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# The Share of Different Vehicles in Air Pollutant Emission in Tehran, Using 2013 Traffic Information

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**ABSTRACT**

**Objectives:** Investigating and determining the share of urban sources of air pollutants is an essential step in pollution control management. Studies indicate the main source of air pollution in Tehran is the indiscriminate use of energy, while vehicles produce more than 85% of air pollution. Thus vehicles have the most important role in Tehran's air pollution.

**Methods:** The present study investigated the share of different types of vehicles in Tehran according to fuel consumption and emission factors and based on output data from the EMME/2 software of Tehran Comprehensive Transportation and Traffic Studies in a morning peak hour in 2013.

**Results:** The emissions of criteria pollutants (CO, HC, $NO_X$, $SO_X$, and P.M.) vary in different types of gasoline and diesel vehicles according to emission factors, type and number of vehicles, fuel consumption, and car mileage. Generally, in a traffic peak hour in a morning in 2013, the share of a variety of sedans, taxis, motorcycles, pickups, minibuses, public buses, trucks, and school buses in pollutants emission was 48.36, 18.87, 16.02, 10.35, 1.50, 2.49, 1.28, 1.13 percent, respectively.

**Conclusion:** A trip by sedans or motorcycles emits 97 times and a trip by taxi emits 63 times as air pollutants as a trip by public buses. Therefore, raising public awareness about emissions of criteria air pollutants by vehicles for one trip or traverse of one kilometer in the city, and also encouraging them to manage their trips and make optimal use of private and public vehicles play important roles in reducing Tehran's air pollution.

**Keywords:** Criteria air pollutants, Emission factor, Vehicles, Tehran's air pollution



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## Introduction

Emission of criteria air pollutants from mobile sources has a dominant share in air pollution in many metropolises with proven adverse effects on human health, visibility and weather [1-3]. Pollutants emission from vehicles is effective in emissions of primary air pollutants (e.g. emission of CO, NOx, $CO_2$, and hydrocarbons HC), secondary air pollutants (e.g. ozone), and aerosols [4-6]. According to the information in the Statistical Yearbook of Iran and statistics of consumption of energy producing petroleum products in 2013, Tehran had more than 8.6 million inhabitants, 33.7% of whom were the working population, 20.9% were students and the rate of private car ownership was 0.38 vehicles per person. Tehran is one of the most polluted cities in the world because of its specific topography and climate, the establishment of thousands of industrial plants, the traffic of a variety of vehicles, daily consumption of more than 10.3 million liters of gasoline, 3.9 million liters of diesel and 1.3 million cubic meters of CNG for transportation. The main cause of air pollution in Tehran is indiscriminate energy consumption and more than 85% of air pollution by weight is emitted by the vehicles in Tehran and CO has the highest amount [7]. Among the Tehran criteria air pollutants, CO has the highest and $SO_X$ has the lowest amount [8]. The results of JICA project by Tehran Air Quality Control Company to determine emission factors in 1992-1994, suggested that the vehicles had the most significant role in Tehran air pollution. The highest emission factors in gasoline and diesel vehicles were that of CO, HC, and $NO_X$. A study in Shiraz showed that among transportation, industrial, commercial, and residential sources of pollution, transportation had the highest share [9, 10]. Based on the analysis of air pollutants in the industrial zone of Cochin, India, CO had the highest amount in the transportation sector [11]. In a study of pollutants emission from 42 diesel vehicles in Istanbul, Turkey, $NO_X$ accounted for the largest share [12]. In a study on the emission factors of diesel vehicles in 9 districts of Hong Kong, $NO_X$ accounted for the largest share of urban air pollution [13]. Investigating the emission factors of vehicles in Beijing, factors such as the type of car, car model year, engine size and driving parameters affected the emission factors of criteria air pollutants [14]. Another way to evaluate air pollution is using the emission factors and calculating the amount of emission from each energy carrier in different sources. Emission factors are experimental data that present emission of pollutants by sources per unit activity in form of tables. Emission factors have been developed for stationary and mobile sources. The activity type of sources depends on their approach to development. The activity in mobile emission sources is usually based on the traveled distance or fuel consumption unit [15-18]. Statistics and information from Tehran Vehicle Registration Plates Centers show that more than 4 million vehicles were registered in Tehran by the end of 2013, where private cars had the largest share by about 3 million cars, and accounting for 72% percent of all mobile sources in Tehran. It is noteworthy about 750,000 formed 18% of the total number of mobile emission sources in Tehran. Pickups, trucks, minibusses and buses comprise 5.5%, 2%, and 0.5% of the total number of vehicles in Tehran, respectively. Of more than 3 million private cars in Tehran in 2013, 90% of cars were produced in Iran. Emission standards, fuel type, age, and class of vehicle affect the air pollutants emission of private cars. The movement of vehicles on roads was affected by complex parameters such as different policies, the cost of fuel, and public transport network. Tehran Comprehensive Transportation and Traffic Studies Company is responsible for studying and planning these parameters. The EMME/2 parameters are annually updated by this company according to the changes made. Tehran hierarchy of roads is as follows: freeways, urban freeways, expressways, urban expressways, two-lane main roads, 4-lane main roads, sidetracks, collectors, local lanes, ramps, major arterials, and minor arterials. Roads are divided into flat, uphill, downhill or undefined according to their degree of slope. Streets categories used in the traffic information and calculation of emission factors must first be matched in order to use traffic information to calculate the emission list. Hence streets were classified as highways, arterials, and local lanes. According to the available information, as well as the data entered into the model, about 50% of streets in Tehran were local lanes, about 37% were arterials, and about 13% were highways. In terms of slopes, 56% were flat, 19% had a positive slope, 20% had a negative slope, and 5% were undefined [19]. Precise calculation and determination of criteria air pollutants in cities are essential for making decisions about air pollution management. Given the importance of air pollution in Tehran and daily increase of vehicles and their considerable share in air pollutants emission, it is necessary to determine the share of different vehicles in criteria air pollutants emission and to provide solutions for their control and reduction. Therefore, the present study aimed to investigate, assess, and determine the share of vehicles in criteria air pollutants emissions in Tehran, and to help the city officials and planners to monitor the main sources of air pollutants, and to inform the habitats about the quality of air in their region.

## Materials and Methods

Fuel consumption is the main parameter in the production and emission of pollutants from mobile sources. Therefore, the present study obtained different fuel consumption data from National Iranian Oil Products Distribution Company. The 2013 data were the most complete, therefore, this year was selected as the study period. Traffic models were developed and used based on the characteristics of the studied areas and the conditions for using vehicles. EMME/2 is a model for checking traffic assignments. Modeling in transportation includes supply and demand. Supply refers to the characteristics of the transport network, and demand refers to the need to travel due to the local conditions. The traffic information base was EMME/2 model output which showed the results for each road in the city. The traffic assignment process including supply and demand for Tehran was performed in this software and a four-step traffic model was developed for traffic modeling and analysis of various scenarios in Tehran. The output of this model is the amount of traffic and speed of different vehicles in each of the roads of Tehran. These results and data were used to calculate the amount of emissions and the share of each vehicle in the production and emission of air pollutants in Tehran. This information was received for seven categories of vehicles, including sedans, taxis, motorcycles, pickups, minibusses, buses and trucks in 17441 roads using a four-step model of Tehran in 2013.

Results only included emissions of pollutants produced in a morning peak hour because the investigation and comparison of the emissions of vehicles in a morning peak hour can properly determine the share of each vehicle.

## Calculation method

This section calculated the ratio of emissions from mobile sources in proportion to fuel consumption. This ratio was calculated for buses, minibuses, and trucks in proportion to diesel consumption and for sedans, pickups, motorcycles, and taxis in proportion to gasoline consumption. The model information on vehicle fuel consumption corresponded with the information from National Iranian Oil Products Distribution Company in the same year. It should be noted that CNG consumption was not considered in this model and all taxis were considered to consume gasoline. Emission factors for mobile sources were defined in terms of the amount of pollutant emitted unit of mileage at different speeds, and slope of the road for various vehicles for the passed standard. Due to the impossibility to regain emission factors of vehicles, the factors of the model were corrected to update the emission factors based on changes in subgroups of vehicles and calculation of fuel consumption. Using corrected emission factors and traffic data, the emission of different vehicles in different locations of Tehran could be calculated. For example, the annual emissions of a pollutant for one of the vehicles on one of the roads in Tehran was estimated as follows:

**Table 1.** Example of the annual emissions of a pollutant for one of the vehicles on one of the roads in Tehran

| Number of road | Path length (m) | Slope | The number of vehicles traffic per year | Average speed (Km/h) |
|---|---|---|---|---|
| 1111 | (L) 870 | Zero degrees (flat) | (N) 500000 | ($V_{ave}$) 35 |

Emission factor of the vehicle at speeds of 20 and 40 kph on a zero slope road for the pollutant:
EF40= 14 mg/Km , EF20= 10 mg/Km
EF35= (40-35)×14+ (35-20) × 10 / 40-20 = 11
Eyear= N × L/1000 ×EF35
The annual emissions of the pollutant:
Eyear=500000×870m/1000×11mg/km=4.78Kg/year

The information is calculated separately for each of the roads in Tehran and about each of the criteria air pollutants. The results are obtained in tons of the pollutant produced in a year for each area, and the sum of it in tons of the pollutant annually produced in each district of Tehran. The share of each vehicle in air pollutant emissions in Tehran is estimated based on the number of vehicles, fuel consumption, pollutant emission factors of each vehicle, traveled distance in kilometers and the number of travels.

## Results

According to Table 1, sedans accounted for 58.14% of the total number of vehicles in traffic peak hour, 60.31% of total transport fuel consumption, 66.96% of total traveled distance in peak hour, 51% of the weight of emitted CO, 43.95% of the weight of emitted HC , 37% of the weight of emitted $NO_X$, 28.57% of the weight of emitted SOx, 2.5% of emitted PM, and finally 48.36% of the weight of total amount of pollutants emitted in the air of Tehran. Similarly, taxis accounted for 20.26% of total fuel consumption and 18.78% of total emitted pollutants weight; pickups accounted for 6.17% of total fuel consumption and 10.35% of total emitted pollutants weight; motorcycles accounted for 3.29% of total fuel consumption and 16.02% of total emitted pollutants weight; minibuses accounted for 3404% of total fuel consumption and 1.50% of total emitted pollutants weight; buses accounted for 2.82% of total fuel consumption and 2.49% of total emitted pollutants weight; trucks accounted for 2.13% of total fuel consumption and 1.28% of total emitted pollutants weight; school buses accounted for 1.36% of total fuel consumption, and 1.13% of total emitted pollutants weight in Tehran.

**Table 1.** The share of different vehicles in emissions of air pollutants in a morning peak hour in 2013

| Types of Vehicles | Percentage of number | Percentage of traveled distance | Percentage of share Fuel consumption | Percentage of total emissions of pollutants | Percentage of emissions for one trip | Percentage of emissions for one-kilometer traveled distance |
|---|---|---|---|---|---|---|
| **Sedans** | 58.14 | 66.96 | 60.30 | 48.36 | 22.63 | 18.89 |
| **Taxis** | 21 | 12 | 20.26 | 18.87 | 14.53 | 27.27 |
| **Motorcycles** | 10.57 | 8.01 | 6.17 | 16.02 | 22.39 | 18.80 |
| **Pickups** | 5 | 6 | 3.29 | 10.53 | 28.26 | 18.36 |
| **Minibuses** | 2.36 | 2 | 3.39 | 1.50 | 0.33 | 2.90 |
| **Public buses** | 1.3 | 2 | 2.82 | 2.49 | 0.23 | 4.74 |
| **School buses** | 0.68 | 1 | 1.63 | 1.13 | 0.47 | 4.44 |
| **Trucks** | 0.81 | 2.03 | 2.13 | 1.28 | 11.17 | 4.32 |
| **Total** | 100 | 100 | 100 | 100 | 100 | 100 |

Figures 1 to 6 show the emissions of criteria air pollutants and the total criteria air pollutants at a traffic peak hour in Tehran, respectively. It should be noted that estimating the emissions of pollutants of all kinds of vehicles during one day or throughout a year is difficult, however determining the share of each vehicle type in emissions of air pollutants based on traffic information in a morning peak hour can be applied to general conditions prevailing in Tehran.

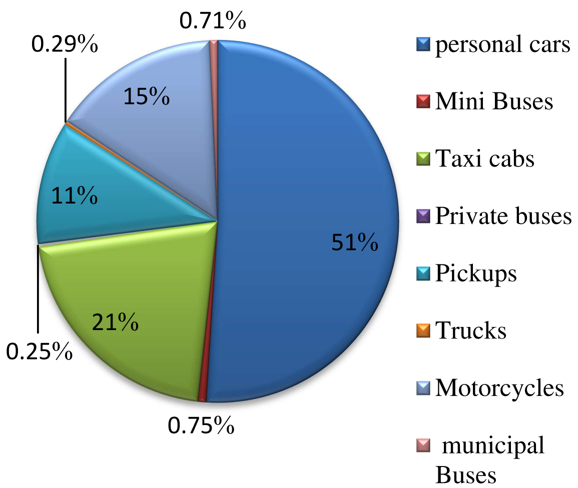


**Figure 1.** Percent share of different vehicles in emissions of CO in a traffic peak hour

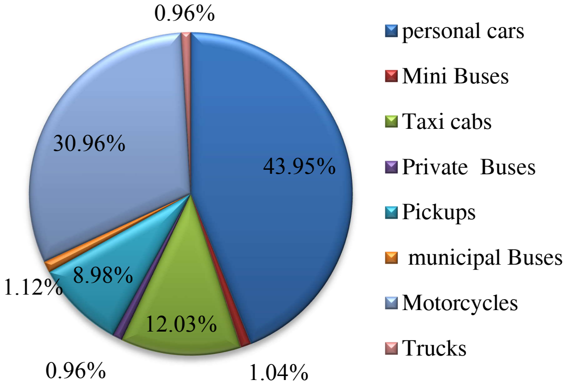


**Figure 2** Percent share of different vehicles in emissions of HC in a traffic peak hour

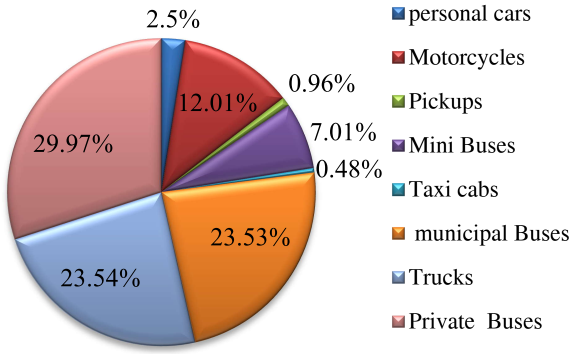


**Figure 5.** Percent share of different vehicles in emissions of PM in a traffic peak hour

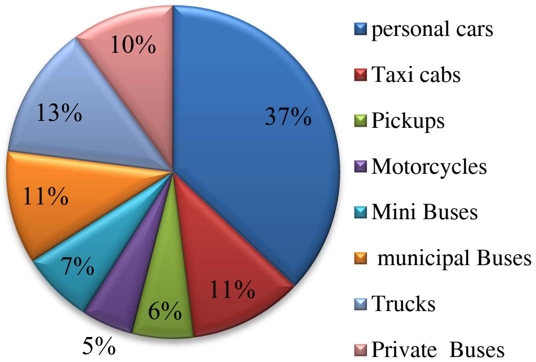


**Figure 3.** Percent share of different vehicles in emissions of $NO_X$ in a traffic peak hour

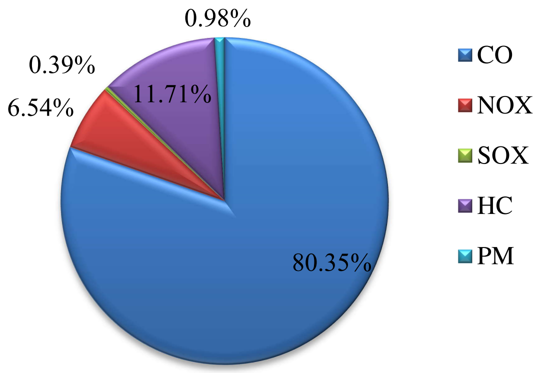


**Figure 6** Percent share of different vehicles in emissions of criteria air pollutants in a traffic peak hour

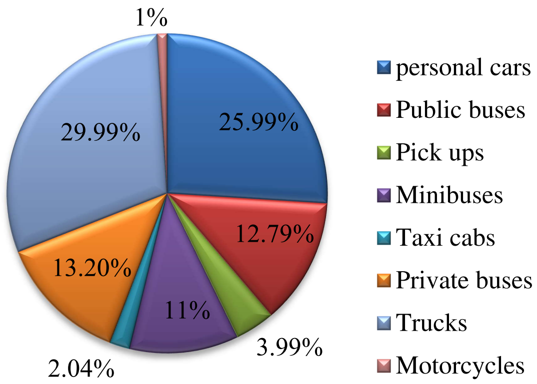


**Figure 4.** Percent share of different vehicles in emissions of $SO_X$ in a traffic peak hour

## Discussion and Conclusion

According to the output of EMME/2 model in 2013 during a morning traffic peak hour from 7:30 to 8:30 in Tehran, the total vehicle traveled distance was about 38.8 million kilometers where the sedans had the largest share with 67%, followed by taxis with 12%, motorcycles with 8%, pickups with 6%, buses with 3%, minibuses, and trucks with 2%. According to the output information of traffic models, the traveled distance of vehicles in a traffic peak hour was more than 8 million km. The traveled distance share of each type of vehicles in Tehran during a traffic peak hour is presented in Table 1. According to Table 1, sedans had the highest amount of traveled distance and minibuses had the lowest traveled distance in a morning peak hour in 2013. Vehicle fuel consumption information in Tehran in 2013 shows that, of the total amount of fuel consumed in the transportation sector, 90% was gasoline and 10% was diesel.

According to the software output in a traffic peak hour, sedans alone accounted for about 67% of all consumed gasoline, while they account for 61.30% of the total number of gasoline-fueled vehicles. They were followed by taxis with 22.21% of the total number and 22.5% of gasoline consumption, pickups with 5.16% of the total number and 6.85% of gasoline consumption, and motorcycles with 11.33% of the total number and 3.65% of gasoline consumption. On the other hand, in the case of diesel-fueled vehicles, minibuses made up more than 45% of the total number of diesel-fueled vehicles, while they only consumed 34% of diesel consumption followed by public buses with 25.39% of total number and 28.29% of diesel consumption, trucks with 15.71% of total number and 21.34% of diesel consumption, and school buses with 13.12% of total number and 16.33% of diesel consumption. In addition, considering pollutants emission based on the amount of emission in one-kilometer traveled distance, or amount of emission in one trip, according to the EMME/2 model output, minibuses had the lowest emissions per traveled kilometer and, buses had the lowest emissions per trip. In a study on the shares of air pollutants emission sources in Tehran in 2003, indiscriminate energy consumption was introduced as the main cause of air pollution in Tehran. That study indicated that more than 85% of pollutants weight was emitted by vehicles and CO was the most emitted pollutant. The results of JICA project by Tehran Air Quality Control Company in 1992-1994, suggested that the vehicles had the most significant role in Tehran air pollution. The highest emission factors in gasoline and diesel vehicles were that of CO, HC, and $NO_X$. Investigating the role of criteria pollutants in Shiraz air pollution to determine the share of transportation, industrial, commercial, and domestic sources of pollution, and the most important factor of air pollution was transportation [9, 10]. Based on the analysis of air pollutants in the industrial zone of Cochin, India, carbon monoxide had the highest amount in the transportation sector [11]. In a study of pollutants emission from 42 diesel vehicles in Istanbul, Turkey, $NO_X$ accounted for the largest share [12]. Also, in studying the emission factors of diesel vehicles in 9 districts of Hong Kong, $NO_X$ accounted for the largest share of air pollution in the city [13]. Investigating the emission factors of vehicles in Beijing, factors such as the type of car, car model, engine size and driving parameters were affected the emission factor of criteria air pollutants [14]. Hence it can be concluded that activities such as vehicle inspections, making energy-saving vehicles with fuel-injected engines, development of public transport infrastructure, and changing consumption patterns have hardly improved air quality in Tehran. However, although mobile sources such as vehicles have a fundamental role in Tehran air pollution, other reasons for the increase of air pollution in Tehran are the dust storms that have recently occurred in the west, southwest and center of Iran. The dust storms used to occur only in spring and summer up to a few years ago, but now they cover eight months of the year and in addition to the southwestern parts of the country, they have reached a wider range in most provinces and metropolitan areas such as Tehran, Isfahan, and Shiraz [20].

It is especially important for urban management and planning for air pollution control to estimate the share of vehicles in Tehran air pollutants, particularly in critical conditions. A trip in private cars or taxis emit 97 and 63 times more air pollutants than traveling by public buses, respectively. A motorcycle can emit the same amount of pollutants as a sedan or a pickup for traveling one kilometer, while its functionality and efficiency of passenger and freight transport is much less than sedans or pickups. Therefore, paying attention to taxis, using hybrid taxis and electric motorcycles, as well as replacing old cars with new, fuel-efficient vehicles; development of public transportation; establishing the culture of reducing unnecessary trips; and using public transport are important steps in reducing air pollution in Tehran that can even remove the need for alternate-day traffic constraints and plans in the long term.

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