Retraction Notice

Title of retracted article: **An Analysis of Air Pollutants' Emission Coefficient in the Transport Sector of Tehran**

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X no

Correction:
☐ yes, date: yyyy-mm-dd
☐ no

Comment:

Free style text with summary of information from above and more details that can not be expressed by ticking boxes.

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Editor guiding this retraction: Prof. Eyualem Abebe (The EIC of OJE)

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An Analysis of Air Pollutants' Emission Coefficient in the Transport Sector of Tehran

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Abstract

The most important factor of mobile sources of pollution includes light and heavy vehicles. More than 75 percent of the sources of air pollution in Tehran come from mobile sources. Therefore, it is necessary to conduct researches in this field to help the decision-makers to find the best and most practical solution. Initially, we have identified the anthropogenic sources of air pollution and their respective shares. Consequently, the impact of pollutants is brought out and finally appropriate actions are prioritized to combat with air pollution in Tehran. The method is based on the IVE model that furnishes appropriate estimation of pollution emissions. Emission coefficients of this software for different vehicles are obtained based on models EMFAC2007, MOBIE6, and COPERTIV. The results showed that the highest value of diffusion coefficient of volatile organic compounds (VOCs) belonged to motorcycles and taxis. The other modes of transport such as pickups, buses and cars do contribute to the VOCs to a lesser extent. According to the modeling, trucks, minibuses and buses have the highest emission coefficient of nitrogen oxides. The pattern is similar in the emission of suspended particles and sulfur oxides.

Keywords

Transportation in Tehran Air Pollution Index, Emission Coefficient

1. Introduction

Air is one of the five basic elements of human life. Every individual breathes in around 22,000 times each day, and needs almost 15 kilograms of air. Humans can survive without food for about 5 weeks and without water for 5 days but cannot live without air more than 5 minutes [1]. From the first decades of the twentieth century, observing the relationship between air pollution and environmental degradation, many developing countries, began conducting researches and extensive scientific programs to control harmful emissions. Unfortunately, in the vast major-

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ity of developing countries, air pollution of large cities is being deteriorated every day. Uncontrolled urban development and expansion of industry and technology, especially in developing countries, regardless of the health of the environment and its inhabitants have led to several problems that threaten the life on the planet. Intensity of infection in the world is reaching out to such an extent that even the potential for land is critical. So urbanization, the accumulation of many people in certain parts of the country, high standard expectation of life with a minimum price regardless of the environment and especially the development of industries to develop new products, all together and the increase in the concentration of dangerous pollutants have been considered [2]. In most countries, the development of industrial and residential areas is conducted without true plans and correct boundaries. In this way the houses are built near the factories and industrial units and consequently, the risks of industrial environments are increased [3]. Also, the existence of thousands of vehicles in commercial and industrial centers has caused air pollution in Tehran significantly and an aura of smoke and dust encompasses the city [4]. Air pollution is one of the main problems of humans today; it has included the city of Tehran as well and in addition to the losses caused to the health of citizens, it imposes social and economic impacts on humans and the environment. The role of human is very low in controlling pollution from natural sources. But by disrupting the natural ecological balance, humans have worsened the situation and have added to the natural infection [5]. These pollutions are resulted from the products of combustion including carbon monoxide, unburned hydrocarbons, suspended particles and nitrogen oxides. In addition, heavy metals, industrial materials such as asbestos and dust that originate inside or outside the country are considered to be one of the important pollutants in the air.

Tehran city has:

- An area of 730 square kilometers, with a population of 8.5 million and density of 508/10 meter per square kilometers; including the population of the margins, the total population of Tehran reaches to 11.5 million (15% of the total population of the country).
- About 2,200,000 residential units [6].
- About 12,000 active industrial units; one third of which are large-scale industrial units.
- About 63,000 academic units [6].
- About 65,000 shop units [7].
- About 3.6 million cars and 2.5 million motorcycles.
- It has 2.731 square kilometers of different passages with an area of 60.611000 square meters with a total capacity of marginal parking, alleys and other non-marginal ones being about 909,000 which is not responsive at all.
- Topography of Tehran acts as a contributory cause of air pollution.

The present study assessed the health impact of air quality on the residents of Tehran, the capital city of Iran, the largest urban area of Iran with a population of 8,700,000 in 2011 (**Figure 1**) [7]. The city also is ranked as one of the largest cities in Western Asia and the 19th in the whole world. As in other large cities, Teh-

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ran is faced with serious air quality problems. In general, 20% of the total energy of the country is consumed in Tehran. Pollutants such as PM_{10}, SO_2, NO_2, HC, O_3 and CO are the major air pollutants in Tehran, about 80% - 85% of which are produced by mobile sources of pollution [8].

Tehran's geographical situation is such that North and East of the city are surrounded by high mountains. Mountains act like a dam preventing the natural movement of air and thus, pollutant gases remaining in the surface and breathing space for a long time. However, the gentle breezes blown from the West and South West of the city are not severe enough to ward off infections. Meanwhile due to the crowd, a variety of vehicles in the city, factories and industrial units and workshops, residential and administrative units and the use of fossil fuels for industrial use, utilities, transportation and so on, Tehran is considered as one of the most polluted cities. The largest air polluter in Tehran is carbon monoxide and the smallest one is sulfur.

These concomitant conditions make Tehran as one of the worst areas in the world for atmospheric pollution with many days exceeding air quality standards during each year [9].

The unstoppable development of Tehran, the growing urban population, overloading, the uncontrolled growth of the industry, uncontrolled exploitation from the resources, the use and exploitation from the old and sometimes destructive technologies, increased production of vehicles in the country with low qualities, non-standard fuel supply, the increasing fossil fuel consumption and lack of proper utilization of energy as well as the climate and land constraints

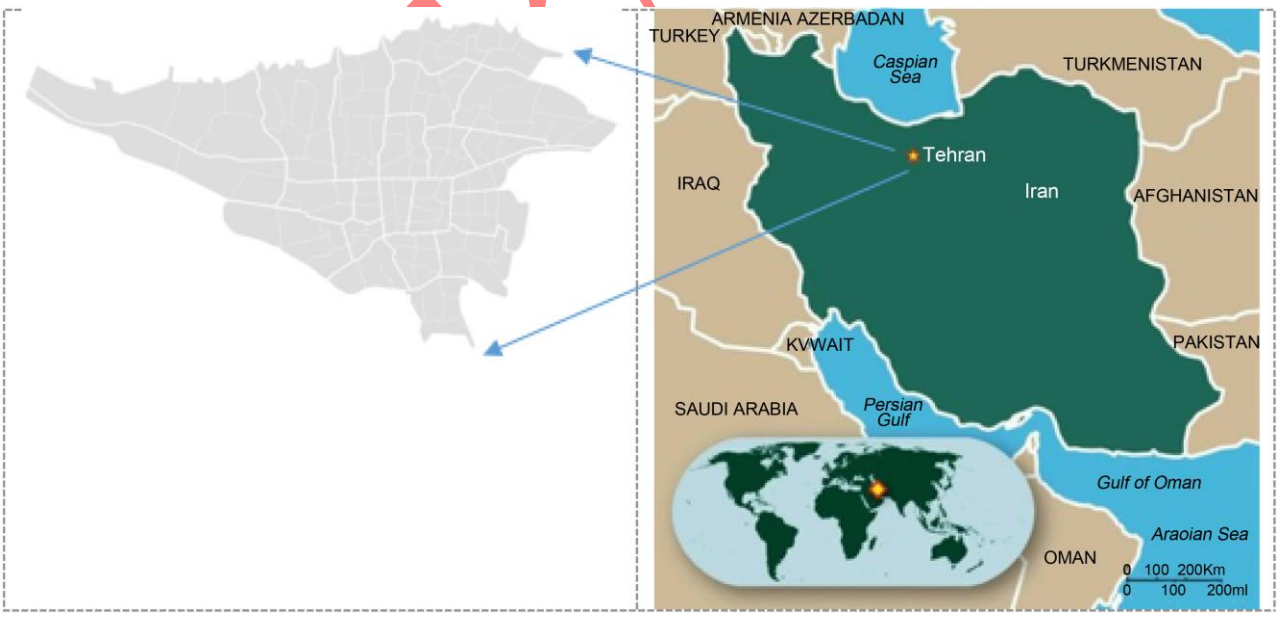

Figure 1. Map of the study area, Tehran, Iran.

have caused this national and local problem called "air pollution in Tehran".

Although the mentioned factors are important in this pollution, the most important factors of mobile sources of pollution are light and heavy vehicles and their related issues; according to statistics, more than 75 percent of the pollution in

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Tehran is caused by mobile sources. Therefore, it is necessary to conduct researches in this area to find the best and most practical solution and to help decision-makers to overcome this problem. The first step is the identification of human sources of air pollution and categorizing them to determine the relative contribution of pollution sources in different times and places in Tehran; with the resulting information the impact of their actions and prioritization of them would be determined and implemented. The determination of the amount of pollutants emitted by the source of pollutant is determined over a period of time and a specific location; this is an essential tool in making decisions to reduce and control air pollution: Major pollutants include PM, NMVOC, CO, NOX, SOX, greenhouse gases CO_2, CH_4 and NO_2. The largest air polluter in air pollution of Tehran is carbon monoxide and smallest one is sulfur [10]. The increasing trend of air pollution in Tehran and the necessity of determining air pollution indices using their emission coefficient, and finally providing procedures for controlling and reducing them have resulted in the attempt to prevent further environmental degradation.

The Implications of the findings of management and control of air pollution are:

- The estimation of the environmental impact of air pollution through modeling researches;
- The determination of the viability and effectiveness of regulations and air pollution standards;
- The determination of the amount of polluting sources' compliance with permit conditions;
- The estimation of changes in emissions from the source;
- The definition of the technical specifications of control equipment of emissions;
- Tracking the levels of emissions over time;
- The determination of the contribution of different sources of pollutants in pollution emissions.

1.1. The Introduction of the Fleet of Vehicles in the Traffic of Tehran

Personal passenger vehicles, taxis, pickups, minibuses, municipal buses, private sector buses, trucks and motorcycles are being used in Tehran; they are studies based on the following parameters: different systems, the year of the vehicle's production, emission standards, fuel type, engine size, gross vehicle weight according to the authorities of the numbering centers, Transportation information of energy of the country, information available on the Associations of Iranian automakers, statistical Yearbook of Tehran, applicable data of transportation in Tehran, technical examination centers, etc. [11] [12].

The status of the fleet of vehicles in the traffic of Tehran is presented in **Figure 2** according to the numbering information of winter 2014.

Also the overall status fleet of vehicles in the traffic of Tehran, on the basis of the production is extracted from the data of numbering centers in Tehran (**Figure 3**).

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The status of technical specifications of different vehicles and applied time of emission standards are also shown in **Figure 4**.

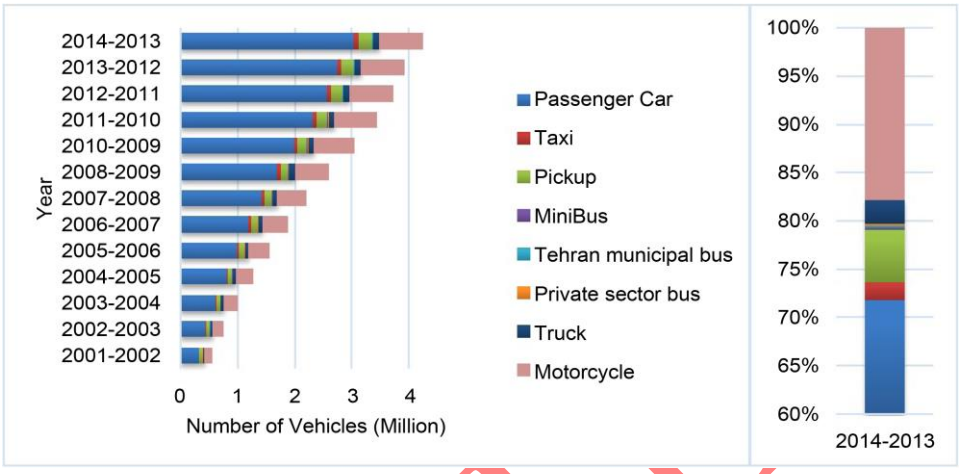

Figure 2. The status of fleet of vehicles in the traffic of Tehran.

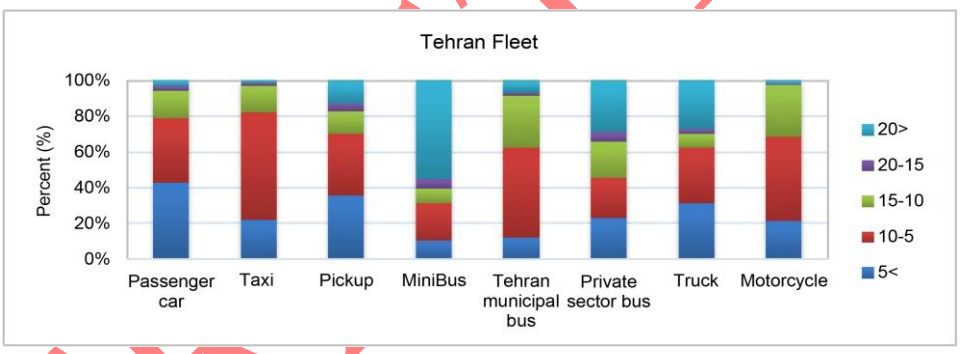

Figure 3. The overall status fleet of vehicles in the traffic of Tehran, on the basis of the production.

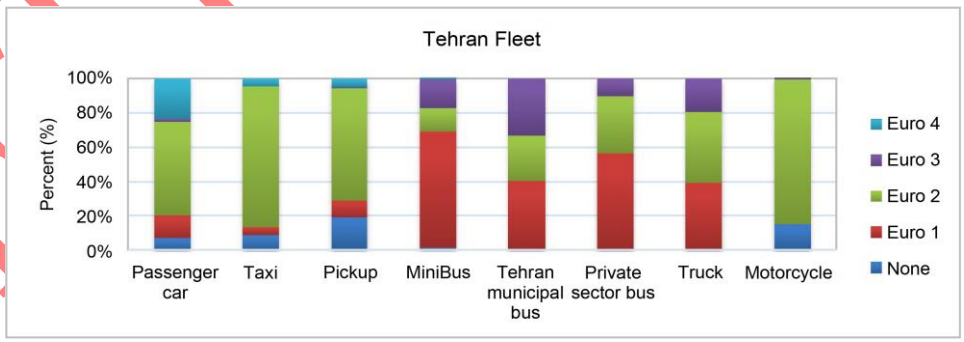

Figure 4. The status of technical specifications of different vehicles and applied time of emission standards.

❖ Personal passenger fleet

Information obtained from the numbering centers of Tehran for private cars show that the total number of registered private cars in Tehran—until the fall of 2014—is 3,046,992 out of which 2,741,337 are domestic cars namely Pride, Peugeot, Samand, L90, RD, Peikan, and Tiba; these cars constituted the 90 percent share of all private car fleet and the rest (about 10%) are foreign cars.

It should be noted that over 65% domestic vehicles are Pride, Peugeot GLX,

Peugeot 206 and Samand.

The age of 823.770 cars are over 10 years and only 707.793 of them contain the Euro4 standard. The rest *i.e.* 2,339,199 of cars don't have any standards or have only Euro2 standards. 94% of private cars consume gasoline, 6% consume natural gas and the remaining, being 367 cars, consume diesel.

❖ Taxi fleet

Information obtained from the numbering centers of Tehran show that the total number of registered taxis in Tehran is 78,232, out of which 92% are domestic cars namely Samand, Peugeot 405, RD, Pride, Peikan, and the rest (about 8%) are foreign cars. Only 3388 taxis contain the Euro4 standard. The rest of cars don't have any standards or have only Euro2 standards. 69% of the taxis are dual-fuel (gasoline and diesel) and 31% only consume gasoline.

❖ Pickups fleet

The total number of registered pickups in Tehran are 254,517, out of which 239,801 (94.2%) are domestic Pickups namely Peikan, pickup, Nissan, Mazda, Zamyad and Pride.

The age of 90,524 cars (35%) are over 10 years and only 11,730 of them (5%) pass the Euro4 standards. 73% of pickups consume gasoline, 25% are dual fuel and only 2% consume diesel.

❖ Fleet of minibuses

The total number of registered minibuses in Tehran is 8913 out of which 55% are over 10 years and only 31% are less than 10 years old. Only 6 minibuses pass the Euro4 standards. 97% of them consume diesel, 1% are dual fuel.

❖ Municipal busses

According to the Tehran Bus, the total number of buses in Tehran is 8208, out of which 3910 (48%) bus are over 10 years and none of them pass the Euro4 standards. 55% of them consume diesel, and 45% are dual fuel (Diesel-CNG).

❖ Private sector bus fleet

Information obtained from the numbering centers of Tehran show that the total number of private buses in Tehran is 4778 out of which 2779 (58%) are over 10 years old and none of them contain the Euro4 standard.

❖ Truck fleet

The total number of trucks in Tehran is 85,730 out of which 23,016 trucks are over 20 years old and none of them contain the Euro4 standards or any higher standards.

❖ Motor cycle fleet

The total number of motorcycles in Tehran is 752,777—until 2011—out of which 62% are 10 years old and none of them contain the Euro4 standard. The majority of them pass only Euro2 standards. The engine size of 2 percent of the motor cycles is up to 100 cc and the 98% have an engine size between 100 - 200 cc and only 577 motor cycles have an engine size over 300 cc. 289,534 motor cycles (38%) are over than 10 years old.

1.2. Traffic Information

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Traffic models are developed and used based on regional characteristics and conditions of use of vehicles. Model EMME/2 is a traffic assignment model used for the study of its results. Modeling of the transportation is consisted of supply and demand; supply is related to characteristics of the transport network and demand is related to the travel demand due to local conditions.

Traffic allocation process, includes supply and demand for Tehran and has been conducted through EMME/2 software. The output of this modeling process contains the traffic and the speed of vehicles with a separation of their type in any of the existing streets of Tehran. In this way can the distribution and the amount of pollution caused by the traffic of different vehicles can be calculated in Tehran.

Figure 5 shows data for the seven categories of vehicles, including personal cars, taxis, motorcycles, pickups, minibuses, buses and trucks in 17.441 streets.

In **Figure 6**, Tehran's street network is shown consisting of 17.441 used street.

Also in **Figure 7** the position of the regions of Tehran and the position of passages of regions 23 and 24 are shown as the suburbs of Tehran, influencing the situation of traffic in the city.

Statistical analysis shows that about 50% of Tehran city's passages are the residential streets. The share of arterial streets and highways are 37 and 13 percent, respectively. Collection of data on the slope of the streets in Tehran shows that 56 percent of the streets of Tehran are flat with zero slopes. The shares of positive and negative sloped streets are 19% and 20%, respectively. About 5 percent, undefined slope have been announced.

According to calculations made by the Company of comprehensive studies on the transportation of Tehran, the total of the traversal of vehicles in the morning peak hour of traffic in Tehran is about 838 million kilometers. In the meantime passenger cars by 67 percent, have the largest share and then taxis, motorcycles, pickups minibuses, buses and trucks have 12%, 8%, 6%, 2%, 3%, and 2% share of the total traffic at peak hours in the morning, respectively.

2. Materials and Methods

Introduction of Method

The IVE (International Vehicle Emission) Model was designed in 2007 with the support of The Environmental Protection Agency of America [13]. The main purpose of this software is to provide an appropriate model for estimating emissions of pollutants in proportion to the situation of developing countries [14].

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Odd and Even Range Plan	Traffic range plan	Width (m)	the type of street	Number of municipality	slope	Last Counter	First Counter
1	1	10.2	arterial 1	12	up hill	59523	2001
1	1	8.5	Collector	12	downhill	59365	2003
1	1	5	arterial 1	12	flat	59524	2004
1	1	9.7	arterial 1	12	downhill	59525	2004
1	1	0	arterial 1	12	flat	69218	2006
1	1	9.5	arterial 1	12	flat	70102	2006

the length of Link km	Coordunates of the last node (utm) yj with m	Coordinates of the last node (utm) xj with m	Coordinates of the first node (utm) yi with m	Coordinates of the first node (utm) xi with m
0.3	3948231	538199	3948530	538233
0.49	3949217	538938	3948778	538731
0.2	3948160	538510	3948118	538702
0.23	3948067	538927	3948118	538702
0.37	3947411	539501	3947379	539132
0.3	3947355	538833	3947379	539132

the speed of private cars and the rest km/h	the speed of municipal buses kn/h	the number of trucks	the number of motor-cycles	the number of private buses	the number of municipal buses	the number of minibuses	the number of taxis	the number of pickups	the number of privte-cars
10.5	8.1	4.18	1070.0	19.32	5.28	33.56	906.23	191.51	3747.5
33.6	21.8	0.76	219.92	1.33	5.28	9.28	120.01	41.12	284.67
11.7	0	1.42	820.07	11.03	0	19.71	448.24	189.90	1428.0
11.4	0	0.96	215.05	0.46	0	7.80	120.97	40.39	320.89
0	17.7	0	0	0	19.23	0	0	0	0
3.4	14.6	8.57	1920.9	23.74	93.43	43.15	741.16	464.64	2650.6

Figure 5. Traffic information prepared by the comprehensive studies on transport company in various places in Tehran.

The emission coefficients of this software for different vehicles are based on models EMFAC2007, MOBIE6, COPERTIV. Compared to similar software like COPER and MOBILE, this software has advantages [15] [16] [17].

The information needed to estimate the curves are obtained through the calculations of emission factors of air pollution in Tehran [4] [8] [9] [18] [19]. The model is developed to be used in developing countries due to lack of basic information in these countries which need to gain basic information from traffic information and the composition of fleet.

As shown in **Figure 8**. The structure of information processing and required input information [20] are indicated in order to use the model IVE.

The calculation method of emission coefficient in IVE emission model.

In order to calculate the amount of pollution caused by vehicles through the model of IVE, four types of information is required:

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Figure 6. Passages intended to calculate the emission coefficient of vehicles traveling in Tehran.

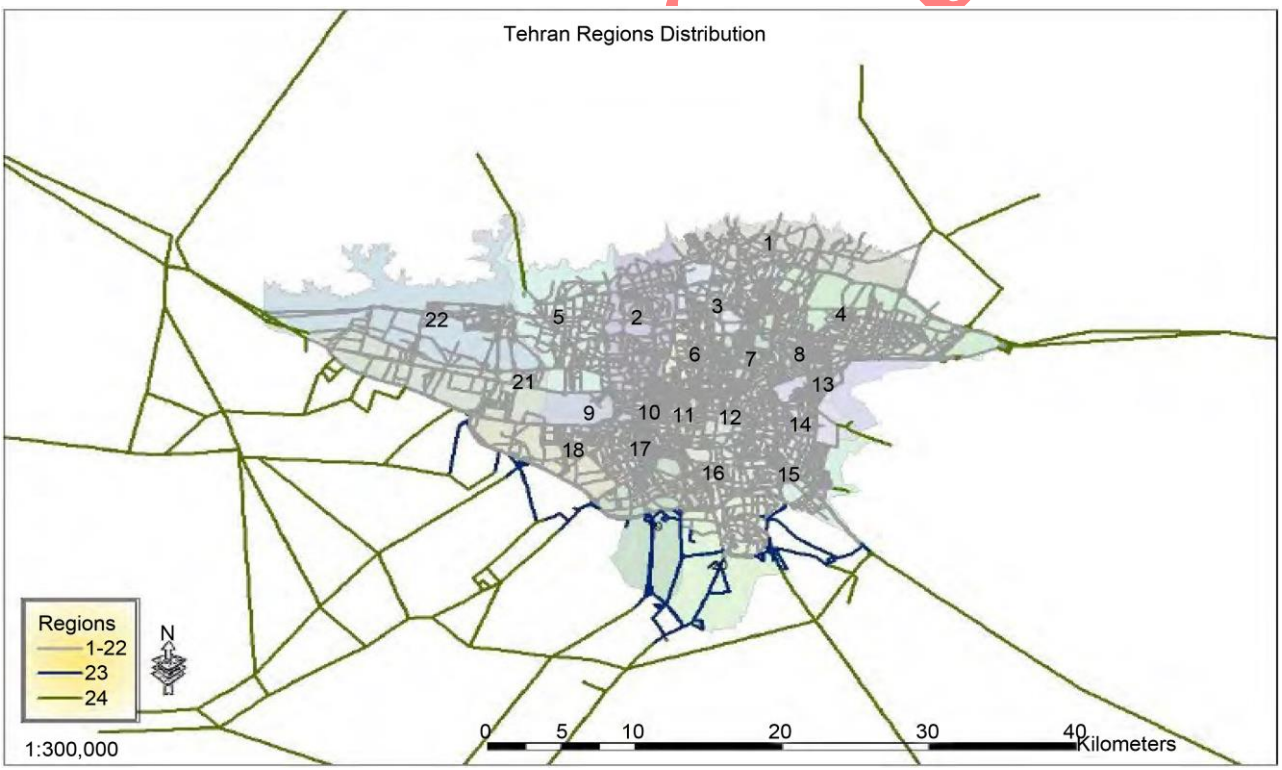

Figure 7. Location of passages in 22 districts of Tehran, in the region 23 and 24.

- The rate of vehicles' emissions in the basic conditions;
- The model for driving vehicle (speed in terms of time);
- The combination of fleet of vehicles in various categories;
- Climatic and geographical conditions of the region as well as fuel characteristics (including temperature, humidity, above mean *sea* level and type of fuel).

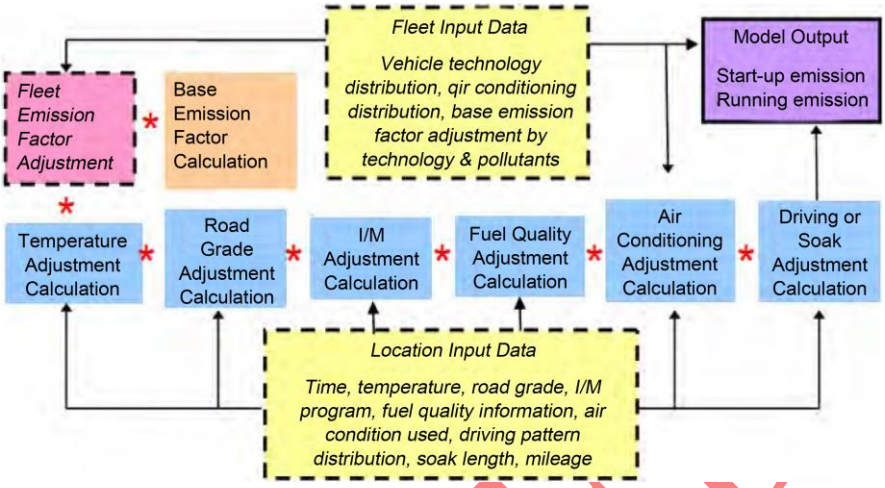

Figure 8. Structure of information processing publishing in IVE model.

Taking advantage of this special data for a region, the emission rate of pollutants emitted by vehicles can be calculated [21].

Categorization and preparation of the information needed for the model IVE in Tehran.

The required Information for the implementation of the above-mentioned model can be divided into two general categories:

1) Fleet File: Contains information on vehicle types and percentage of the use of each type of technology in the fleet as well as information related to the seven types of vehicles (cars, taxis, motorcycles, …) documented by the reports of numbering centers in Tehran along with information about the fleet being equipped with air-conditioning, etc.

2) Location File: The following information will be included in the model:

- environmental conditions such as temperature, humidity and altitude;
- Gasoline characteristics such as percent of sulfur compounds, the amount of available gasoline and the amount of oxygen-containing compounds;
- The composition of the fleet of vehicles used in the study area;
- Information on the driving pattern such as the percentage of time spent in each BIN, total distance traveled and average speed;
- Information on the number of fire starts and Soak Times in order to calculate the emissions caused by the cold start.

The conducted studies are related to the morning traffic peak on a day in October 2015, therefore, emission coefficient for this date is calculated using the IVE model.

3. Discussion and Conclusion

In **Figures 9-15**, the emission factors of vehicles for carbon dioxide and carbon monoxide, volatile organic compounds, volatile organic compounds evaporation, sulfur oxides are shown for three residential, arterial streets and highways and separately for the three slopes of the streets including passenger cars, taxis, motorcycles, municipal buses, private bus, minibuses, trucks and pickups.

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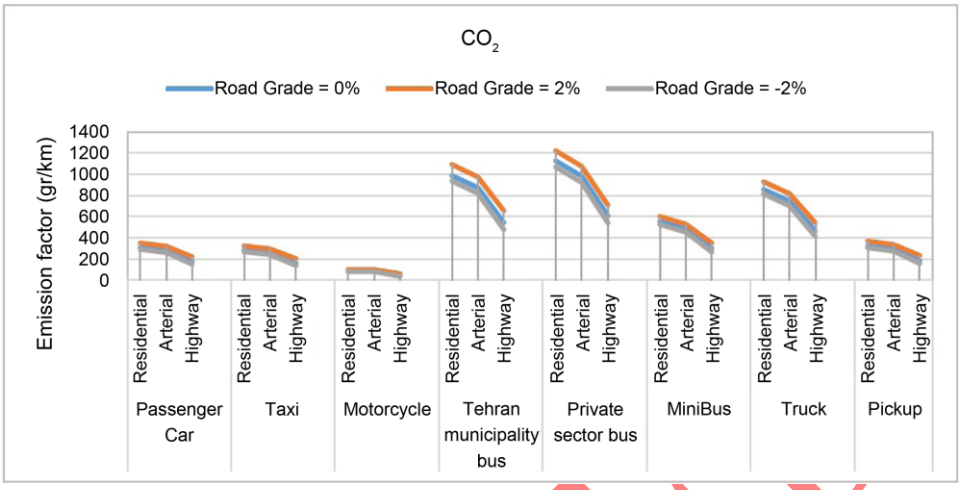

Figure 9. Coefficient of carbon dioxide emissions based on the IVE for the combined fleet of vehicles.

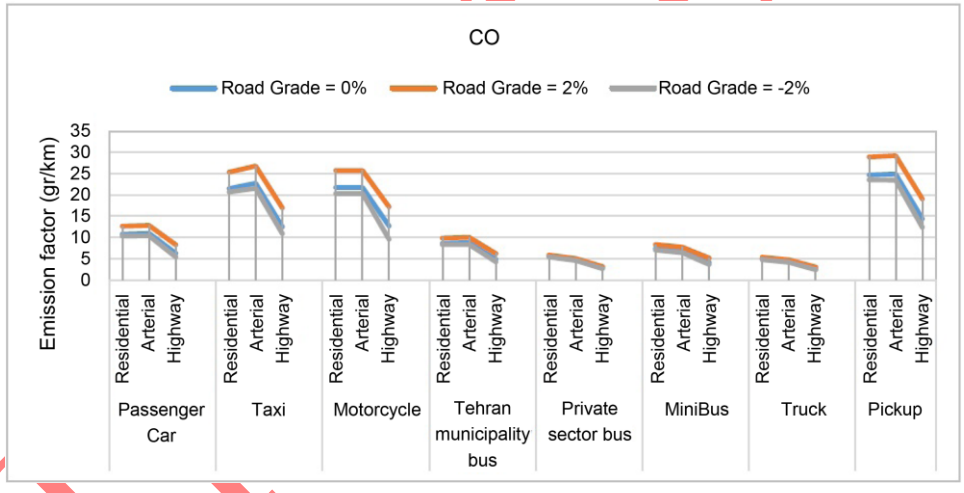

Figure 10. Coefficient of carbon monoxide emissions based on the IVE model for the combined fleet of vehicles sorted by the type of passages.

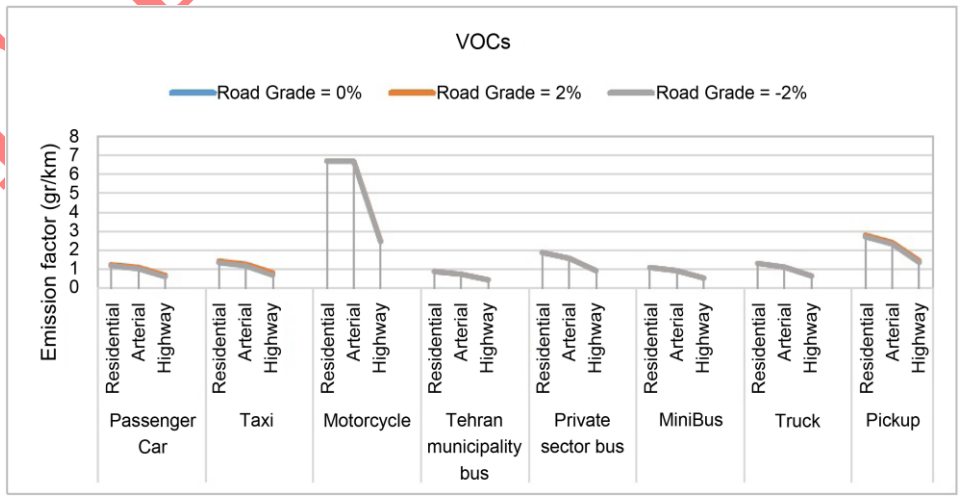

Figure 11. Coefficient of volatile organic compounds emissions based on the IVE model for the combined fleet of vehicles sorted by the type of passages.

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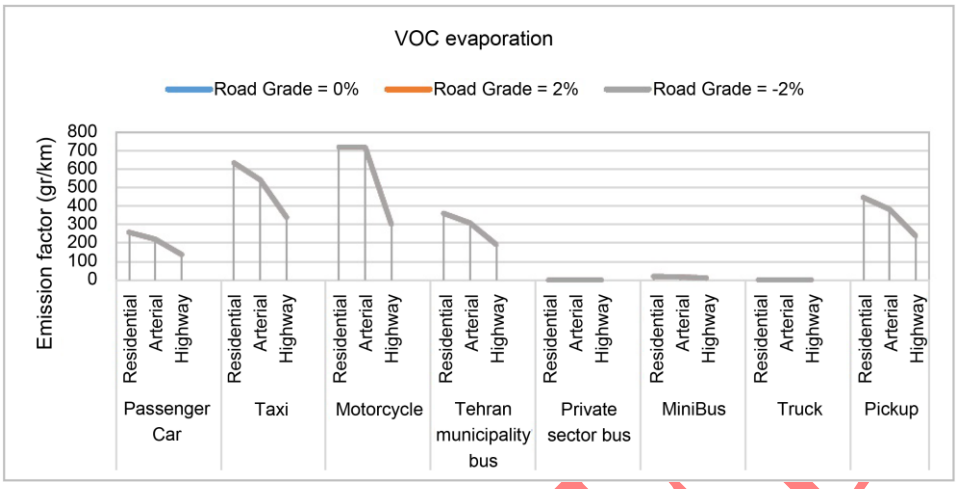

Figure 12. Coefficient of volatile organic compounds evaporation emissions based on the IVE model for the combined fleet of vehicles sorted by the type of passages.

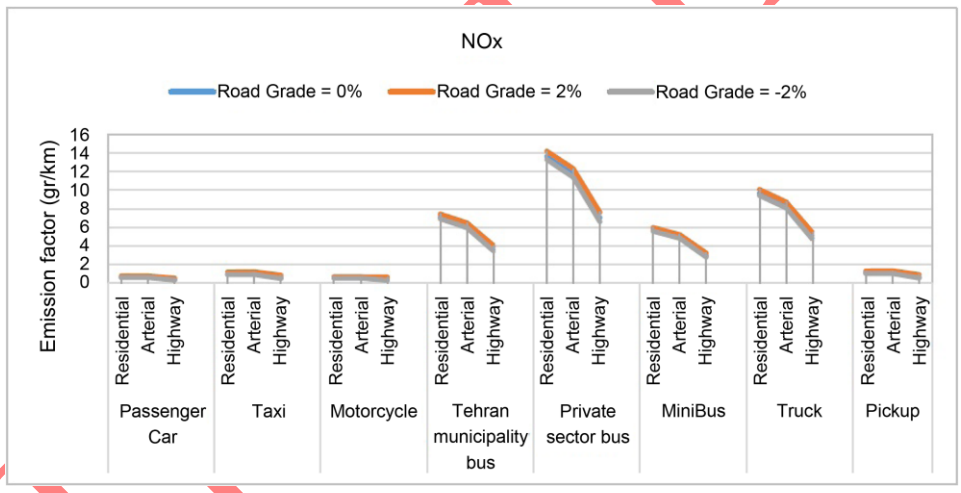

Figure 13. Coefficient of nitrogen emissions based on the IVE model for the combined fleet of vehicles sorted by the type of passages.

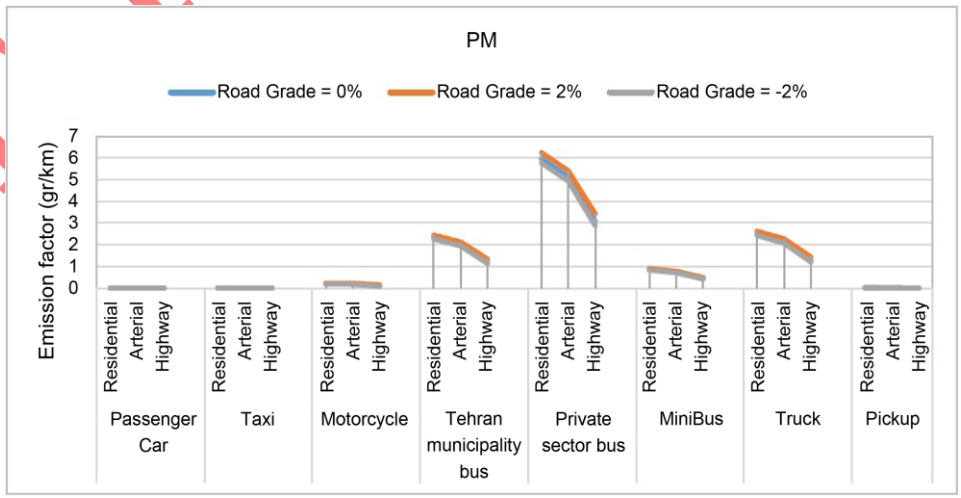

Figure 14. Coefficient of suspended particles' emissions based on the IVE model for the combined fleet of vehicles sorted by the type of passages.

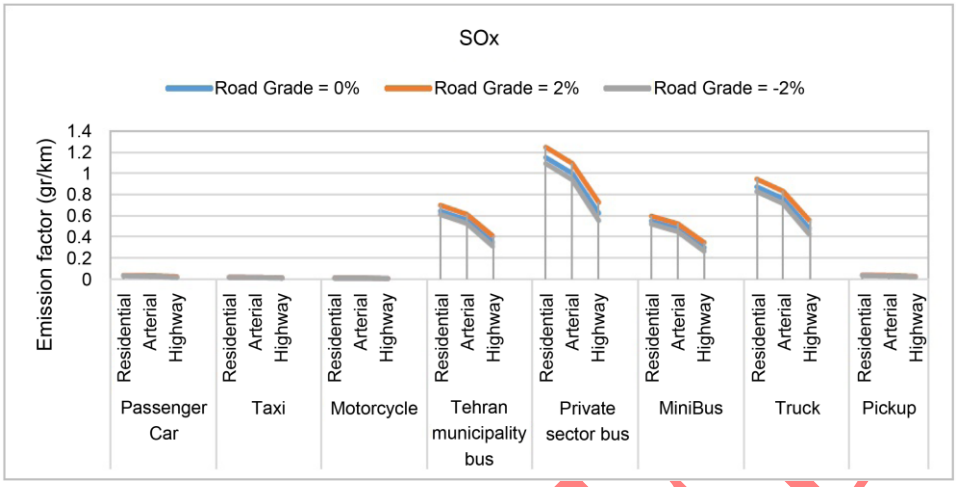

Figure 15. Coefficient of sulfur oxides emissions based on the IVE model for the combined fleet of vehicles sorted by the type of passages.

The results showed that taxis, motorcycles and pickups, emit the highest carbon monoxide per kilometer and diesel vehicles with regard to the composition of their fleet and choice of fuel, emit the least amount of carbon monoxide in the air per kilometer.

Notably, the amount of carbon monoxide emissions from motorcycles per kilometer is also important.

The highest rate of emissions of volatile organic compounds in the air for the same amount of kilometers is related to fleet of motorcycles compared with the composition of other vehicles.

The emission factor related to Evaporative volatile organic compounds for motorcycles and taxis fleet shows the highest value and then trucks, buses and cars indicate the maximum amount of evaporation of volatile organic compounds to emit per kilometer.

According to the modeling done by emission model of IVE, trucks, minibuses and buses have the highest coefficient of nitrogen oxides emissions and the pattern is the same for the emissions of suspended particles and sulfur oxides. In municipal buses because of the large number of natural gas buses, the average emission coefficient of suspended particles and sulfur oxides is less than the service buses and trucks. But emission coefficient of suspended particles shows that motorcycles emit more particles compared with passenger cars, taxis and trucks. Emissions of nitrogen oxides for per kilometer for fleet of taxis and pickups are more than passenger cars and motorcycles.

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