



PEDESTRIANISATION AS AN EFFECTIVE MEASURE TO CONTROL AIR POLLUTION TOWARD SUSTAINABLE DEVELOPMENT

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Abstract

The built environment and consequently vehicular transport has a significant impact on public health and environmental quality. Also vehicular transport as an impact of built environment is one of the most important source for environmental decay such as noise pollution in city centers. So, one of the transport schemes like pedestrianization can have a significant impact on environmental quality and improve noise pollution condition. This paper shows, to what extent the built environment and implementation of pedestrianization scheme has influence on reducing noise pollution level at Tehran' city center.

There is a direct interaction between man, human health, environment quality, sustainable development and pedestrianisation. The results of the survey suggest that the implementation of pedestrianisation in Tehran's city center has been very successful. As a result was founded an increase in walkability to be associated with an increase in time spent in physically active travel, fewer vehicle miles traveled, fewer grams of oxides of nitrogen (NOx) emitted, and fewer grams of volatile organic compounds (VOC) emitted.

Keywords: Sustainable development, Air pollution, Pedestrianisation, Built environment.



Introduction

Pedestrianisation implementation is often at historical and central part of cities, it's an often scheme at development countries because of specific city center conditions like; traffic congestion, environmental quality problems, aesthetics aspects and etc. the effects of this scheme are the improvement of accessibility at central area's land use, the separation of vehicular traffic from pedestrian flows, improvement of pollution emissions due to traffic, improvement at visual pollutions specially regarding to historical structures. Within the framework of this paper the attempt is made to shows the impact of built environment and pedestrianisation on the air quality through comparison of before and after pedestrianisation implementation with regards to streets various typology.

Safe, attractive and accessible spaces are the major components of sustainable cities. The pedestrianisation schemes such as closing streets to vehicular traffic even permanently and during limited times, can help to improve safety, satisfaction and accessibility for pedestrians and also it will improve environmental quality. Pedestrian streets also improve public health through physical activity and active transportation. These schemes help to decrease the number of cars, reduce air pollutant factors like SO₂, NO, CO... and increase the environmental quality level at city center. Finally these methods can create the sustainable, safe and livable city for its residents.

Study Area

The study area is Tehran's city center and oldest core of capital. Tehran city, is consist of 22 municipal districts, with the population of around 9 million. Its climate features a semi-arid climate which is largely defined by its geographic location, with the towering of "Alborz" Mountains at its north direction and the central desert at its south part.

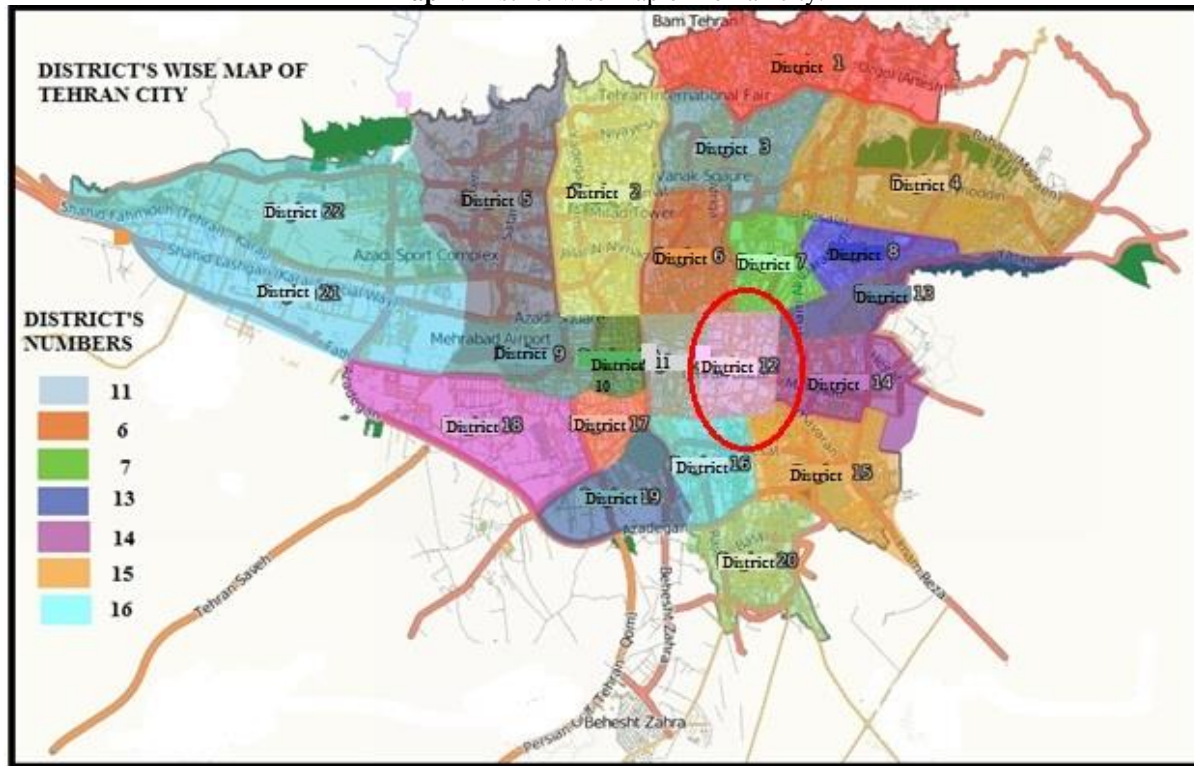
The study area is located in the heart of the capital and within municipal district number 12, with the area of 16.91 (sq.km) also consist of 6 sub districts and 13 Neighborhoods. District 12 is the oldest part and first core of the city that every tourist who come to gain a real understanding of capital has to visit this area. The highest concentration of historical monuments in Tehran is in city center and it's connected to whole directions of capital through subway.

City center is surrounded by seven districts, such as: districts 11, 6, 7, 13, 14, 15 and 16. Also as sample four historical and commercial axes was selected within city center which three of them, "Sepahsalar", "17 shahrivar" and "15 Khordad" streets are pedestrianized axes and at "Laleh zar" street pedestrianisation is not implemented yet.

Map 1. Shows the location of district 12 in the middle of its neighbors.



Map 1. District wise map of Tehran city.



Source: www.en.tehran.ir.

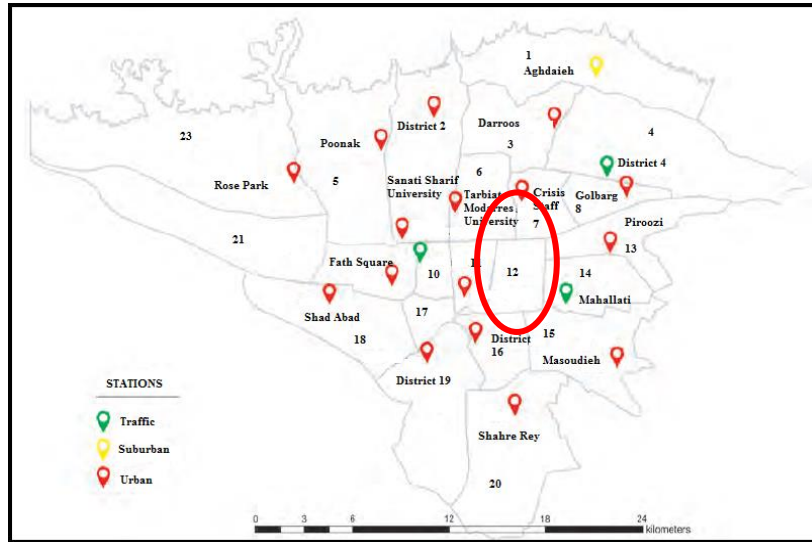
Methodology

To do assessment of pedestrian effectiveness on environmental quality like air quality, the statistical air pollution interpolation model is developed. This interpolation model was used to prepare maps for current air pollution data records. This interpolation model can be classified as a kriging model. At first step, air pollution data were collected from Tehran air quality department at 11 different stations within city center and from surrounding districts at different seasons. Then the site-independent data is evaluated by kriging scheme. Finally, a road network map is added to the kriging interpolation results till four sample streets location and their pollutant level be obvious on final maps. The indicator is optimized independently for the seven pollutants O₃, NO₂, NO_x, SO₂, NO, PM₁₀, CO and NO. As the result, this model is able to account for the local character of the air pollution phenomenon where no monitoring stations are available through entering some points from different air quality stations that are located at surrounding districts and some points near to selected streets. Air quality maps are prepared for the seven mentioned pollutants and compared with standard air quality limits. Finally condition of seven pollutants has compared with previous years of pedestrian construction for each one of four specific streets, at end could see the impact of pedestrian performance and other comprehensive transportation plan of Tehran on air quality and traffic flow at pedestrianized parts of the city center.

Currently there are 20 Air Quality Control stations within Tehran city. At these stations major pollutants are measuring continuously. pollutants like; Carbon dioxides (CO), Sulfur dioxides (SO₂), Ozone (O₃), Nitrogen oxides (NO, NO₂, NO_x), Suspended particles with a diameter less than 10 microns (PM₁₀), Suspended particles with a diameter less than 2.5 microns (PM 2.5). Map6 shows the location of air quality control stations within Tehran city and the location of district number 12.



Map 6. The location of Air Quality Control stations in Tehran city.



Three stations ‘Mahallati’, ‘District 10’ and ‘District 4’ are at ‘Traffic station’ category because are near to crowded and bustling streets. The purpose of the establishment of these streets is concentration investigation of the streets near populated areas. These streets are under the direct influence of street and vehicles.

“Aghdasieh” station is the only suburban station, the purpose for the establishment of this station is to investigate the effects of air contaminants on countryside population and study of photochemical pollution especially ozone. The change trend of the concentration of index pollutants brought in Tehran city at monthly and seasonal period (in comparison with last years) and annual period (in comparison with last years).

Analysis and Results

Data regarding to the level of seven air pollutants was collected from 11 air quality control centers that three of them are located near to sample streets and other eight ones are at surrounding districts and nearby considered samples. Data for each one of seven pollutants was entered at separate year wise tables for November 2015, 2010 and 2005. Then, data was transferred into the GIS software and was analyzed through krigging model, seven maps were prepared for the study area. At below, maps number 7 & 8 relatively show the level of Nitrogen Dioxide (NO₂) at Tehran city and district number 12.

At below, table 1. Shows the decreasing trends from 2010 to 2015 at different air quality centers, specifically at November but during different years.

Table 1. Level of (NO₂) pollutant in different air quality centers at November.

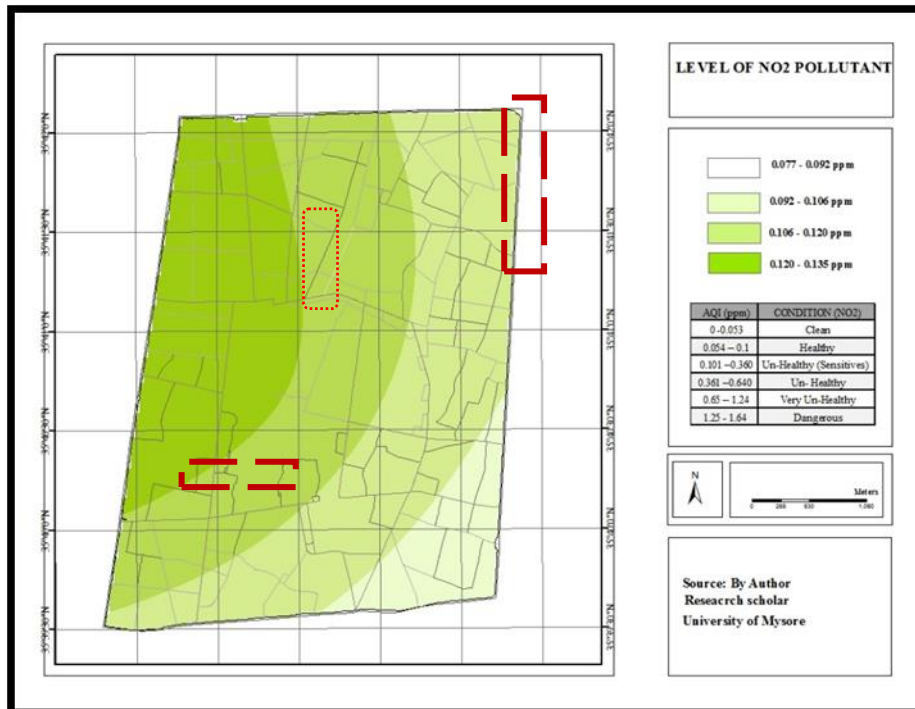
MONTHS	2010	2012	2015
BAZAR	194	136.8	128.3

POINT 3	211	-	132.7
PIRUZI	107.6	117.6	101.8
AMAHALLATI	-	103.3	67.8
DISTRICT 11	-	150.2	139
DISTRICT 16	-	110.7	79.2
DISTRICT 7	-	131.1	77.4
OSTANDARI	-	174.1	112.7
MASUDIEH	-	44.5	24.4
TARBIAT MODARRES	-	-	141.5
RESALAT TOWER	-	137.5	87.5

Source: Air quality control company, Tehran (2015).

Map 2. Shows the level of NO₂ pollutant at city center at November 2015 that some parts of district 12 are at un-healthy condition for sensitive groups. The “Panzdah khordad” (Bazaar) and “Laleh zar” streets are in un-healthy level between 0.106 – 0.120 (ppm) also “17 shahrivar” and “Saf” streets are in the healthy level between 0.092 – 0.101 (ppm). With refer to table 1, the decreasing trend of NO₂ pollutant is obvious at November from 2000 till 2015. So can see the positive influence of pedestrianisation before and after implementation on NO₂ factor.

Map 2. Interpolation map for level of (No₂) within study area during November 2015



Source: Air quality control company, Tehran (2015).

Level of Carbon Monoxide (CO) within study area



Table 2 shows the decreasing trend at the level of Carbon Monoxide (CO) from 2010 to 2015 at different air quality centers, specifically at November.

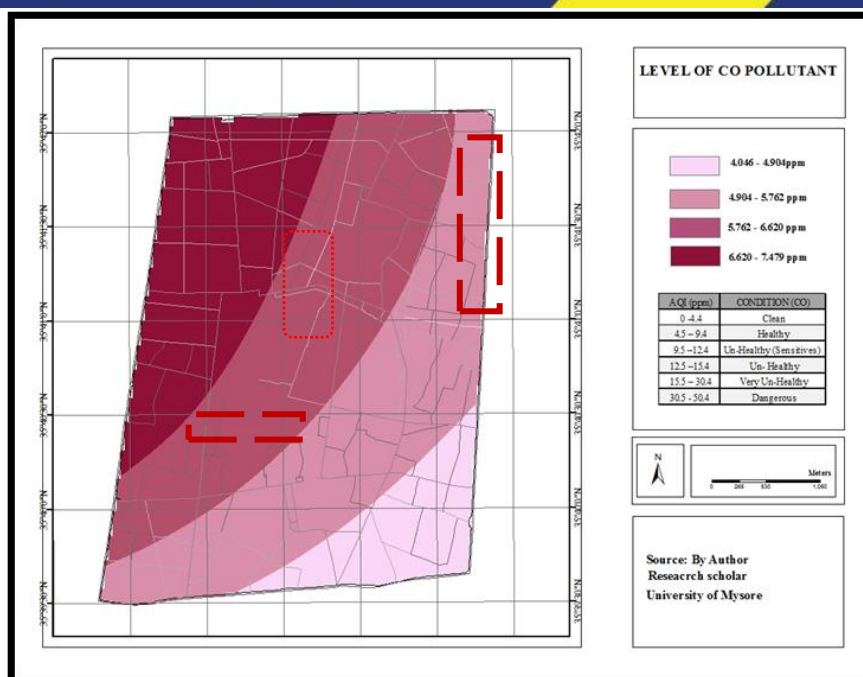
Table 2. Level of (CO) pollutant in different air quality centers at November.

MONTHS	2010	2012	2015
BAZAR	9.3	6.8	6.6
POINT 3	10.4	7.6	7.1
PIRUZI	9.0	-	5.1
AMAHALLATI	-	4.6	3.8
DISTRICT 11	-	8.7	8.1
DISTRICT 16	-	4.7	3.5
DISTRICT 7	-	6.7	4.9
OSTANDARI	-	10.6	9.1
MASUDIEH	-	1.1	0.8
TARBIAT MODARRES	-	-	5.9
RESALAT TOWER	-	6.8	5.6

Source: Air quality control company, Tehran (2015).

District number 12 in case of Carbon Monoxide (CO) is in the healthy condition and has a decreasing trend in compare to before implementation of three streets. Level of (CO) at “Panzdah khordad” and “Saf” streets are in the range of 5.76 – 6.62 (ppm), this number for “Laleh zar” and “Hefdah shahrivar” streets are relatively 6.62 – 7.47 (ppm) and 4.9 – 5.76 (ppm) which are in the healthy range.

Map 3. Interpolation map for level of (co) within study area during November 2015



Source: Air quality control company, Tehran (2015).

Level of Nitrogen Dioxide (NO_x) within study area

According to table 3 there is a decreasing trend at the level of Nitrogen Dioxide (NO_x) from 2010 to 2015 at two stations of “Bazaar” and “Point3”. The information about other stations at 2010 was not available.

Table 3, shows the level of (NO_x) from 2010–2015 specifically at month of November.

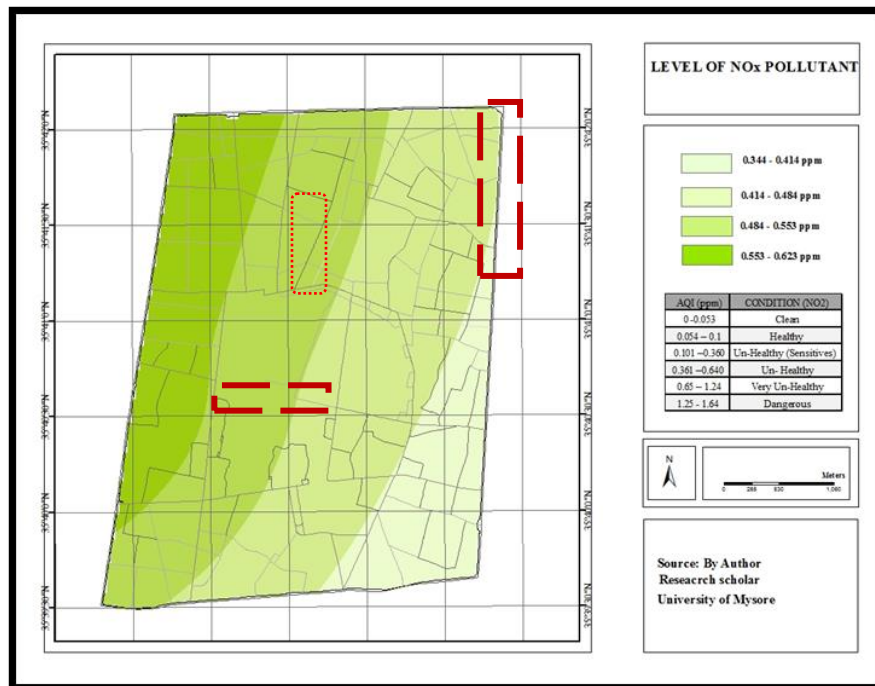
Table 3. Level of (NO_x) pollutant in different air quality centers at November.

MONTHS	2010	2012	2015
BAZAR	739	-	516
POINT 3	841	692	619
PIRUZI	-	440	372
AMAHALLATI	-	360	302.3
DISTRICT 11	-	745	675
DISTRICT 16	-	448	416
DISTRICT 7	-	491	354.8
OSTANDARI	-	840	741
MASUDIEH	-	81.5	57.4
TARBIAT MODARRES	-	-	555
RESALAT TOWER	-	508	428

Source: Air quality control company, Tehran (2015).

Level of (NO_x) in whole parts of district 12 is in un-healthy condition. Range of pollution at “Panzdah khordad” and “Laleh zar” streets are in the range of 0.484- 0.553 (ppm), “Saf” street (0.414 – 0.484 ppm) and “Hefdah shahrivar street (0.344 – 0.414 ppm). Map 6 shows the range of (NO_x) pollutant within district 12 at November 2015.

Map 4. Interpolation map for level of (Nox) within study area during November 2015



Source: Air quality control company, Tehran (2015).

Level of Sulfur Monoxide (SO₂) within study area during November 2015



Same as previous items also table 4 shows the decreasing trend from 2010 to 2015 in different air quality centers, during month of November.

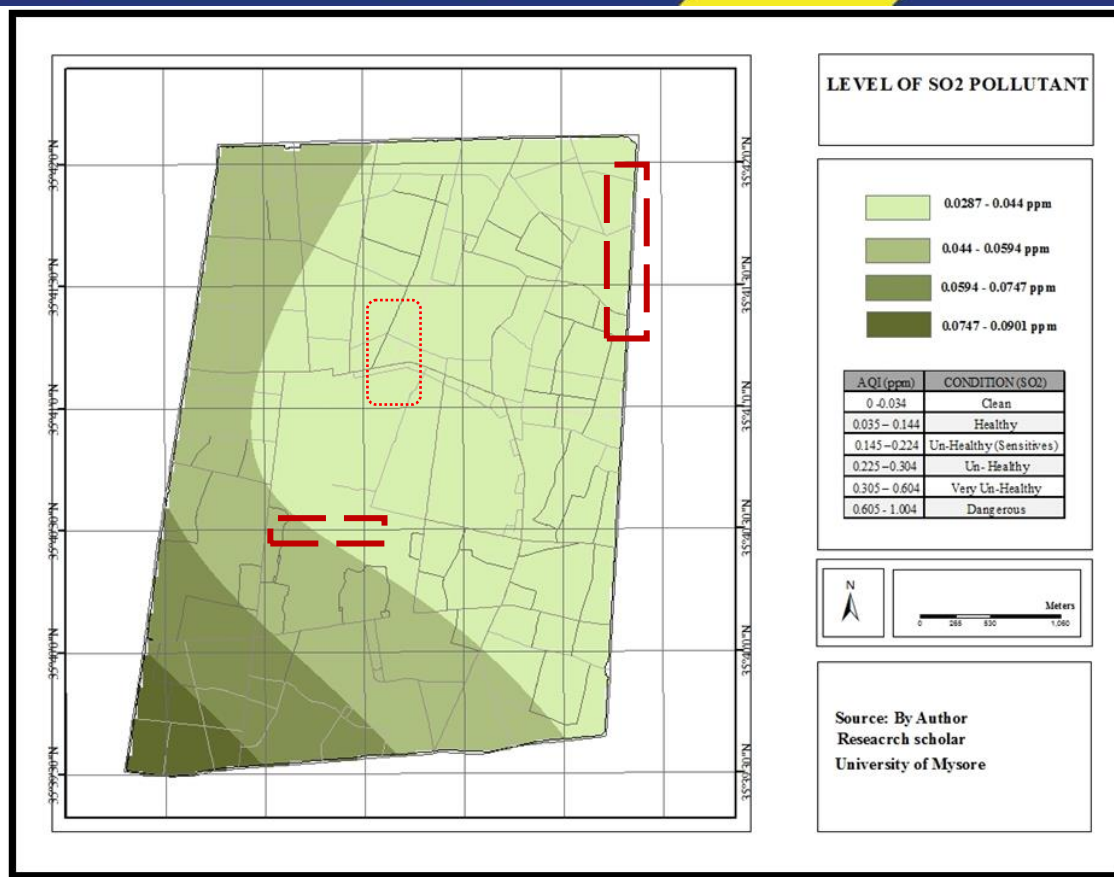
Table 4. Level of (SO₂) pollutant in different air quality centers at November.

MONTHS	2010	2012	2015
BAZAR	55.5	83.9	36.8
POINT 3	67.1	91.5	56.8
PIRUZI	97	39	34.7
AMAHALLATI	-	38.6	26.6
DISTRICT 11	-	99.7	83.4
DISTRICT 16	-	83	125
DISTRICT 7	-	50.7	27.4
OSTANDARI	-	67.5	67.5
MASUDIEH	-	18.5	7.0
TARBIAT MODARRES	-	107	99.2
RESALAT TOWER	-	47.6	30.1

Source: Air quality control company, Tehran (2015).

District 12 is in the clean and healthy level regarding to (SO₂) pollutant. Whole of four mentioned streets are in the clean level in the range of 0.0287 - 0.044 (ppm) and the other parts of district are in the healthy situation. Same as other pollutant level of (SO₂) pollutant at 2015 have a decreasing trend in compare to time before implementation of the project at 2007.

Map 5. Interpolation map for level of (so₂) within district 12 during November 2015



Source: Air quality control company, Tehran (2015).

Level of Ozone (O3) within study area during November 2015

Below table shows the decreasing trend for the parameter of ozone from 2010 to 2015 at different air quality centers, at November 2015.

Table 5. Level of (O3) pollutant in different air quality centers at November.

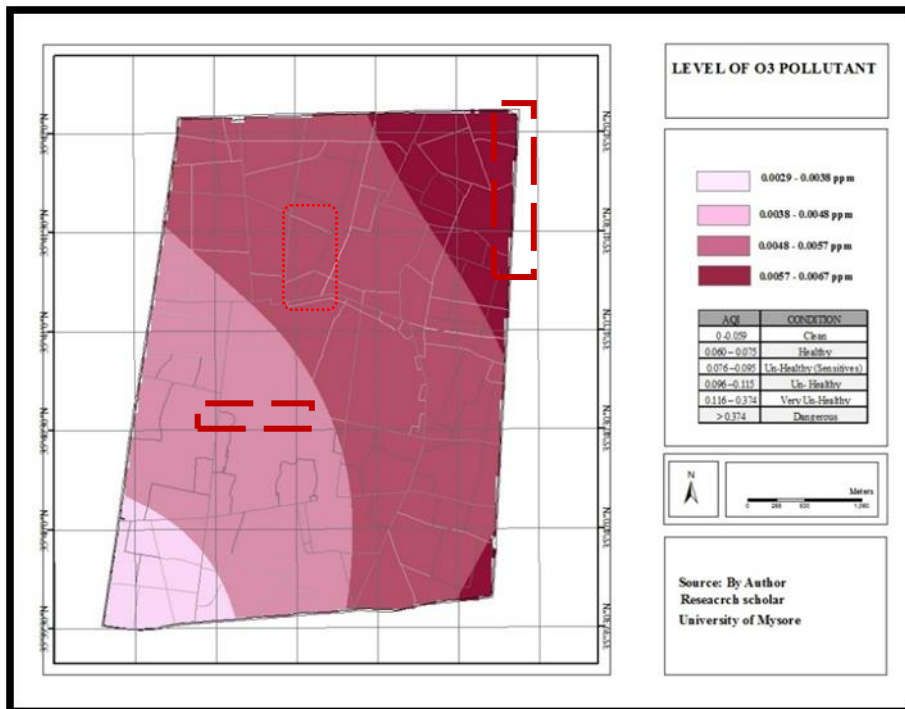
MONTHS	2010	2012	2015
BAZAR	15.4	6.0	4.6
POINT 3	14.4	5.7	4.5
PIRUZI	36	10.1	8.5
AMAHALLATI	-	9.0	6.6
DISTRICT 11	-	5.7	4.0
DISTRICT 16	-	9.5	1.2
DISTRICT 7	-	10.1	8.2
OSTANDARI	-	6.6	4.4
MASUDIEH	-	26	19.7
TARBIAT MODARRES	-	11.8	6.9
RESALAT TOWER	-	10.4	7.4

Source: Air quality control company, Tehran (2015).

This map shows that the level of ozone pollutant is under danger limit, it means is below 0.076 (Un-Healthy limit) which means, district 12 is in the healthy situation. Level of (O₃) at “Panzdah khordad” street (Bazaar) is between 0.0038 – 0.0048 ppm and for “Saf” street is in the range of 0.0048 – 0.0057 ppm and for the “Hefdah shahr river” street which has implemented about three years, the level of (O₃) is in the range of 0.0057 – 0.0067 ppm. Which whole of them are in the healthy condition.

Same as other pollutant level of (SO₂) pollutant at 2015 have a decreasing trend in compare the time before pedestrian implementation project at 2007.

Map 6. Interpolation map for level of (o3) within district 12 during November 2015



Source: Air quality control company, Tehran (2015).

Level of Nitrogen Monoxide (NO) within study area during November 2015

Table No.6. Shows the decreasing trends for the parameter of ozone from 2010 to 2015 at different air quality centers, at November 2015.

Table 6. Level of (NO) pollutant in different air quality centers at November.

MONTHS	2010	2012	2015
BAZAR	542	482	460
POINT 3	630	734	544
PIRUZI	510	323	270

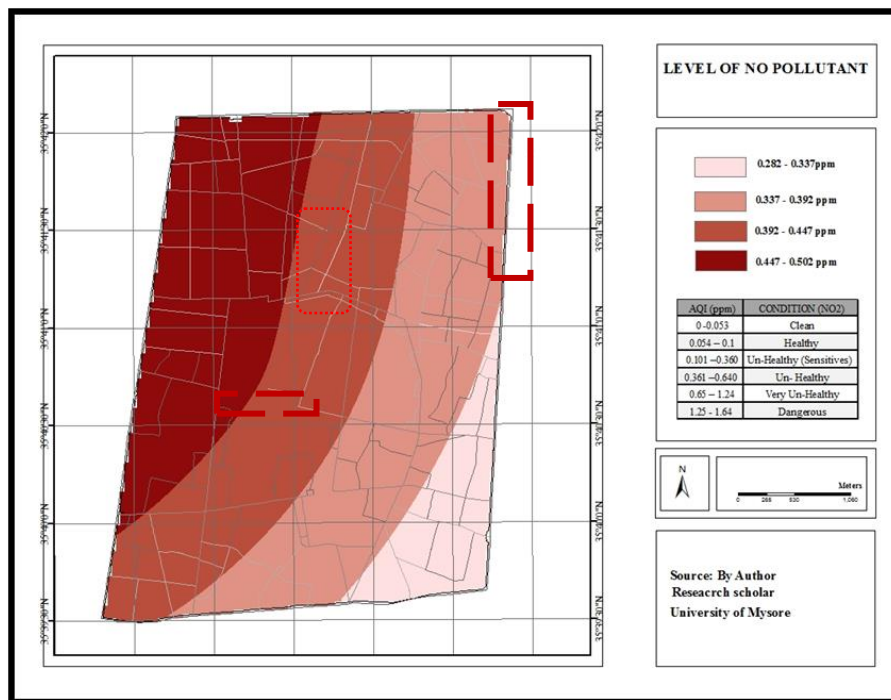


AMAHALLATI	-	257	234.5
DISTRICT 11	-	595	536
DISTRICT 16	-	338	336.7
DISTRICT 7	-	360	277.5
OSTANDARI	-	666	631
MASUDIEH	-	37	33
TARBIAT MODARRES	-	461	414
RESALAT TOWER	-	370	340.6

Source: Air quality control company, Tehran (2015).

Level of Nitrogen Monoxide (NO) pollutant in district 12 is in the un-healthy condition, but its trend have a decreasing process from 2007 till 2015. “Panzdah khordad” and “Laleh zar” streets are in the un-healthy condition (0.282 – 0.337 ppm) and the other two streets are in un-healthy situation for sensitive groups in the range of 0.337 – 0.392 (ppm).

Map 7. Interpolation map for level of (no) within district 12 during November 2015



Source: Air quality control company, Tehran (2015).

Level of Carbon Monoxide (PM10) within study area

Suspended particles (PM10) mostly produce because of industries activities and from automobile exhaust. Fortunately this air pollution factor also have a decreasing trend form 2007 till 2015 at district and its recent condition at study area is in the healthy level.



Table No.7. Shows the year wise decreasing trends for concentration of suspended particles at different stations within district 12 and its surrounding districts from 2005 to 2015 only at month of November.

Table 7. Level of (PM10) pollutant in different air quality centers at November.

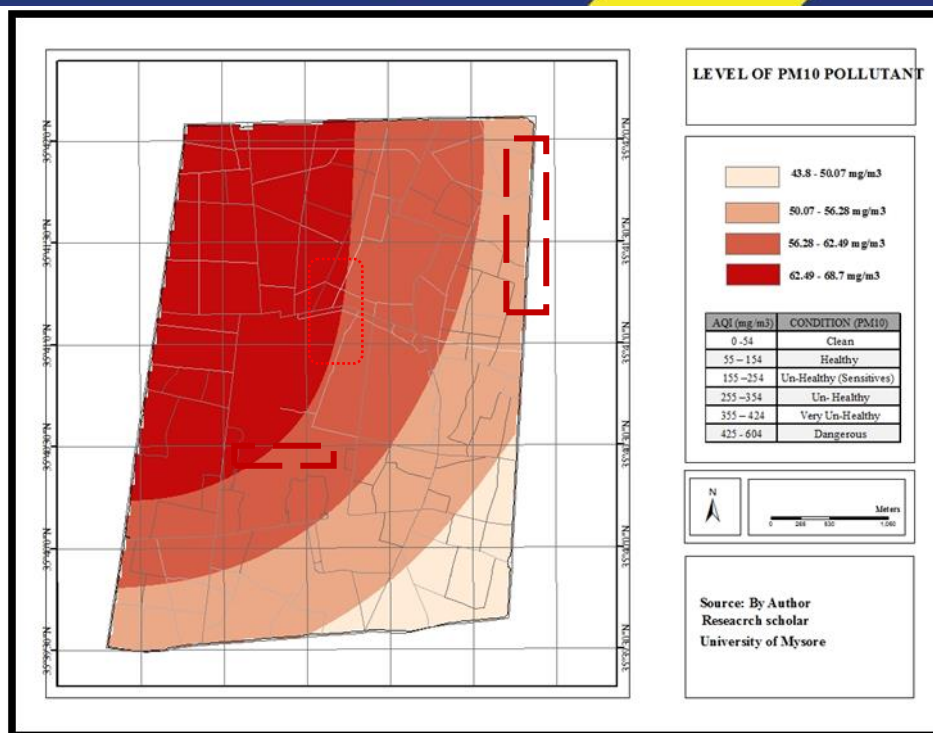
MONTHS	2005	2010	2012	2015
BAZAR	105.2	8.8	63.6	70
POINT 3	103.5	8.7	91.8	79.4
PIRUZI	-	-	96.9	52.6
AMAHALLATI	-	-	41.7	36.5
DISTRICT 11	-	-	75.5	62.8
DISTRICT 16	-	-	43.9	36.3
DISTRICT 7	-	-	57.4	41.1
OSTANDARI	-	-	101.5	81.3
MASUDIEH	-	-	16.3	19.9
TARBIAT MODARRES	-	-	107.9	62.3
RESALAT TOWER	-	-	72	56.4

Source: Air quality control company, Tehran (2015).

Level of suspended particles around “Panzdah khordad” and “Laleh zar” streets is in the range of 62.4 – 68.7 (mg/m³), 56.28 – 62.4 (mg/m³) for “Saf” street and the same range for “Hefdah shahrivar” street is 50.07 – 56.28 (mg/m³).

As you see, whole of the air pollutant factors had a decreasing trend from 2007 till 2015, so this shows that implementation of pedestrian streets and other policies like consideration of traffic plan for vehicles, dominant use of public transportation (such as metro or bus) for transportation within district 12, replacement of bus and taxies with new ones and transfer of workshops and industries to the urban suburb could help to reduce the volume of traffic and air pollution during 2007 – 2015.

Map 8. Interpolation map for level of (pm10) within district 12 during November 2015



Source: Air quality control company, Tehran (2015).

Conclusion

Despite the increasing of population and number of vehicles at recent decade but air pollution, specifically seven mentioned pollutants had a decreasing trend during 2007 till 2015. At the first glance can see conflict between these two phenomenons. At recent years, municipality of Tehran with different plans and projects in Tehran city especially at central part of city could control the increasing process of air pollution. Projects and plans such as; traffic plan at traffic jams and city center, One-way streets, Underpasses, metro lines, pedestrianisation projects at different part of Tehran city, restrict the entry of vehicles particularly to bazaar and historical parts of the city and etc.

The decreasing trend of air pollution specifically around central part of the city and implemented pedestrianisation streets, shows the positive result of this plan on environmental quality and air quality.

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