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Correlation of air pollutants with land use and traffic measures in Tehran, Iran: A preliminary statistical analysis for land use regression modeling

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Original Article

Abstract
Land use regression (LUR) models have been globally used to estimate long-term air pollution exposures. The present study aimed to analyze the association of different land use types and traffic measures with air pollutants in Tehran, Iran, as part of the future development of LUR models. Data of the particulate matter (PM_{10}), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) were extracted from 23 Tehran's air quality monitors for 2010. The data of different land use types and traffic measures within the circular buffer radii 100 to 1000 meters and distances to them were calculated using Geographic Information System (GIS). Thereafter, the association of the mentioned air pollutants was evaluated with land use types and traffic measures. The annual average concentrations of PM_{10}, SO_2 and NO_2 were 100.8 µg/m^3, 38 parts per billion (ppb), and 53.2 ppb, respectively. The PM_{10} was associated with transportation area, other areas, and with distance to the other nearest land use ($P < 0.05$). The SO_2 concentration was associated with official or commercial land use, and with other area land use ($P < 0.05$). Noteworthy, the NO_2 concentration was associated with official or commercial land use, and with other areas ($P < 0.05$). The air pollutant concentrations was analyzed with different land use types and traffic measures as a preliminary work for development of LUR models in Tehran. It is hoped these analyses lead to successful development of LUR models in the near future.
KEYWORDS: Land Use Regression, Land Use Types, Traffic Measures, Particulate Matter, Sulfur Dioxide, Nitrogen Dioxide

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Introduction

Recently, extensive epidemiological studies have linked the indoor and outdoor short and long-term air pollution exposures to the considerably significant acute and chronic adverse health effects,[1,2] particularly studies on development of asthma,[3] respiratory and cardiovascular diseases,[4]

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birth outcomes and developmental effects,[5] leukemia,[6] mortality,[7,8] and even neighborhood walkability.[9] Generally, albeit these studies collected a very large datasets on health outcomes, air pollution exposure assessment has been a challenge in the majority of the epidemiological studies.[10-12] Though personal monitoring through several consecutive days in studies with less than hundreds of subjects has assessed short-term exposures, it has still been a serious challenge as the study population increases. However, since epidemiological studies on long-term air pollution exposures need only annual (or any other long-term average) exposure concentrations, and ideally as close to the individual-level as possible, and even more because their study population mainly comprises several hundreds to thousands of subjects, the mere monitoring will not be feasible.[12-15] Initial epidemiological surveys have assigned only one average exposure to all the participants in a large geographical area, and assumed that the concentration of the pollutant of interest is homogeneous throughout the whole such an area. However, various investigations have now demonstrated that there is a considerable difference on a very small-scale in the ambient air pollution concentrations.[16-18] Consequently, individual-scale exposure assessment is warranted to minimize exposure misclassification in epidemiological studies.[19] Hence, various approaches have been used in recent years to capture small-scale spatial variations of outdoor air pollution, which are described elsewhere.[20-22] More recently, land use regression (LUR) modeling -which is classified as geospatial modeling techniques- has been developed and emerged as a successful approach to predict neighborhood-scale air pollution exposures, even better than kriging and dispersion models.[21,23,24] Initially, this technique was applied in Europe,[25] but recently several applications have been reported in North America,[26-28] China,[29] and Japan.[19] As part of the future LUR models development, this study aimed to analyze the association of different land use and traffic measures with air pollutant concentrations in Tehran, Iran.

Materials and Methods

The study area encompassed Tehran, Iran, with approximately 613 square kilometers study area (Figure 1). Tehran is the largest city in Iran and suffers from extreme air pollution concentrations. The population of the city is about 9 million people, albeit it would be much higher during daily time hours.[30]

The data of air pollutant concentrations for 2010 were extracted from 23 air quality monitors belong to Air Quality Control Company (AQCC) and Department of Environment (DOE). These included particulate matter with aerodynamic diameter of 10 micrometer or smaller (PM_{10}), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2). Data were purified in Microsoft Office Excel and then were imported to the R statistical software.[31] The missing data were imputed using AMELIA program.[32]

The data of land use and traffic measures have been originated from a study on seismic micro-zoning of Greater Tehran area.[33] The land use was in ten categories including: 1. residential, 2. green space, 3. urban facilities, 4. industrial or workshop, 5. official or commercial, 6. transportation, 7. military, 8. arable, 9. arid or undeveloped and finally 10. other land use areas. The total length of the land use types were considered for analyses within circular buffer radii 100 to 500 meters and distances of the air quality monitors toward them. The traffic measure variables were surrogates of traffic including length of the streets, highways, bridges, and all roads within the circular buffer radii 100 to 1000 meters around the air quality monitoring stations and distances away (Figure 2) (Table 1). All these variables were calculated and analyzed in Geographic Information System (GIS) using ArcGIS® 9.3 (ESRI®, Redlands, CA, USA).

Descriptive statistics including annual average of the air pollutant concentrations were calculated and reported. Meanwhile, the

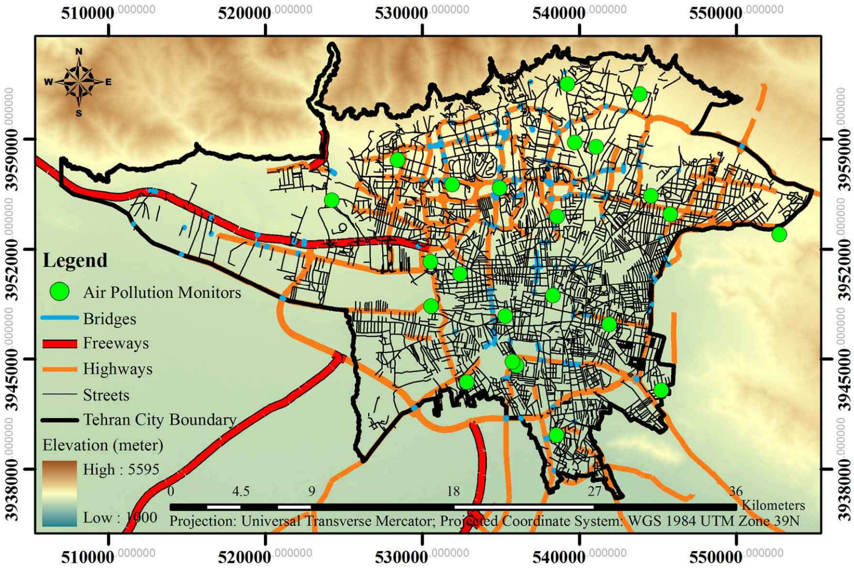

Figure 1. Study area of Tehran, Iran

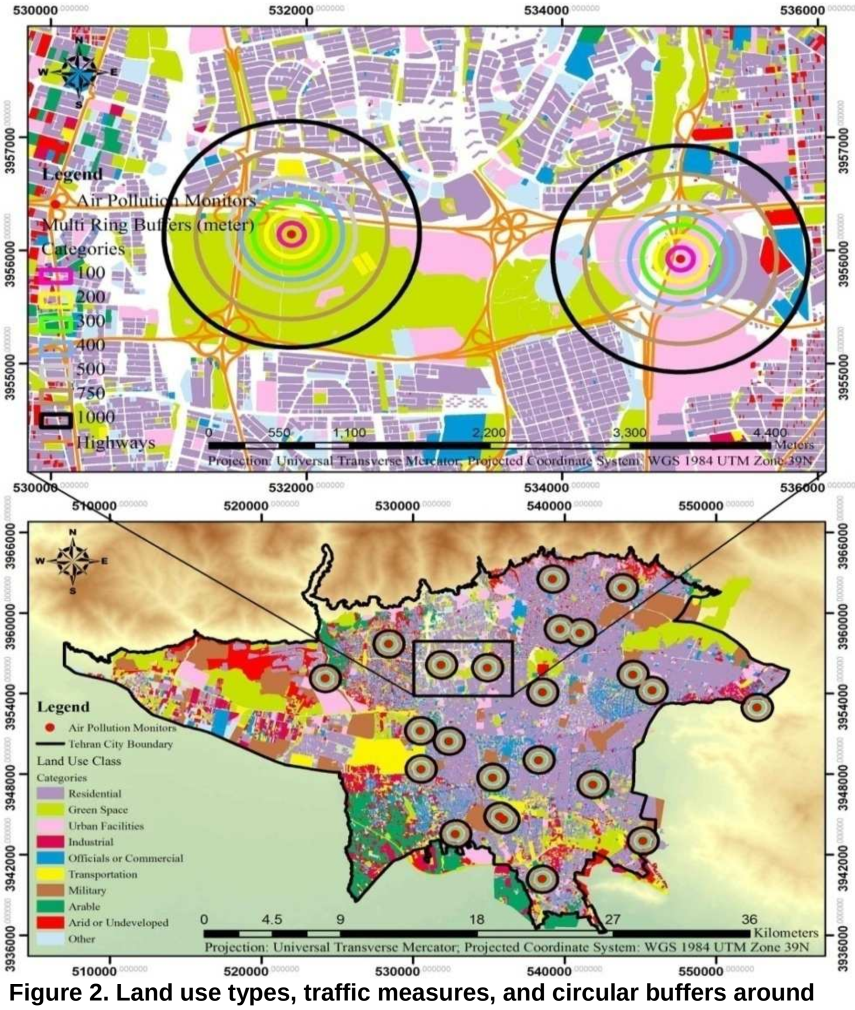

Figure 2. Land use types, traffic measures, and circular buffers around the air quality monitoring stations with different radii

Table 1. Summary of the traffic measures variables

Variable name	Buffer radii (m) around monitors
Length of streets	100, 200, 300, 400, 500
Length of highways	100, 200, 300, 400, 500
Length of bridges	400, 500
Length of all road types	100, 200, 300, 400, 500, 750, 1000
Distance to streets	-
Distance to highways	-
Distance to bridges	-
Distance to all road types	-

maximum, minimum and median of which were plotted by the box plots. Descriptive statistics were also calculated for all the traffic measures and land use type variables. Thereafter, the correlations of the measured air pollutant concentrations were calculated with all the land use types and traffic surrogate measures. The p-value less than 0.05 set as a significant level in all the statistical analyses. All the statistical analyses were performed by Stata Statistical Software, Release 12.0 (Stata Corporation, College Station, TX, USA) and R statistical software.

Results and Discussion

In this study, it was tried to analyze the associations of different land use and traffic measures with air pollutant concentrations as part of the future land use regression models development in Tehran, Iran. The annual average concentrations of PM_{10}, SO_2 and NO_2 were 100.8 µg/m^3, 38 parts per billion (ppb), and 53.2 ppb, respectively. Meanwhile, descriptive statistics of the air pollutants concentrations are shown in figure 3. Moreover, descriptive statistics of all traffic measures are tabulated in table 2. In addition, descriptive statistics of all the land use variables are tabulated in table 3.

The air pollutant concentration in Tehran is much higher than other contexts of the world where land use regression models have been

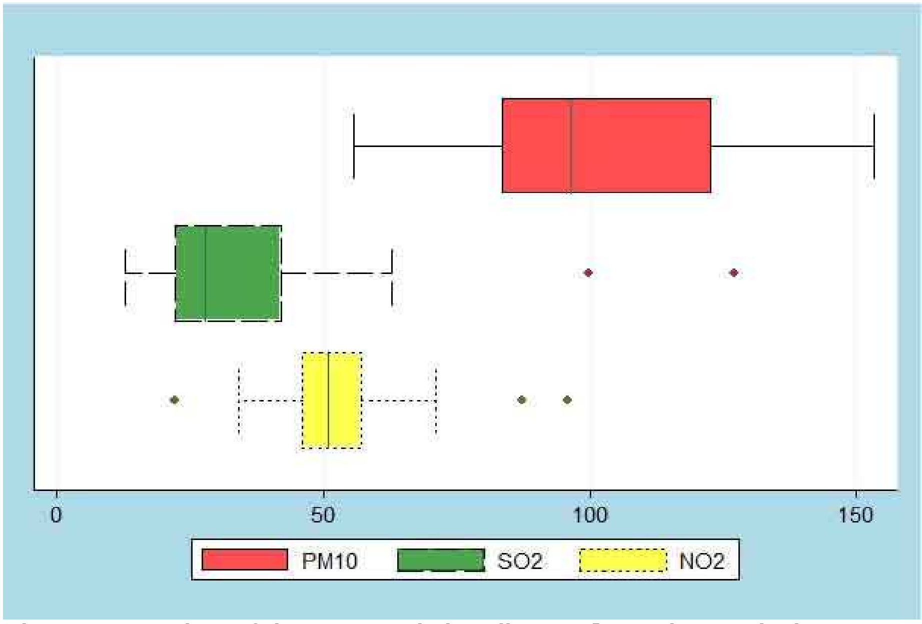

Figure 3. Box plots of the measured air pollutants [Note that particulate matter (PM10) units is in µg/m3, sulfur dioxide (SO2) and nitrogen dioxide (NO2) units are in ppb]

Table 2. Summary of the traffic surrogates variables

Variable name (buffer radii in meter)	Minimum	Maximum	Mean	Standard deviation
Length of streets (100)	0	280	92.83	96.5
Length of streets (200)	0	1130	438.04	352.8
Length of streets (300)	0	2505	1006.09	624.1
Length of streets (400)	0	3880	1705.00	969.3
Length of streets (500)	0	5180	2698.48	1276.9
Length of all road types (100)	0	905	388.48	232.8
Length of all road types (200)	0	3840	1752.61	986.7
Length of all road types (300)	440	7595	3906.52	2015.7
Length of all road types (400)	825	13870	7055.87	3588.7
Length of all road types (500)	1260	21325	11370.43	5196.3
Length of all road types (750)	3350	48995	26045.00	11401.6
Length of all road types (1000)	4985	83030	46360.87	20103.9
Length of highways (100)	0	235	31.30	71.4
Length of highways (200)	0	760	97.61	204.4
Length of highways (300)	0	1100	209.57	363.0
Length of highways (400)	0	1635	389.57	570.8
Length of highways (500)	0	2810	666.96	871.3
Length of bridges (400)	0	690	66.09	169.4
Length of bridges (500)	0	1535	123.04	330.5
Distance to the nearest street	4	511	119.36	117.2
Distance to the nearest all road type	10	211	43.09	47.4
Distance to the nearest highway	21	2258	649.60	597.3
Distance to the nearest bridge	39	6032	1367.00	1244.0

reported.[10,27,34-36] In Tehran, the PM_{10} pollutant was associated with transportation area within buffer radii 100, 200, 300, 400 and 500 meters; with other area land use within buffer of 500 meters; and with distance to the other nearest land use ($P < 0.05$). The SO_2 concentration was associated with official or commercial land use area within buffer radii 300, 400, and 500 meters; and with other area land use within buffer of 100, 200, 300, 400 and 500 meters ($P < 0.05$). Noteworthy, the NO_2 concentration was associated with official or commercial land use area within buffer radii 200, 300, 400, and 500 meters; and with other area land use within buffer of 100 meters ($P < 0.05$).

These variables have been studied in other cities of the world. In other parts of the world, these pollutants have been associated mainly with traffic counts or surrogates of the traffic.[12] As shown in figure 2, the official or commercial land use areas are mainly located close to streets, roads, and highways where they are highly correlated with traffic counts. Thus, the significant associations of SO_2 and NO_2 with official or commercial land use areas demonstrated that traffic, indirectly, is the origin of these pollutants. This is in line with the results of other studies around the globe.[12,21]

In conclusion, some air pollutant concentrations in this research were analyzed with different within-city land use types and traffic measures as a preliminary work for development of the land use regression models in Tehran. It is hoped this analyses lead to successful development of land use regression models in the near future.

Table 3. Summary of all the land use variables

Variable Name (buffer radii in meter)	Minimum (m^2)	Maximum (m^2)	Mean (m^2)	Standard deviation (m^2)
Residential area (100)	0	16275	6811	5735
Residential area (200)	0	74250	31878	23586
Residential area (300)	0	184025	75405	52749
Residential area (400)	0	309975	140676	89313
Residential area (500)	0	485975	232904	133962
Green space area (100)	0	31425	4989	8207
Green space area (200)	0	115100	18452	27013
Green space area (300)	0	236650	35172	52847
Green space area (400)	0	385175	54657	83057
Green space area (500)	0	531450	71021	111868
Urban facilities area (100)	0	22200	3634	5618
Urban facilities area (200)	0	77500	15541	20204
Urban facilities area (300)	0	151050	33985	41399
Urban facilities area (400)	0	251750	55903	65748
Urban facilities area (500)	75	373250	80625	88154
Industrial area (100)	0	1600	203	439
Industrial area (200)	0	2750	530	885
Industrial area (300)	0	15175	2443	4271
Industrial area (400)	0	52975	8197	15044
Industrial area (500)	0	104500	14827	27268
Official or commercial area (100)	0	19200	2935	4813
Official or commercial area (200)	0	36975	7211	9718
Official or commercial area (300)	0	87925	14404	19743
Official or commercial area (400)	0	154425	23959	33034
Official or commercial area (500)	0	258775	38432	53712
Transportation area (100)	0	14725	1461	3734
Transportation area (200)	0	60575	5397	13239
Transportation area (300)	0	130075	14760	30261
Transportation area (400)	0	212625	28141	54161
Transportation area (500)	0	308150	45684	83081
Military area (100)	0	13575	872	2922
Military area (200)	0	54250	4107	12517
Military area (300)	0	111350	9477	26033
Military area (400)	0	190000	18220	45361
Military area (500)	0	307775	30455	73689
Arable area (100)	0	0	0	0
Arable area (200)	0	4850	210	1011
Arable area (300)	0	19125	1013	4005
Arable area (400)	0	33675	2061	7077
Arable area (500)	0	64550	4805	14842
Arid or undeveloped area (100)	0	9550	1477	3057
Arid or undeveloped area (200)	0	33700	5029	9158
Arid or undeveloped area (300)	0	77450	11469	21663
Arid or undeveloped area (400)	0	130050	20630	38153
Arid or undeveloped area (500)	0	179125	29328	52120
Other areas (100)	0	75	3	15
Other areas (200)	0	6550	431	1425
Other areas (300)	0	19475	1516	4748
Other areas (400)	0	31775	2829	7278

Table 3. Summary of all the land use variables (Continues)

Variable name (buffer radii in meter)	Minimum (m^2)	Maximum (m^2)	Mean (m^2)	Standard deviation (m^2)
Other areas (500)	0	45100	5108	10681
Distance to nearest residential land use	0	622	96	153
Distance to nearest green space land use	0	1351	161	299
Distance to nearest urban facilities land use	0	482	95	107
Distance to nearest industrial or workhouse land use	36	990	345	277
Distance to nearest commercial or official land use	0	710	124	178
Distance to nearest transportation land use	0	1716	435	460
Distance to nearest military land use	7	3934	984	1041
Distance to nearest arable land use	130	4235	1478	1184
Distance to nearest arid or undeveloped land use	0	1906	335	433
Distance to nearest other land use	47	6831	1719	2022

Conflict of Interests

Authors have no conflict of interests.

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