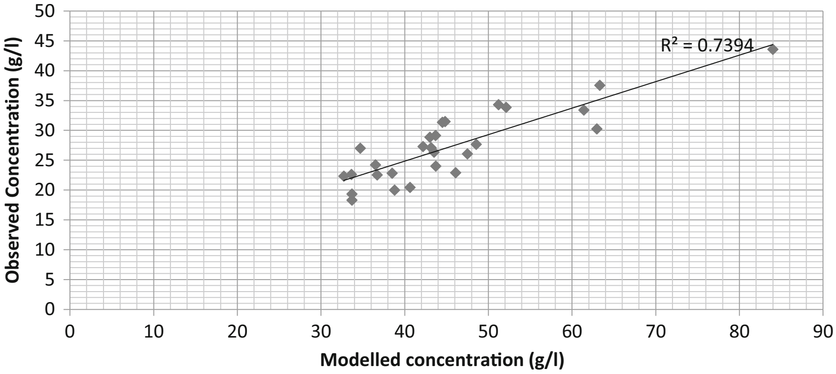


Fig. 4 The regression between CO concentration in modelling and field measurement- Spring 2015

4.3 Data comparison and results evaluation

Environmental pollution measuring devices are able to measure the concentration in ppm, volume percentage or the weight of the pollutants based on a determinded volume of the air (such as g/m^3), while IVE model shows the emissions in grams and finally by using the kilometers usage of vehicle and travel time by fleet shows emissions on grams per traveled distance or grams per time unit. However, for comparing the pollutants in both methods of modelling and field data collection, having a similar method of measuring is necessary. To solve this problem data have been converted to unit of the pollutants into g/l using the Eqs. (2) and (3) [4, 17].

To convert the concentration units achieved by the environmental pollution gauge device into g/l the following equations are used:

$$EF_{CO} = \frac{C_{CO}}{C_{CO2} + C_{CO} + 4C_{HC}} \rho_f w_c \frac{M_{CO}}{12} \tag{2}$$

$$EF_{NOx} = \frac{C_{NOx}}{C_{CO2} + C_{NOx} + 4C_{HC}} \rho_f w_c \frac{M_{NOX}}{12} \tag{3}$$

Where M represents the molar mass (28.1 g/mol for CO, 30 g/mol for NO and 46.01 g/mol for NO_2), the fuel density (740 g per liter for gasoline), is the share of fuel carbon (Usually 0.85) and, C_{CO}, C_{CO2} C_{HC}, C_{NOX} are the concentration of pollutants in terms of percent. These equations are mostly used for spectrometer systems that have a function similar to environmental devices and assuming that the ratio of the pollutants in a mass is preserved that these equations can be used in environmental assessments.

For concentrations derived from modelling the Eq. (4) is used as well:

$$F_E\left(\frac{g}{l}\right) = F_E\left(\frac{g}{km}\right) * F\left(\frac{km}{l}\right) \tag{4}$$

Where, presents the emission factors in terms of g/km and g/lit and F is the average km per consumed liter of fuel [17].

By converting and standardization of the concentration of pollutants resulting from the two methods of field data collection and modelling, the difference between this data is compared based on the Tables 3 and 4 and the correlation between the concentrations of the models have been calculated and measured (Figs. 3, 4, 5, and 6) . It can be seen that:

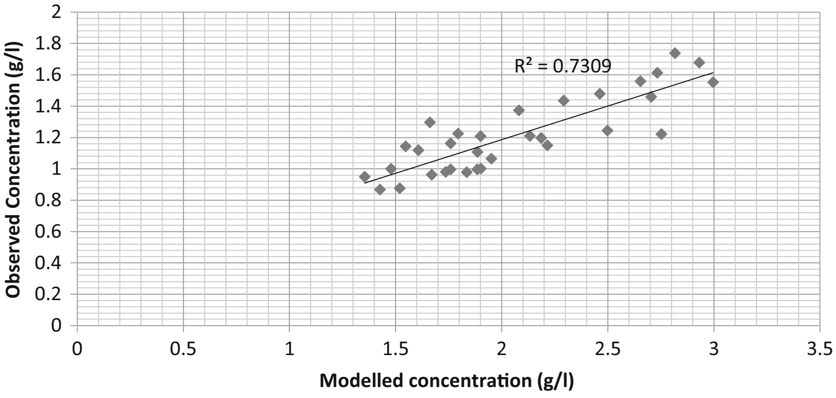
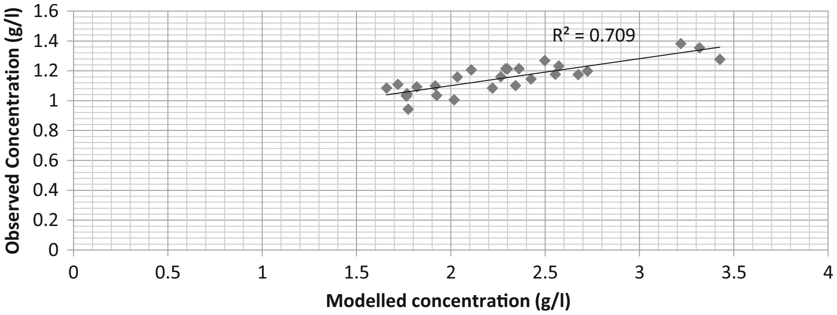


Fig. 5 The regression between nitrogen oxides concentration in modelling and field measurement - winter 2015

Fig. 6 The regression between nitrogen oxides concentration in modelling and field measurement- Spring 2015



- The difference between the concentrations of the average CO pollutants has been 1.2 and 1.6 times for winter and spring repectively.

  - According to Table 4 this difference for NO_X emissions has been 1.7 and 1.9 times for winter and spring respectively.
  - The differences are for the fact that the measuring device of this study is the environmental gauge device and evaluate the pollutant after withdrawal of supply and decreased with ambient air and it cannot measure it as it comes out of the exhaust. The device used in this study was installed on the edge of the intersection and the pollutants are spreaded and decreased before reaching the sensor. It is observed that the difference in both pollutants is higher in spring, the reason of which might be the wind and increased dispersion of pollutants.

- Since the objective of using this model in this research is descriptive analysis and in order to evaluate it, the model sensitivity should be analyzed and the amount of following changes by the model must be estimated. When the results of field measurements differ from different parameters, the model must follow these alterations as well. One of the best ways for this sensitivity analysis is measuring the correlation of the model results and real perceptions. The correlation coefficient is applied to specify the sensitivity of two data series versus each other in face of changes as it presents the severity of relation, correlation and proportionality of the data. As the value approaches 1 it showes higher sensitivity of the data in a direct manner. In this study the correlation between CO concentrations in both methods was 0.86 in spring and 0.88 in winter. Also correlation between NO_X concentrations in both methods was 0.84 in spring and 0.85 in winter. The results of the model were connected with the results of measurement and change by converting different parameters with a harmonized, linear trend with high regression coefficient.

The high correlation values for the existing data refers to high levels of proportionality of IVE model calculations with field data collections and indicates that the function of this model is appropriate for the conditions stated in the changes, and present a proper calculation response against changes. As a result, the model is suitable for the assessment and interpretation of emissions behavior in different parameters and it is possible to analyze different transportation policies in these areas before and after implementation in terms of environment and make the best decisions.

5 Conclusion

In this research, a comprehensive field study has been performed at an intersection of Najafabad city in Isfahan province in winter and spring over a period of 59 days. The terms of the intersection entered IVE model and sensitivity analysis was performed and the results were compared to field measurement data for the NO and NO_2 and CO pollutants. The outcomes of the correlation between the concentrations of CO pollutant in both methods were 0.86 in the spring and 0.88 in winter.

Also in intersection suburbs and in low traffic hours with the determined fleet combination, 7.58 g/l CO and 0.63 g/km NO_X have been produced. This value equals 7.91 g/l for CO and 0.64 g/km for NO_X.

Because of the volume of resulting traffic during study period and considering environmental pollution produced by vehicles, only within 50 m from the intersection, the emission share of 1 h under light traffic conditions at this intersection for CO is minimum 1225 g and maximum 2730 g in winter and minimum 1474 g and maximum 3785 g in spring, for NO_X is minimum 97 g and maximum 215 g in winter and minimum 119 g and maximum 247 g in spring. It shows the more pollutant production and propagation in spring in comparison with winter. It suggests to study in summer and autumn also do this research in intersections located in other city by different weather and traffic characteristic. By the result of this study and future study in this field can have a unique emission forecasting in intersection.

Appendix 1

Table 5 The volume of the vehicles at the intersection at 11-12

Vehicle Volume (Vehicles/h)	Day (Spring 2015)	Vehicle Volume (Vehicles/h)	Day (Winter 2015)
2590	April 15	2540	January 1
2180	April 16	2080	January 3
2240	April 17	2480	January 5
2770	April 19	2010	January 6
2350	April 20	2790	January 10
2550	April 21	2790	January 11
2430	April 22	2660	January 12
2760	April 23	2680	January 20
3010	April 24	2830	January 21
2440	April 25	1900	January 23
2980	April 30	2100	January 24
2440	May 1	2360	January 25
2810	May 3	2380	January 26
2680	May 4	2840	January 30
2200	May 7	2710	January 31
2170	May 8	2720	February 4
2680	May 12	2300	February 6
2620	May 13	2230	February 7
2210	May 14	2110	February 8
2920	May 15	2080	February 12
2630	May 16	1990	February 13
2710	May 17	2170	February 14
2700	May 18	2010	February 16
2540	May 19	1980	February 17
2350	May 20	2050	February 18
2630	May 21	2410	February 22
2460	May 25	2820	February 24
–	–	2440	February 25
–	–	2500	February 26
–	–	2220	February 27
–	–	2020	March 2
–	–	1970	March 3

Appendix 2

Table 6 The average speed of the fleet crossing at 11-12

Average speed (Km/h)	Day 2015	Average speed (Km/h)	Day 2015
19	April 15	18	January 1
21	April 16	20	January 3
21	April 17	19	January 5
18	April 19	22	January 6
22	April 20	17	January 10
19	April 21	16	January 11
21	April 22	18	January 12
17	April 23	18	January 20
15	April 24	16	January 21
21	April 25	22	January 23
15	April 30	20	January 24
20	May 1	19	January 25
17	May 3	19	January 26
19	May 4	17	January 30
20	May 7	18	January 31
21	May 8	16	February 4
18	May 12	19	February 6
19	May 13	20	February 7
23	May 14	19	February 8
15	May 15	20	February 12
18	May 16	21	February 13
18	May 17	20	February 14
19	May 18	19	February 16
19	May 19	23	February 17
22	May 20	23	February 18
19	May 21	20	February 22
20	May 25	17	February 24
–	–	19	February 25
–	–	19	February 26
–	–	20	February 27
–	–	20	March 2
–	–	22	March 3

Appendix 3

Table 7 Boundaries assumed in VSP/Engine stress binning

	VSP) KW/Ton)		Engine Stress			VSP) KW/Ton)		Engine stress	
Index	min	max	min	max	index	min	max	min	max
1	−80	−44	−1.6	3.1	31	−7	−2.9	3.1	7.8
2	−44	−39.9	−1.6	3.1	32	−2.9	1.2	3.1	7.8
3	−39.9	8	−1.6	3.1	33	1.2	5.3	3.1	7.8
4	8	−31.7	−1.6	3.1	34	5.3	9.4	3.1	7.8
5	−31.7	−27.6	−1.6	3.1	35	9.4	13.6	3.1	7.8
6	−27.6	−23.4	−1.6	3.1	36	13.6	17.7	3.1	7.8
7	−23.4	−19.3	−1.6	3.1	37	17.7	21.8	3.1	7.8
8	−19.3	−15.2	−1.6	3.1	38	21.8	25.9	3.1	7.8
9	−15.2	−11.1	−1.6	3.1	39	25.9	30	3.1	7.8
10	−11.1	−7	−1.6	3.1	40	30	−80	7.8	12.6
11	−7	−2.9	−1.6	3.1	41	−80	−44	7.8	12.6
12	−2.9	1.2	−1.6	3.1	42	−44	−39.9	7.8	12.6
13	1.2	5.3	−1.6	3.1	43	−39.9	−35.8	7.8	12.6
14	5.3	9.4	−1.6	3.1	44	−35.8	−31.7	7.8	12.6
15	9.4	13.6	−1.6	3.1	45	−31.7	−27.6	7.8	12.6
16	13.6	17.7	−1.6	3.1	46	−27.6	−23.4	7.8	12.6
17	17.7	21.8	−1.6	3.1	47	−23.4	−19.3	7.8	12.6
18	21.8	25.9	−1.6	3.1	48	−19.3	−15.2	7.8	12.6
19	25.9	30	−1.6	3.1	49	−15.2	−11.1	7.8	12.6
20	30	1000	−1.6	3.1	50	−11.1	−7	7.8	12.6
21	−80	−44	3.1	7.8	51	−7	−2.9	7.8	12.6
22	−44	−39.9	3.1	7.8	52	−2.9	1.2	7.8	12.6
23	−39.9	−35.8	3.1	7.8	53	1.2	5.3	7.8	12.6
24	−35.8	−31.7	3.1	7.8	54	5.3	9.4	7.8	12.6
25	−31.7	−27.6	3.1	7.8	55	9.4	13.6	7.8	12.6
26	−27.6	−23.4	3.1	7.8	56	13.6	17.7	7.8	12.6
27	−23.4	−19.3	3.1	7.8	57	17.7	21.8	7.8	12.6
28	−19.3	−15.2	3.1	7.8	58	21.8	25.9	7.8	12.6
29	−15.2	−11.1	3.1	7.8	59	25.9	30	7.8	12.6
30	−11.1	−7	3.1	7.8	60	30	1000	7.8	12.6

Appendix 4

Table 8 Meteorological parameters related to the period under study

Humidity (%)	Temperature (°C)	Day	Humidity (%)	Temperature (°C)	Day
25	21	April 15	22	8	January 1
13	23	April 16	20	11	January 3
20	21	April 17	18	10	January 5
15	25	April 19	25	13	January 6
22	27	April 20	22	15	January 10
31	25	April 21	28	12	January 11
12	24	April 22	18	17	January 12
14	25	April 23	12	16	January 20
9	23	April 24	15	17	January 21
7	24	April 25	23	15	January 23
18	28	April 30	28	16	January 24
11	26	May 1	32	19	January 25
22	25	May 3	20	17	January 26
10	27	May 4	17	19	January 30
18	27	May 7	25	18	January 31
14	28	May 8	30	18	February 4
21	29	May 12	32	15	February 6
13	26	May 13	28	12	February 7
12	29	May 14	24	10	February 8
11	27	May 15	19	14	February 12
18	25	May 16	22	14	February 13
25	26	May 17	27	15	February 14
15	25	May 18	33	17	February 16
20	27	May 19	37	16	February 17
15	27	May 20	24	14	February 18
19	26	May 21	31	17	February 22
14	26	May 25	30	18	February 24
–	–	–	26	18	February 25
–	–	–	20	18	February 26
–	–	–	24	19	February 27
–	–	–	19	17	March 2
–	–	–	27	16	March 3

Appendix 5

Table 9 Modelled vehicle technology within the area under study

Index	Mileage	Evaporative emissions control	Exhaust system	Fuel control system	Weight	Type of vehicle
0	<79	PCV	None	Carburetor	Light	Cars / Trucks
1	80–161	PCV	None	Carburetor	Light	Cars / Trucks
2	>161	PCV	None	Carburetor	Light	Cars / Trucks
3	< 79	PCV	None	Carburetor	Average	Cars / Trucks
4	80–161	PCV	None	Carburetor	Average	Cars / Trucks
5	> 161	PCV	None	Carburetor	Average	Cars / Trucks
99	<79	PCV	None	Multi-Point FI	Light	Cars / Trucks
100	80–161	PCV	None	Multi-Point FI	Light	Cars / Trucks
101	> 161	PCV	None	Multi-Point FI	Light	Cars / Trucks
102	<79	PCV	None	Multi-Point FI	Average	Cars / Trucks
103	80–161	PCV	None	Multi-Point FI	Average	Cars / Trucks
104	>161	PCV	None	Multi-Point FI	Average	Cars / Trucks
117	<79	PCV	3way	Multi-Point FI	Light	Cars / Trucks
118	80–161	PCV	3way	Multi-Point FI	Light	Cars / Trucks
119	> 161	PCV	3way	Multi-Point FI	Light	Cars / Trucks
120	<79	PCV	3way	Multi-Point FI	Average	Cars / Trucks
121	80–161	PCV	3way	Multi-Point FI	Average	Cars / Trucks
122	> 161	PCV	3way	Multi-Point FI	Average	Cars / Trucks
129	<79	PCV	3Way / EGR	Multi-Point FI	Average	Cars / Trucks
130	80–161	PCV	3Way / EGR	Multi-Point FI	Average	Cars / Trucks
131	> 161	PCV	3Way / EGR	Multi-Point FI	Average	Cars / Trucks
180	<79	PCV	Euro II	Multi-Point FI	Average	Cars / Trucks
181	80–161	PCV	Euro II	Multi-Point FI	Average	Cars / Trucks
182	> 161	PCV	Euro II	Multi-Point FI	Average	Cars / Trucks
1206	0–25	None	None	Carb-4cycle	Light	Small engines
1207	26–50	None	None	Carb-4cycle	Light	Small engines
1208	> 50	None	None	Carb-4cycle	Light	Small engines
1233	0–25	None	3way	Carb-4cycle	Light	Small engines
1234	26–50	None	3way	Carb-4cycle	Light	Small engines
1122	<79	None	Euro I	FI	Heavy	Truck / Bus
1123	80–161	None	Euro I	FI	Heavy	Truck / Bus
1124	> 161	None	Euro I	FI	Heavy	Truck / Bus
1131	<79	None	Euro II	FI	Heavy	Truck / Bus
1132	80–161	None	Euro II	FI	Heavy	Truck / Bus

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