Dung Truong

Distribution of Air and Noise Pollution Caused by Traffic Activities within Ho Chi Minh City Central Area and Forecasting Future Pollution Levels

Metropolia University of Applied Sciences

Bachelor's degree of Engineering

Environmental Engineering

Bachelor's Thesis

November 21th, 2019

Metropolia
University of Applied Sciences

Author(s) Title Number of Pages Date	Dung Truong Distribution of Air and Noise Pollution Caused by Traffic Activities within Ho Chi Minh City Central Area and Forecasting Future Pollution Levels 41 pages 21th November, 2019
Degree	Bachelor of Engineering
Degree Programme	Environmental Engineering
Specialisation option	Sustainable Development
Instructor	Ismo Halonen

Consciousness of air pollution has increasingly garnered attention from people over the world; it has been recognized as targets of health, energy and cities, which are known as SDG3, SDG7 and SDG11 in the World Sustainable Development Goals (SDGs) by WHO since 2015. In Ho Chi Minh city (HCMC), Vietnam, citizens are suffering from the effects and consequences of health that are caused by air pollution. This situation has progressively become serious.

The cause of pollution is believed to be the rapid growth in population within HCMC, causing expansion in the number of traffic vehicles, industrial facilities and construction sites. However, the slowness in urbanization to meet the increasing demand of the city, is also an indirect cause of air pollution.

This thesis concentrates on observing and analyzing air monitoring data in HCMC, with respect to the following indicators of pollution types: total suspended particles (TSP), carbon monoxide (CO), nitrogen dioxide (NO2) and noise pollution, measured at 9 monitoring stations from 2007 to 2017 within HCMC central area. The goal of this thesis was to illustrate air pollution in HCMC and also to indicate that environmental protection should consider humans.

Keywords	air pollution, time series analysis, IDW interpolation, geographic information system

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1 Introduction

Air pollution is one of many significant impacts on the environment as a result of industrialization and urbanization. In Vietnam, air pollution is believed to be a leading impact, affecting human health. According to World most polluted countries 2018 [1], Vietnam was ranked as the 17th country that has the average concentration of PM2.5, particulate matter less than 2.5 micrometers, of 32.91 µg/m³. In addition to this, the country's two largest cities, Hanoi and HCMC, are also ranked the 18th and 28th most polluted country for its performance in Air Quality index (AQI), 97 and 77. Although HCMC is likely to have a better air quality than Hanoi, people in both cities are living in an environment without guarantee of health.

HCMC is known as the largest city in Vietnam, it plays a crucial part, in which significantly contributes to the national economy, as a political, cultural and educational centers. Being one of the largest centers of Southeast Asia, this city has a large transportation system not only connecting national cities, provinces but also being an important international gateway. During the period from 1995-2015, HCMC population increased 78%, the number of businesses also accounted for one third of the total number of businesses and the city attracted the most foreign direct investment over the country.

However, the pioneering spirit and leading position of the City are on the decline. The cause of this situation is due to the existence of many development bottlenecks at the local, regional and national level. Like many fast-growing cities, HCMC is facing many inadequacies and problems in urban planning and management. In a report submitted to the Politburo in 2012, the City Government frankly admitted: "Urban planning and management has not kept pace with development and there are many weaknesses." [2]

The concentrated development by region puts great pressure on the environment and the quality of life in large cities like HCMC and Hanoi. This thesis aims to analyze the distribution of emissions and noise pollution caused by traffic activities within HCMC central area, and to not only show a comprehensive picture of the pollution levels in HCMC, but also reflect on its impacts on the quality of life of people living in the city.

2 Ambient air quality and noise issue in Ho Chi Minh city

2.1 History of formation

The city was formed and named as Gia Dinh at the end of 1600s by Nguyen Huu Canh. In 1945 the French entered Indochina; to serve colonial exploitation, Gia Dinh government was renamed Saigon. Saigon quickly followed the development trend of the world and became one of the two most important cities in Vietnam, dubbed the "Pearl of the Far East".

Saigon became the capital of the Republic of Vietnam and was known as one of the important cities of Southeast Asia in 1954 before its collapse in 1975. The Vietnamese territory was then completely unified.

On 2 July 1976, the National Assembly of Vietnam consistently changed the name of Saigon to Ho Chi Minh City.

Currently, TP. HCM City consists of 24 districts with 322 wards, communes and towns.[3]

2.2 Research area

HCMC is located in the region between the Southeast and the Southwest of Vietnam. This city today consists of 24 districts, total area of 2,095.06 km². A map of HCMC territory is shown in Figure 1.

Figure 1 Ho Chi Minh City Territory

The research area consists of 19 urban districts; namely District 1, District 2, District 3, District 4, District 5, District 6, District 7, District 8, District 9, District 10, District 11, District 12, Binh Thanh, Binh Tan, Thu Duc, Tan Phu, Tan Binh, Phu Nhuan and Go Vap.

District 4 is the smallest district, 4.18 square kilometers in area, while area of District 9 is 114 square kilometers, which is the largest district area. A map of the HCMC central districts is shown in Figure 2.

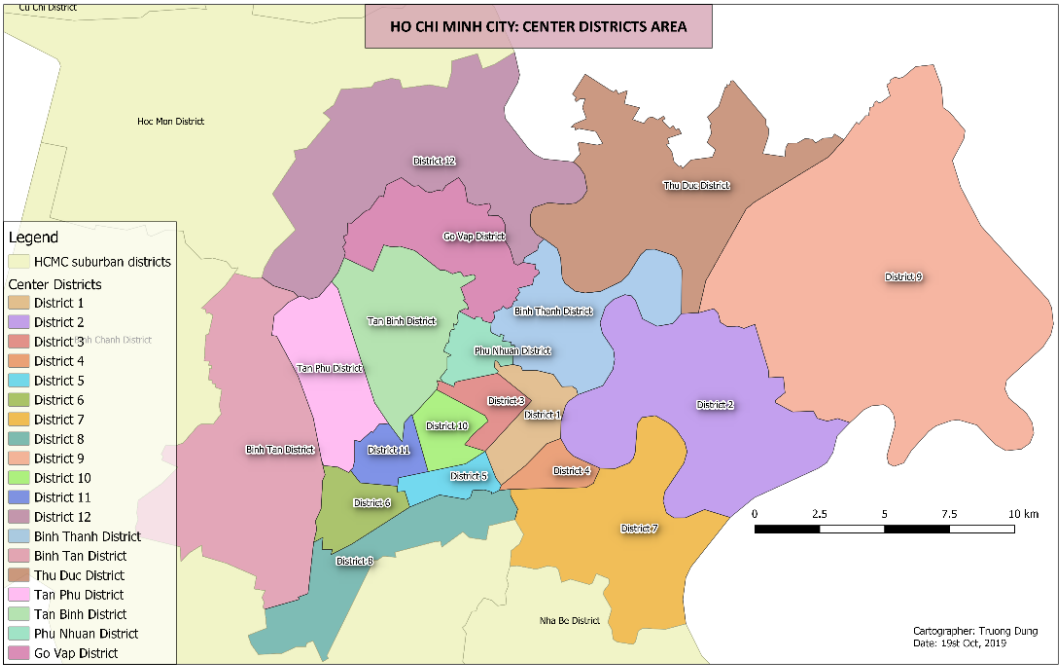


Figure 2 Central districts within HCMC borders

2.3 Source of pollution

2.3.1 Population

According to the official census results on April 1, 2009, the city population is 7,162,864 people, which accounts for 8.34% of Vietnam's population. The average population density is 3,419 people / km². Population distribution by districts is shown in Figure 3.

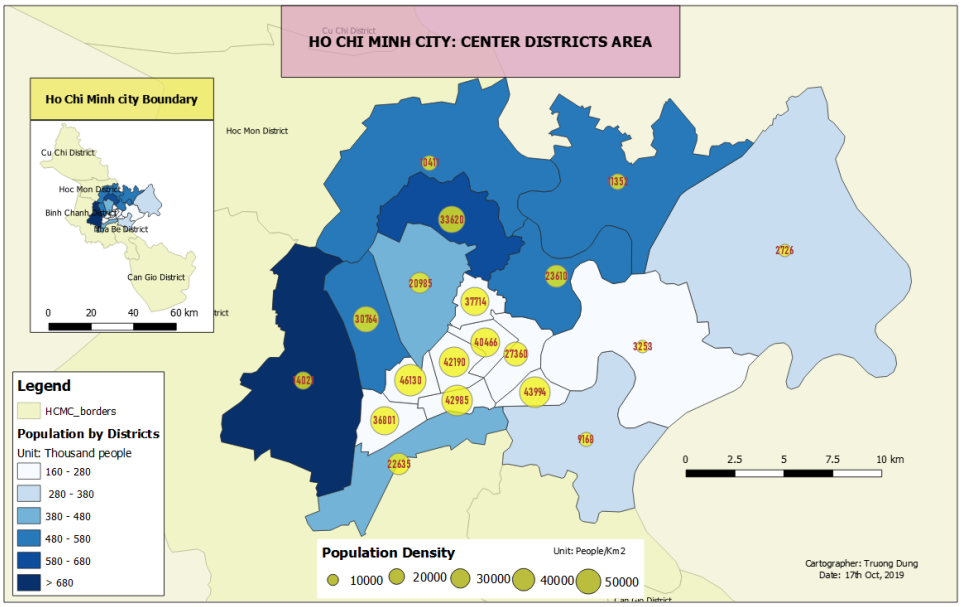


Figure 3 Population by HCMC central districts

Figure 3 shows the population distribution of HCMC center area including population in every center district as well as its population density. The figure indicates that a large amount of population lives in Binh Tan district with more than 680 thousand people; however, it is also one of the districts that has the lowest population density, along with districts 9, 7, 12 and Thu Duc. Districts 1,2,3,4,5,6,10,11 and Phu Nhuan have lower population, range from 160 to 280 thousand people, except for District 2, the other 8 districts, however, show very high population density. Especially, average population in District 11 is 46130 people in every square kilometer, followed by districts 4 and 5 with an average population of 43994 and 42985 people in every square kilometer.

By 2019, the city's population will increase to 8,993,082 people and it is also the place with the highest population density in Vietnam. However, if unregistered residents are counted, the actual population of this city in 2018 was nearly 14 million [4]. The explosion of population in HCMC could be considered as an indirect cause of major environmental pollution including air pollution. The rapid increase of the population gives the city a plentiful labor force, however, it also entails a burden on urbanization and the environment.

Air pollution in HCMC is mainly caused from three main sources: transport, industry and construction. In addition, HCMC has about 1,000 large-scale factory factories and tens of thousands of small-scale manufacturing establishments located in alternating with residential areas [5]. Emissions from manufacturing activities cause air pollution affecting

not only surrounding area's air quality but also life quality of people living within the polluted area. In addition, construction activities take place throughout the city and almost operate round the clock causing air pollution and noise directly affecting the lives of people.

2.3.2 Growth in Number of Vehicles

2.3.2.1 Vehicles

The number of motorcycles sold in the Vietnamese market in 2018 reached 3.39 million, an increase of 3.5% compared to last year's figures. Vietnam is continuously one out of five countries using most motorcycles and motorbikes in the world [6]. Motorcycles and mopeds are considered the most popular because they offer convenience in mobility at a reasonable price and with flexibility in time. Number of vehicles within HCMC territory is showed in figure 4.

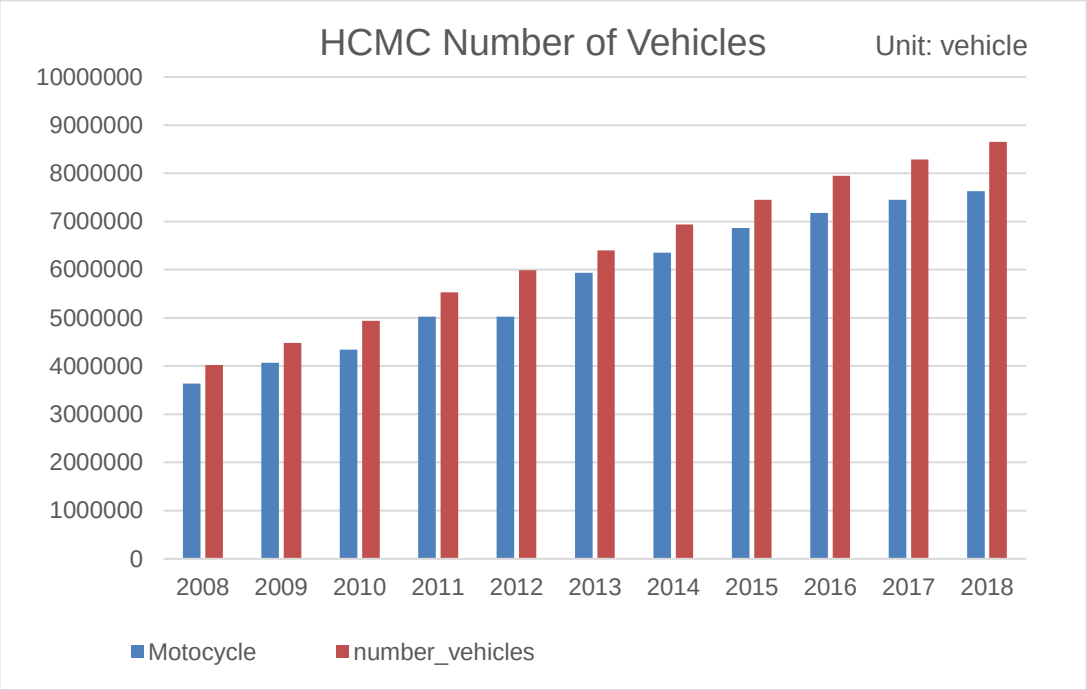


Figure 4 Annual number of vehicles and motorcycle in HCMC [25]

According to statistics collected from HCMC Statistical Department, in 2018 the city has 8.6 million in number of registered vehicles, which is 2.14 times more the number of vehicles in compare to 2008. Motorcycle vehicles account for 88% total number of transport vehicles; there was also an average of 3694 motorcycles and mopes in 2018 in every square kilometer. On the other hand, this means an average of 1.13 people will own a motorbike. As a result, it is clearly seen that motorcycles are the major source of

emission from transport activities causing air pollution. By looking at the numbers, we can also conclude that at least 88% of HCMC population is not either considering public transport as an option or satisfied with the city public transport service.

The increase in population is putting HCMC under great pressure to develop the transport infrastructure. The number of vehicles has increased rapidly during the past 10 years, causing the transport infrastructure in HCMC to be paralyzed due to frequent traffic congestion. Emissions and smog from a variety of vehicles directly affect the environment.

2.3.2.2 Transport infrastructure

The city targets “as long as 1 km2 of land, there must be at least 10 km of roads” [26]. However, HCMC can only reach 20% of the target, for instance 1 km2 of land has only more than 2 km of roads.

Mr. Ngo Hai Duong, Head of Department of Road Traffic Infrastructure Management, Department of Transport, reported that including internal roads in projects, residential areas, the total roadway surface area of the current HCMC is about 37.7 million m2. Nonetheless, the area of sidewalks is already accounted for about 15.5 million m2 in total roadway area [7]. “According to statistics, the roads of HCMC are 4155 km in length; however, roads having its widths of more than 7 m only account for 1716 km. The number of roads with a width of less than 7 m account for 58.7% “, Mr. Duong informed.[7]

Figure 5 is illustrating the comparation between number of vehicles and total roadway area in HCMC.

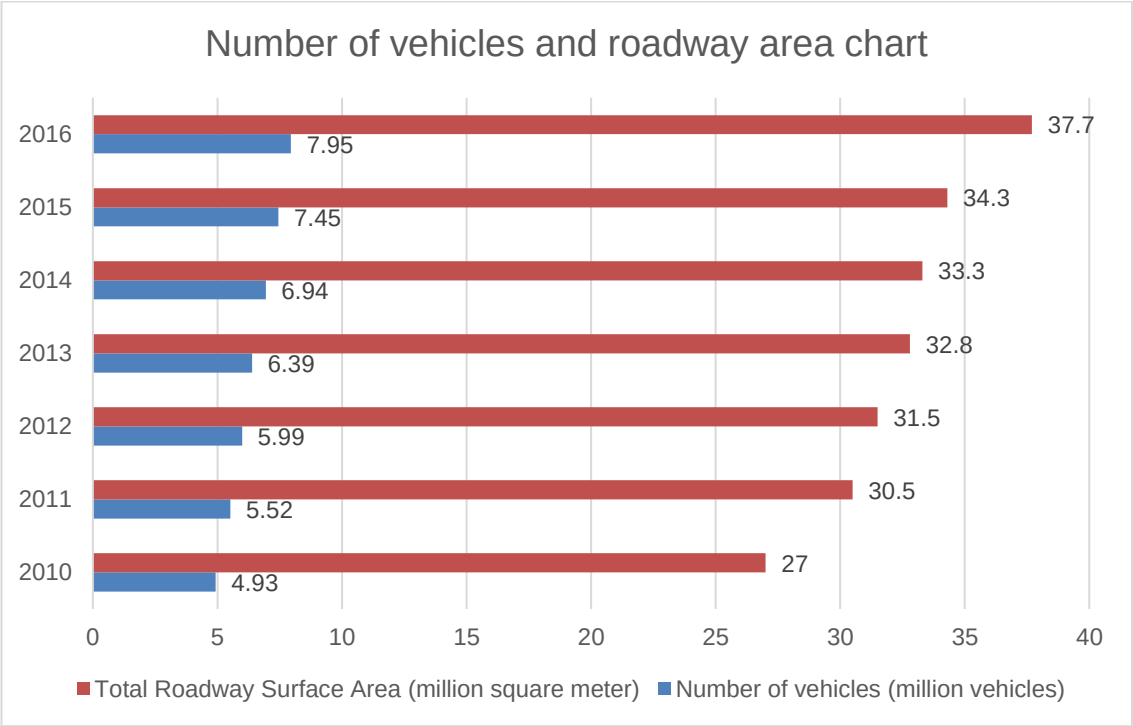


Figure 5 HCMC total roadway area compared to number of vehicles within the city [25]

The large number of vehicles not only causes frequent traffic congestion, but also becomes a source of air pollution owing to exhaust from the engine, friction between wheels and roads or breaks produce a significant volume of emissions, for example, GHG, NOx, CO and particulate matter. Moreover, noise pollution from traffic congestion also directly affects the quality of life of people living in the city.

According to the Department of Transport [7], traffic congestion at rush hours in HCMC often occurs on the roads leading to the center, the entrances to the airport, seaports and roads in the central area. "Roads have become overloaded, vehicles are getting increasingly crowded, traffic speeds are decline and travel becomes difficult", the Department of Transport spoke [7].

Figure 6 displays 37 traffic congestion points within HCMC central area in 2017.

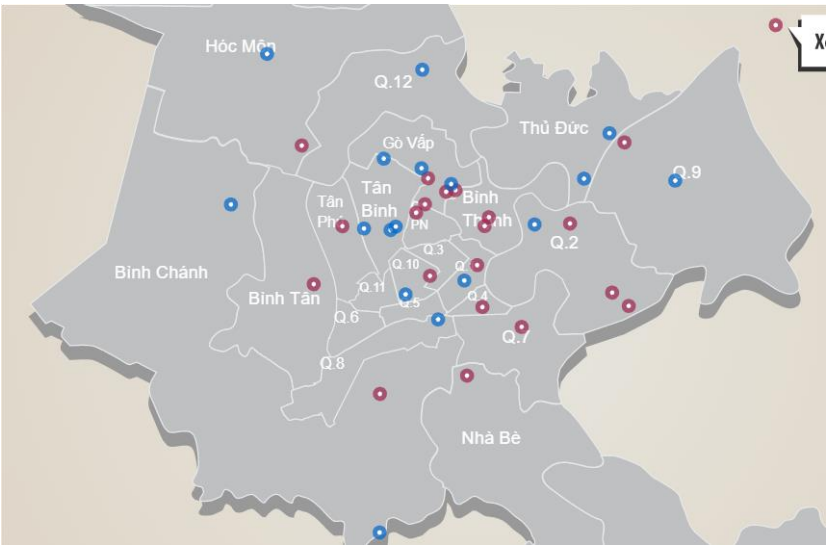


Figure 6 37 traffic congestion points, blue points are congestion points expected to be eliminated by 2018 [24]

According to Mr. Ngo Hai Duong, Head of the Department of Road Traffic Infrastructure Management, Department of Transport from the beginning of 2017 [24], has identified 37 points at risk of congestion and has implemented many solutions. Traffic at many points has been significantly improved; however, there were other traffic points within the area start having risk of traffic congestion. A series of arterial roads, as well as major intersections in HCMC, often suffer from congestion, traffic congestion affecting the environment.

In the past, because of the eagerness to develop public transport and reduce demand for personal vehicle, HCMC had invested massively in thousands of buses in a short time. As a result, most of the buses invested for the city public transportation are large compared to the center roadway. City buses occupy much space on the road; moreover, they neither achieve high efficiency nor attract passengers.

Although HCMC has launched many campaigns to encourage people to take the bus, with a commitment to renovating the appearance to the inside quality, public transport system in HCMC still has many shortcomings, such as buses exploiting their right to enter the two-wheel drive lane and scrambling to catch passengers, which makes the majority of citizens not want to use the service. Among many causes for decreasing bus goers, occasional punctuality due to traffic jams accounts for 80%. Thus, people prefer other vehicles to public transports. [8]

2.3.2.3 Air pollution caused by traffic activities

A series of arterial roads, as well as major intersections in HCMC, often fall into congestion. This is an obvious scenario; the rapidly increasing population in the city, and the failure of public services to satisfy travel demand of commuters have led to an increase in the number of private vehicles. Meanwhile, the city's infrastructure development was slow causing traffic congestion. As a result, traffic congestion has become the major source of emissions. Transportation experts list four main causes of traffic congestion in big cities like HCMC:

The first reason is drivers' lack of compliance with the Road Traffic Law; drivers passing red lights are not uncommon in Ho Chi Minh City, not mentioning encroachment on the sidewalk and lanes, not only cause congestion but also easily cause accidents. Nevertheless, a driver must pass the Road Traffic Law test in order to get a driving license [9].

The second reason is the large gap between available transport infrastructure and the increasing in individual vehicles in traffic; transport infrastructure, within the city, merely meets 30% the demand of traffic activities. Furthermore, traffic infrastructure consists of many narrow and degraded roads while construction process was also slow and inactive.

The third cause was mentioned as the weakness of public transport system. HCMC should set goals to develop not only public transport network but also the service quality in order to decrease either traffic jams or two-wheels vehicles.

Occupation of sidewalks and roadways for trading and business purposes of local retailers was considered as the fourth reason. This not only causes traffic congestion, but also jeopardizes both the seller and the participant.

2.3.3 Industrial production and construction activities in HCMC

2.3.3.1 Manufacturing activity

Apart from the large volume of air emissions from vehicles participating in traffic, HCMC has about 1,000 large factories and over 10,000 of small manufacturing establishments alternating with residential areas in the districts. Ho Chi Minh is Vietnam's most industrialized city; therefore, it is not surprising that the number of manufacturing facilities as well as production activities within the city is increasing every year.

Number of manufacturing enterprises in HCMC from 2012 to 2016 is displayed in figure 7.

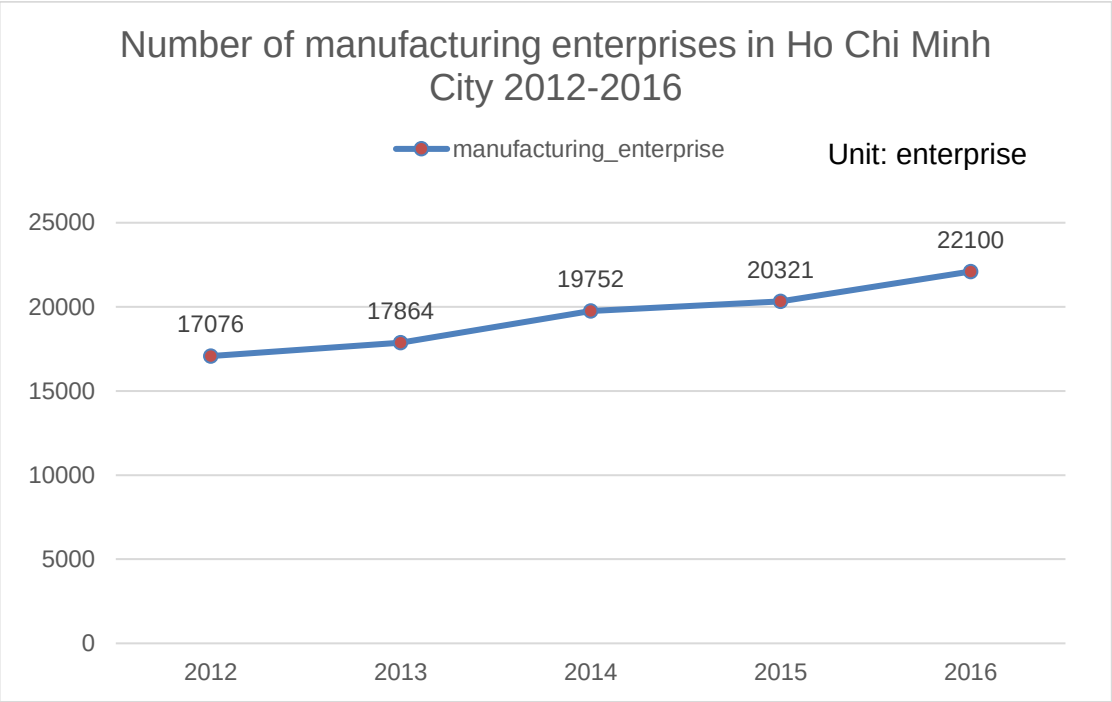


Figure 7 Number of manufacturing enterprises in Ho Chi Minh City 2012-2016 [25]

According to Figure 7, the number of manufacturing enterprises within the HCMC territory raised 30% within 4 years from 2012 to 2016.

As reported by HCMC Department of Statistic, there are 40 different industrial estates within the city, excluding small private industrial facilities located among residential areas. Total industrial area is 83.95Km2, accounting for 4,8% of total area of HCMC.

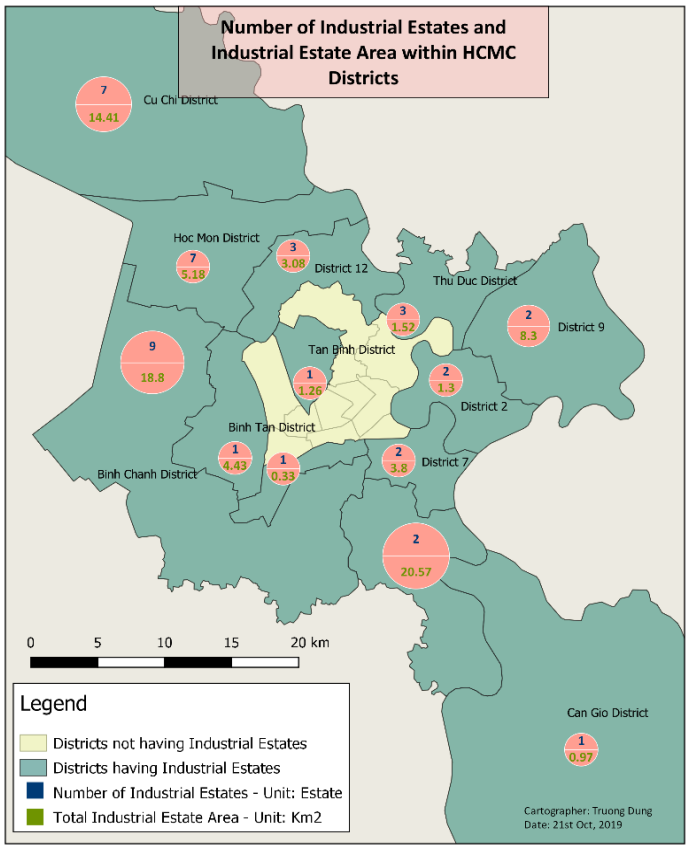


Figure 8 Number of industrial estates (upper number) and their area within HCMC territory [25]

Industry is the key economic sector of HCMC, contributing 30% of total national budget revenue. The city's industrial manufacturing production accounts for about 30% of the national industrial value and attracts a large amount of FDI capital for the whole country. In addition, these major industries, such as thermoelectricity, metal processing, cement production, chemical production, construction material production, and food processing, are considered to become the principal focus on which the city planning to develop in the recent decades. Other characteristics of industries in HCMC are the following:

- First, ancient technology and backward equipment are still used,
- Second, demand on raw material and fuel is stated to be immense,
- Third, infrastructures of the industries are still located in the residential area,
- And lastly, exhaust treatment facilities are not available. [8]

As a result, industrial manufacturing activities in HCMC cause various environmental problems; factories operating throughout day and night creates a high frequency of noise, seriously affecting the living quality of people in the surrounding area.

2.3.3.2 Residential Construction

The rapidly increasing population has led to a great demand for accommodation. Construction in residential areas, therefore, also increase considerably each year; old houses are being upgraded and new buildings in diverse scales, are constantly being constructed to meet the housing needs.

Figure 9 shows that the number of constructions within HCMC residential areas has seen a continuous growth of 28,5% in 4 years, from 2014 to 2018. It appears that construction sector has produced particulate matter of multiple sizes due to various processing activities, for instance, construction materials, transportation, and dissemble constructions.

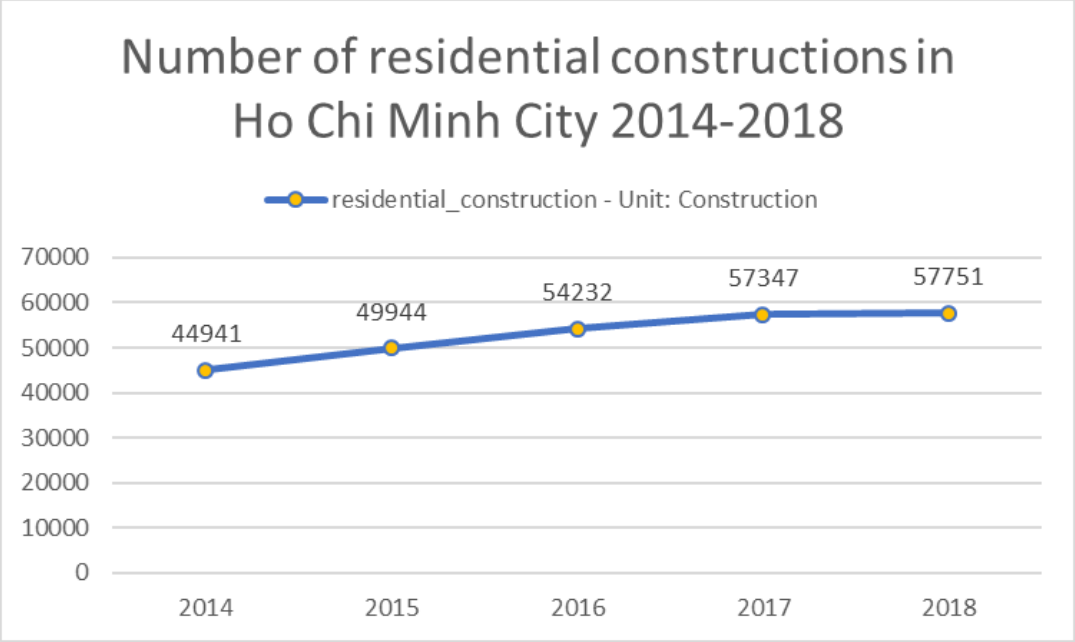


Figure 9 Annual residential constructions occurs in HCMC 2014 – 2018 [25]

2.3.3.3 Environmental violation

Regardless of continuous development in industrialization and modernization, HCMC has faced many difficulties in managing the environmental problems related to manufacturing activities of enterprises within the territory.

Number of environmental violation cases in HCMC from 2014 to 2018 in illustrated in figure 10.

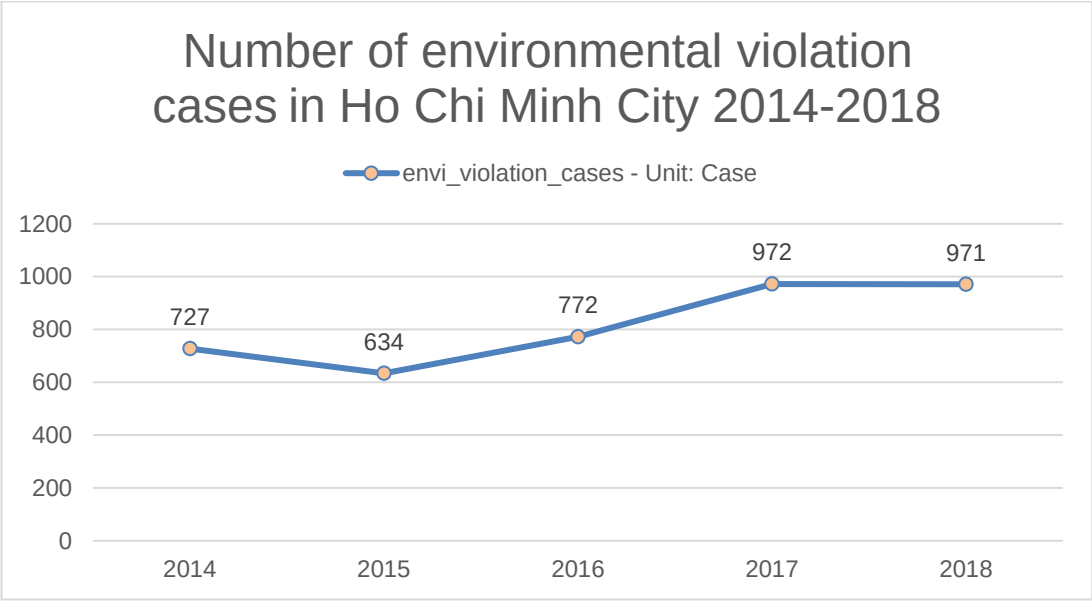


Figure 10 Annual environmental violation cases in HCMC 2014 - 2018 [25]

Industrial production in HCMC largely focuses on manufacturing mechanics, electronics, chemicals - rubber - plastics, construction materials and food processing [10].

The environmental pollution violations, according to Figure 10, included not only industrial emissions but also different violations related to the environment, both of which either directly or indirectly affected the quality of surrounding atmosphere in HCMC. A large number of industrial manufacturing enterprises resulted in the city's difficulties in comprehensive managing.

2.4 Types of pollutants

2.4.1 Carbon dioxide (CO2)

Carbon dioxide is accounting for the majority of greenhouse gases (GHG), which are released to the environment and causing serious climate change to the Earth. This emission is generated when fuel combustion occurs, usually in vehicle engine. HCMC owns a large number of vehicles in the city, thus facing large amount of annual GHG. [15]

2.4.2 Hydrocarbons (HCs)

HCs is emitted to the environment during any incomplete combustion. This pollutant plays an important role, together with volatile organic compounds (VOCs), in forming both toxic ozone pollutant on the Earth's ground surface and photochemical smog. [15]

2.4.3 Carbon monoxide (CO)

Carbon Monoxide (also known as CO) is a colorless odorless poisonous gas; when being inhaled into the body, it prevents the red blood cells from absorbing oxygen. A normal person who is exposed to CO in a long period could be ill or even dead.

Carbon monoxide is generated in different sources; however, the majority of carbon dioxide comes from incomplete combustion of fossil fuels, such as oil, gas, gasoline or coal. In HCMC, a high concentration of CO in the atmosphere occurs, mainly because of emissions coming from transport activities, industrial manufacture, and residential construction activities. [15]

2.4.4 Nitrogen dioxide (NO_2)

When combustion occurs in an engine burning fuel, nitrogen is released, combining with oxygen atoms to generate nitric oxide (NO). Nitric oxide does not threat human's health at normal concentration; however, it will further combine again with oxygen during combustion to generate nitrogen dioxide (NO2), which is dangerous. Nitrogen dioxide and nitric oxide are commonly recognized as oxides of nitrogen (NOx)

NO_2 is a pink-brown gas; its odor can be detected at a concentration of 0.12 parts per million. NO_2 absorbs sunlight and produces a series of photochemical reactions threatening human health when exposed to it in a short period. In HCMC, majority of NO_2 are from motor vehicles exhaust and industrial manufacture.

Indeed, the higher levels of nitrogen dioxide people breathe in, the higher tendency of them facing respiratory problems. Owing to nitrogen dioxide affecting on the lining of the lungs, immunity could be weakened leading to lung infections. In addition, wheezing, coughing, colds, flu and bronchitis can occur.

Moreover, people with asthma, especially children and older people with heart disease, could bear the brunt of frequent and more severe attacks when exposed to intensive levels of nitrogen dioxide. [11]

2.4.5 Sulfur Dioxide (SO_2)

SO_2 is a colorless inorganic gas, heavier than air and is an acid oxide. SO_2 is generated when burning fuels and other materials, for example, coal, gas, wood and other organic substances such as dry manure and litter. When the SO_2 concentration reaches 5 parts per million, the pathological syndromes of the exposed person begin to appear.

SO_2 is considered a significant environmental hazard, which presents in the emissions of factories and vehicles. This gas pollutes the atmosphere and is one of the substances that causes acid rain to erode buildings, destroys trees and seriously affects human

health. SO_2 causes shortness of breath and burning in the nose and throat, which are the symptoms of pneumonia, respiratory infections, and eye inflammation. [12]

2.4.6 Ozone (O_3)

Ozone (O_3) is naturally presents at high altitudes, protecting us against harmful ultraviolet rays. Nonetheless, when this gas is on the ground (also known as tropospheric ozone or bad ozone), it causes pollution. It is a poison to living organisms and a greenhouse effect when in the upper layer of the troposphere.

Ozone pollution on the ground is also a result of a relatively complex mechanism; because this gas is not directly generated by human but is formed from the impact of solar radiation and other contaminants such as nitrogen dioxide and volatile organic components.

When ozone is in contact with human or animal lungs, it attacks and damages the lining epithelial cells of the airways, causing inflammation of cells that leads to coughing symptoms, feeling uncomfortable in the chest, and reducing the function of lungs, making it impossible to breathe normally. Therefore, ozone pollution can make asthma and chronic obstructive pulmonary disease worse and reduce the body's ability to fight off microorganisms from entering the respiratory system. [13]

2.4.7 Total Suspended Particles (TSP, PM10, PM2.5)

Total suspended particle matter includes a variety of solid particles, suspended in the atmosphere. Its size differs from below 0.1 micrometer to 100 micrometers in diameter; however, the major of tsp in the atmosphere ranges from 0.1 to 30 micrometer. Depending on the sizes, particles are named fine particles, coarse particles, and super-coarse particles, which are particles having diameters less than 2.5 micrometers (PM2.5), larger than 2.5 micrometers (PM10), and larger than 10 micrometers, respectively. [19]

These particles are generated in many different sources, such as traffic activities, construction sites, and industrial manufacturing. The large part of these particles is the result of multiple complicated chemical reactions, which involves chemicals exhaled from factories, traffic vehicles, and incinerators, for instance, sulfur dioxide and nitrogen oxides. [20]

While particulate matters having diameter smaller than 10 micrometers (PM10) can cause serious health problems over human respiratory system and lungs, particulate matters less than 2.5 micrometers even have higher possibility of entering circulatory system. People exposed to pollutants are more likely to suffer from chronic respiratory, heart and lung diseases. [21]

2.4.8 Noise Pollution

Noise pollution is the noise in the environment that exceeds a specific threshold, causing discomfort to people or animals. In many countries, the source of sound pollution is mainly from external noise such as traffic, transportation, motor vehicles, trains and airplanes.

Poor qualification in urban planning can create noise pollution, for example, residential areas located along with industrial buildings can be affected by noise within industrial buildings.

Sound is measured in decibels (dB). A normal person who is exposed to a high level of noise, which is known to be about 70 dB [14], for a certain period of time, is likely to have chronic hearing damage. Nevertheless, the hearing threshold within the human tolerance limit is approximately 120 dB.

Noise pollution creates a wide range of negative effects on people living within affected areas, including damage in brain and hearing power, increasing risk of cardiovascular diseases, insomnia, psychological disorders, etc. [14]

2.5 Impacts of air and noise pollution occurring in HCMC

The awareness of environmental protection and global warming is increasingly popular in the world, the issue of air pollution in Vietnam, particularly HCMC, has gained much attention in recent years.

According to the Department of Natural Resources and Environment of HCMC, either the concentration of CO and TSP or noise level in the atmosphere, caused by traffic activities, often exceeds the prescribed standard. Specifically, the monitoring showed that many large traffic points, including 9 traffic points in the project, were heavily polluted. Average concentration of CO often exceeds allowed limit, while average concentration of TSP is always 3 times higher than the standard. In fact, photochemical smog often appears within HCMC central area, which is thought to be caused by air pollution, seriously affecting the environment and people's health. [16]

A normal person inhales at least 10.000 litters of air per day [17]. Hence, when the air quality of surrounding atmosphere is not guaranteed, a series of respiratory diseases, heart disease or even cancer occur in humans as a result.

In "Air environment and related diseases" seminar organized by HCMC Medical Association, experts confirmed that air pollution affects not only the airways but also all organs such as skin, heart, and nervous system. According to statistics, Vietnam has an average of more than 20,000 people with lung cancer yearly (about 56 people infected each day),

of which up to 17,000 people die. It is estimated that there would be 34,000 people infected by 2020. [18]

3 Experimental materials and methods

3.1 Research Materials

The project involved the usage of data including spatial data and non-spatial data.

3.1.1 Spatial data

The vector data, shapefile (.shp), was edited to suit the sample data collected, then converted to raster format. Vector data was used as the background for air pollution maps, and raster data was used in the interpolation algorithm.

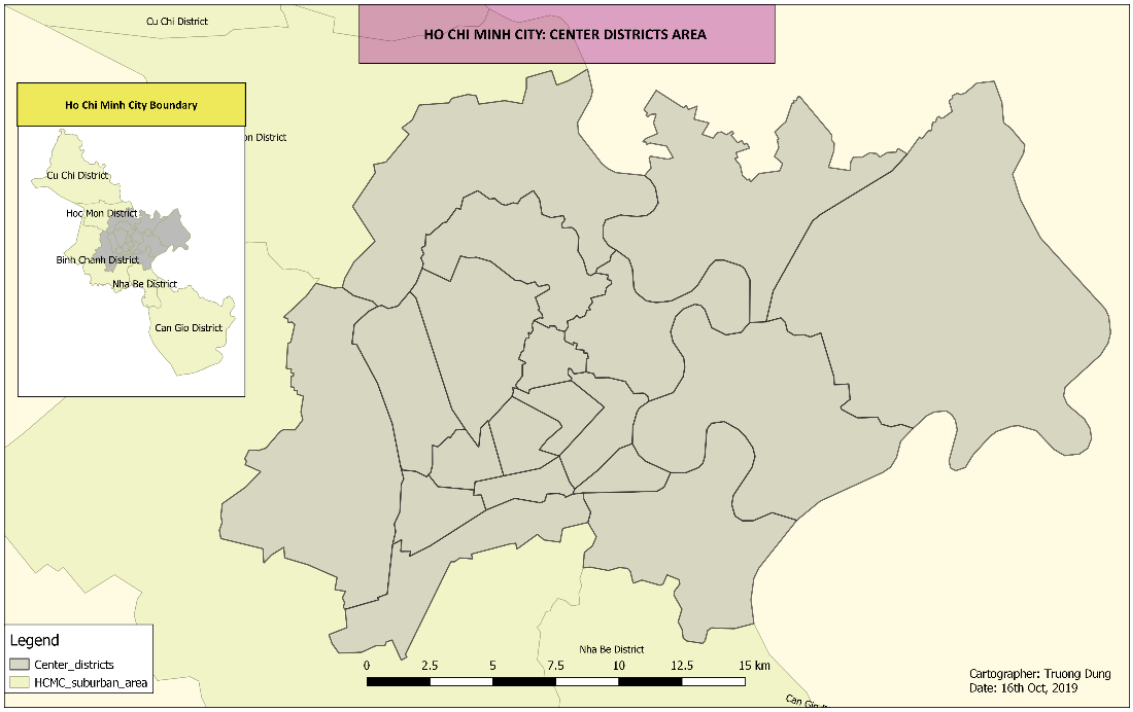


Figure 11 Research area

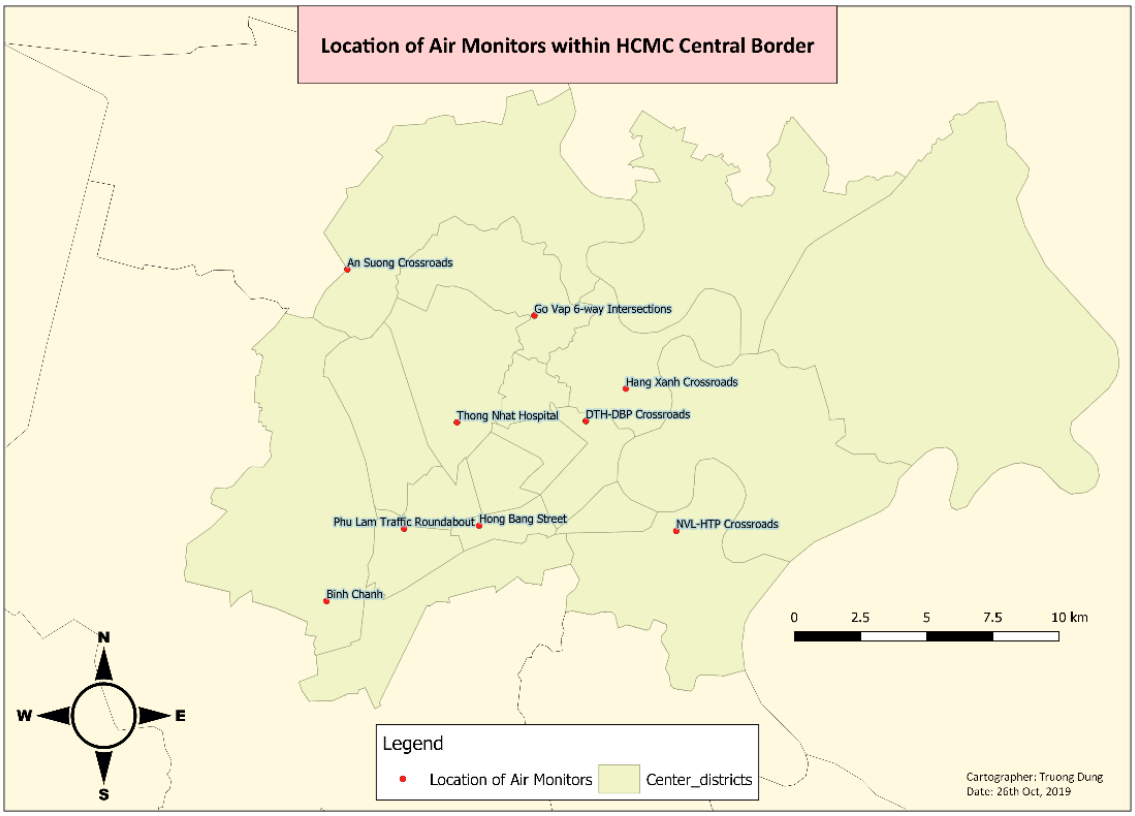


Figure 12 Location of 9 air monitors within HCMC territory

Nine air monitors were located in nine different sampling areas within HCMC territory.

Table 1 Names and locations of sampling areas

Sampling Area	Location Code	District
Hang Xanh Crossroads	HX	Binh Thanh District
DTH-DBP Crossroads	DTHvDBP	District 1
Phu Lam Traffic Rounda-bout	VXPL	District 6
An Suong Crossroads	AS	Hoc Mon District
Go Vap 6-way Intersec-tions	GV6	Go Vap District
NVL-HTP Crossroads	NVLvHTP	District 7
Hong Bang Street	HB	District 5
Thong Nhat Hospital	TN	Tan Binh District
Binh Chanh	BC	Binh Tan District

3.1.2 Non-spatial data

Data on the concentration of pollutants measured at the sampling location, from the raw data processed, the average output of hour, average of 3 hours, average of 5 hours, average of 8 hours, and average day, average month, average year. The project used average emissions concentration data, regarding CO, NO2 and TSP from 2007 to 2017 and average noise data from 2009 to 2017 collected at 9 key traffic points in HCMC.

Although it is not possible to illustrate the concentration of the remaining substances in the air, the available data could partly reflect the pollution level of HCMC.

Table 2 Total suspended particles data [25]

year	HX	DBPvDTH	VXPL	AS	GV6	NVLvHTP	HB	TN	BC
2007	0.4271	0.563	0.3817	0.615	0.3702	0.4628	0.47	0.47	0.47
2008	0.4363	0.5775	0.3725	0.7382	0.45	0.5292	0.5173	0.5173	0.5173
2009	0.4756	0.5878	0.4676	0.7652	0.4504	0.56	0.5511	0.5511	0.5511
2010	0.4834	0.5127	0.7179	0.8027	0.5086	0.6132	0.6064	0.6064	0.6064
2011	0.482	0.4916	0.5288	0.6877	0.4866	0.4997	0.5294	0.5294	0.5294
2012	0.4845	0.5313	0.5032	0.6625	0.5021	0.5023	0.531	0.531	0.531
2013	0.4429	0.5013	0.5743	0.623	0.5131	0.4825	0.5229	0.5229	0.5229
2014	0.3863	0.4768	0.5832	0.6071	0.4435	0.4917	0.3492	0.3087	0.3961
2015	0.327	0.3849	0.4139	0.5653	0.4413	0.5338	0.3001	0.2764	0.4206
2016	0.3133	0.3543	0.3516	0.5218	0.7012	0.4159	0.2878	0.3101	0.4483
2017	0.3335	0.3617	0.3254	0.7633	0.5833	0.4362	0.2713	0.2789	0.2891

Table 3 Carbon monoxide data [25]

Year	HX	DBPvDTH	VXPL	AS	GV6	NVLvHTP	HB	TN	BC
2007	10.2973	14.4897	10.149	12.4714	13.6338	9.5844	11.7709	11.7709	11.7709
2008	10.554	14.5948	10.91	13.1624	16.5523	9.6374	12.5685	12.5685	12.5685
2009	10.7574	14.6043	11.5589	14.1246	18.472	9.7874	13.2174	13.2174	13.2174
2010	10.219	15.1191	9.9673	14.9491	14.6385	9.9119	12.4675	12.4675	12.4675
2011	10.9252	13.8259	10.2581	13.8896	14.7312	9.7725	12.2338	12.2338	12.2338
2012	9.9604	12.8903	8.872	11.9129	14.4964	8.8136	11.1576	11.1576	11.1576
2013	9.8363	13.1334	9.1324	12.9632	15.8285	9.1025	11.6661	11.6661	11.6661
2014	5.8359	9.9978	6.2465	10.2838	11.1028	5.9897	7.3086	8.7516	5.8119
2015	8.6646	10.0227	9.1649	12.0036	14.5543	9.8335	8.8423	8.6735	6.0862
2016	11.1665	11.9966	5.9992	9.1607	10.0726	11.1683	8.007	9.8864	7.9766
2017	11.5164	12.7886	5.1672	8.2925	9.2422	12.9663	7.121	7.8211	7.9201

Table 4 Nitrogen dioxide [25]

Year	HX	DBPvDTH	VXPL	AS	GV6	NVLvHTP	HB	TN	BC
2007	0.1708	0.2279	0.1576	0.2174	0.2002	0.1582	0.1887	0.1887	0.1887
2008	0.1854	0.2375	0.1602	0.2186	0.2037	0.1597	0.1942	0.1942	0.1942
2009	0.1892	0.251	0.1627	0.2385	0.2186	0.162	0.2037	0.2037	0.2037
2010	0.1765	0.2124	0.1622	0.2268	0.2126	0.1907	0.1969	0.1969	0.1969
2011	0.15	0.2322	0.1507	0.2268	0.177	0.161	0.183	0.183	0.183
2012	0.1701	0.2125	0.1718	0.211	0.1714	0.17	0.1845	0.1845	0.1845
2013	0.1616	0.1806	0.1694	0.2	0.0595	0.1701	0.1569	0.1569	0.1569
2014	0.0782	0.1263	0.062	0.1133	0.0635	0.0759	0.0687	0.0688	0.0546
2015	0.0553	0.0761	0.0532	0.0865	0.0678	0.0621	0.0681	0.0678	0.0687
2016	0.0384	0.0487	0.0528	0.076	0.0698	0.0487	0.0523	0.0538	0.0507
2017	0.05	0.0518	0.0543	0.0818	0.0748	0.0499	0.0489	0.0428	0.0491

Table 5 Noise data [25]

year	HX	DBPvDTH	VXPL	AS	GV6	NVLvHTP	HB	TN	BC
2009	80	78	78.4	80.6	77.1	77.3	80.4	80	75
2010	78	78.3	76.4	81	78	76.3	78	78	78
2011	79	73.7	78.9	81.6	78	76.3	77.9	77.9	77.9
2012	78.5	79.7	79	80.4	78	76.9	78.8	78.8	78.8
2013	76.5	80	78	80.4	78	77.5	78.4	78.4	78.4
2014	75	77.5	70.4	78.9	71.1	71.1	66.8	71	62.8
2015	74.2	77.2	75.7	79.1	77	75	70.1	72	62.1
2016	73	76.5	75.3	81.8	79.5	72.9	71.2	72.6	60.1
2017	74.4	77	75.1	81.5	78.9	74.4	71.3	73.4	67.8

*** Yellow-highlighted data is missing data and is replaced by yearly means values of others monitors.

Table 6 Average concentration of HCMC ambient air and noise level [25]

year	NO2_mg/m3	CO_µg/m3	TSP_mg/m3	Noise_db
2007	0.1887	11.77	0.47	
2008	0.1942	12.57	0.5173	
2009	0.2037	13.22	0.5511	78.5
2010	0.1969	12.47	0.6064	78
2011	0.183	12.23	0.5294	77.9
2012	0.1845	11.16	0.531	78.8
2013	0.1569	11.67	0.5229	78.4
2014	0.079	7.93	0.4492	71.6
2015	0.0673	9.76	0.407	73.6
2016	0.0546	9.49	0.4116	73.7
2017	0.0559	9.2	0.4047	74.9

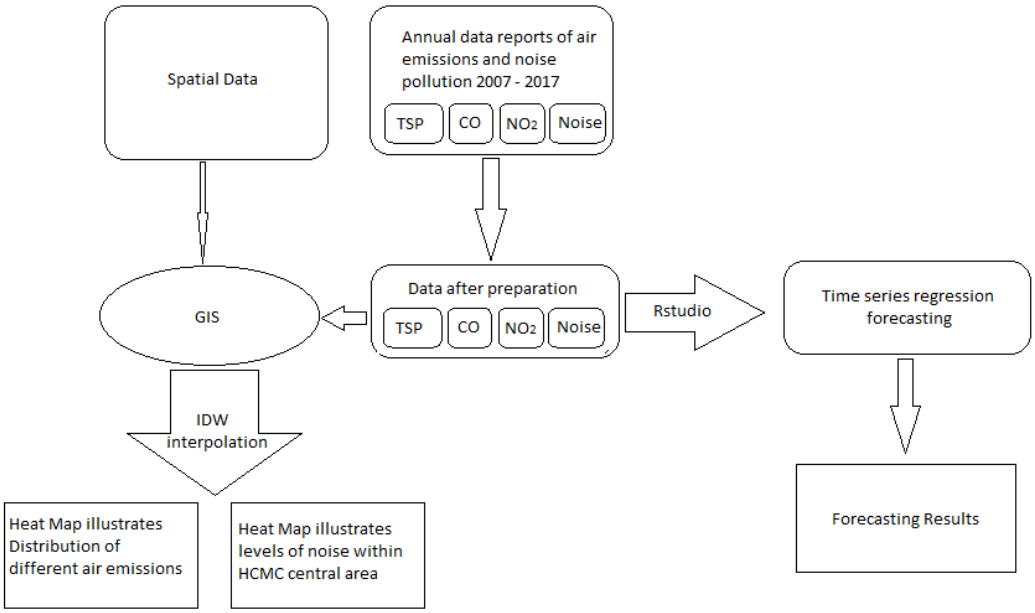
In this thesis, annual average concentration of ambient air and average noise level of HCMC are recognized as annual average concentration of ambient air and average

noise level collected from nine air quality monitors at nine traffic points within HCMC territory.

3.1.3 Research software

Rstudio and QGIS are open-source and free software. Rstudio is a programming language for statistical computing and graphics, which was used to implement forecasting model. QGIS supports viewing, editing, and analysis of geospatial data, the software illustrated the distribution of HCMC ambient air and noise pollution using IDW interpolation.

3.2 Proposed approach



3.3 Methods

Two methods were used to create the emission and noise level heat maps and forecasts: inverse distance weighted (IDW) interpolation and time series regression.

Inverse distance weighted (IDW) interpolation is a method of taking average values of sample data points in a group of processing cells that defines approximate cell values. In this process, the affect would get higher when a point is closer to the center of the cell being estimated. [22]

Time series regression is a method of which based on the response history and the trends from relevant predictors, statistically predicting a future response. This approach could be used to comprehend and anticipate the behavior of dynamic systems from experimental or observational data. [23]

3.4 Factors affecting the concentration of air emissions and noise pollution

The pollution-evaluation functions are certainly multivariate and nonlinear functions. Factors influencing the cleanliness of the city ambient air include the following:

Natural factors, for instance temperature, humidity, wind direction, wind speed, and precipitation. By cause of unique features in the climate of HCMC, which are recognized as two seasons: rainy and dry, the concentration of pollutants in the atmosphere is significantly affected.

Socio-economic factors, such as growth rate in population, complexity of transportation infrastructure, government policies and awareness of environmental protection among citizen.

Building a function, which considers air pollution changes caused by traffic activities, involving all the affecting factors, is a complicated and difficult problem. Within limitation of accessing to resources of data, the author of the thesis considered only the forecast of air pollution, without taking into account other factors. This might cause either inaccuracies or ineffective results in the forecasts of this thesis. In fact, real-time pollution data at any given time might be different from the author's predicted data because of the reason given above. However, the available data and the efficiency of the algorithms in this project were capable of reflecting pollution problems taking place in HCMC.

4 Research Results

4.1 Distribution of air emissions and noise pollution in HCMC

4.1.1 Distribution of carbon monoxide 2007 – 2017

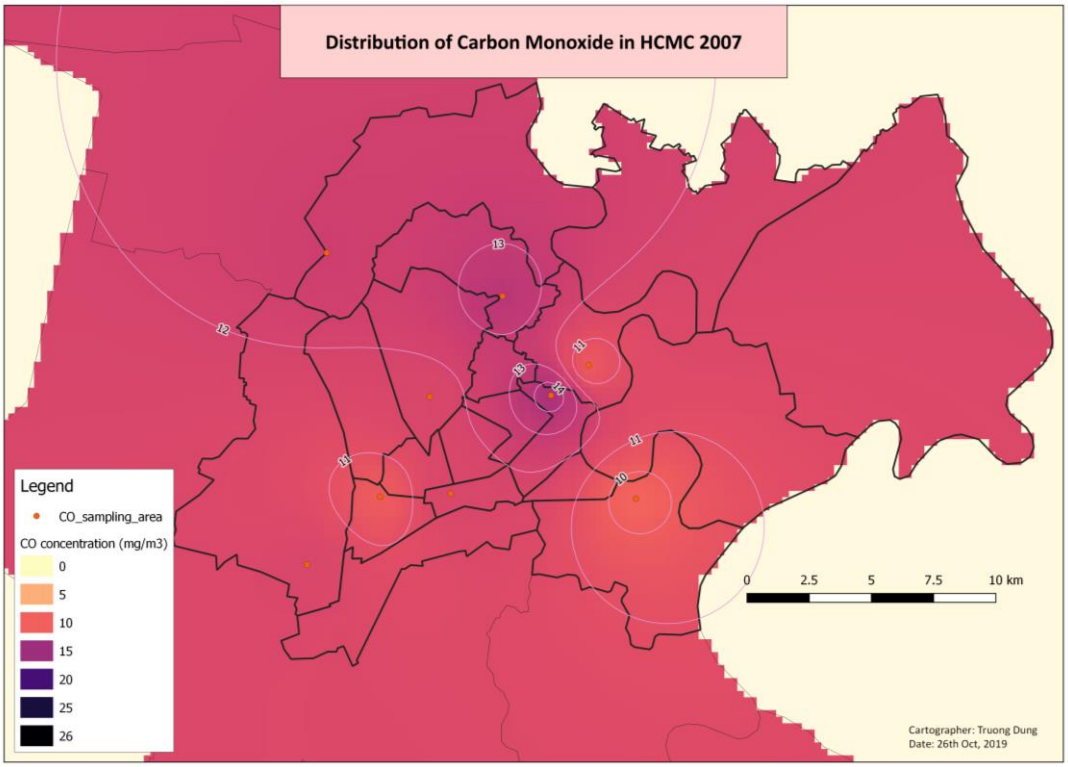


Figure 13 Distribution of carbon monoxide 2007

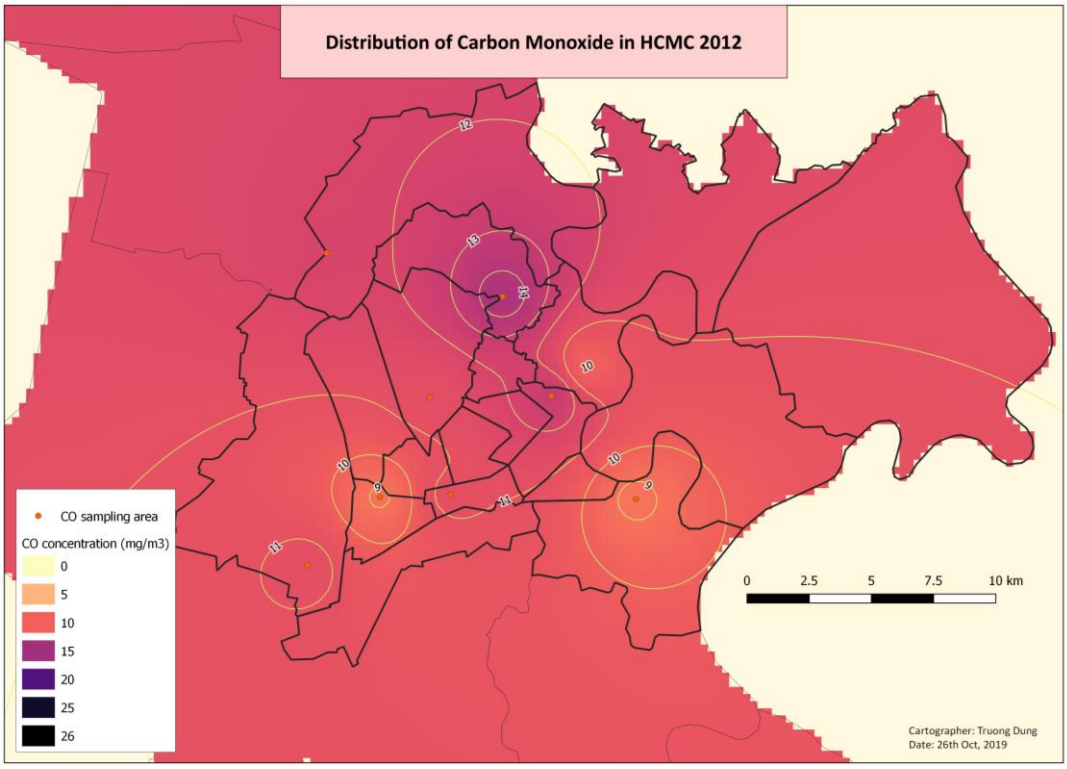


Figure 14 Distribution of carbon monoxide 2012

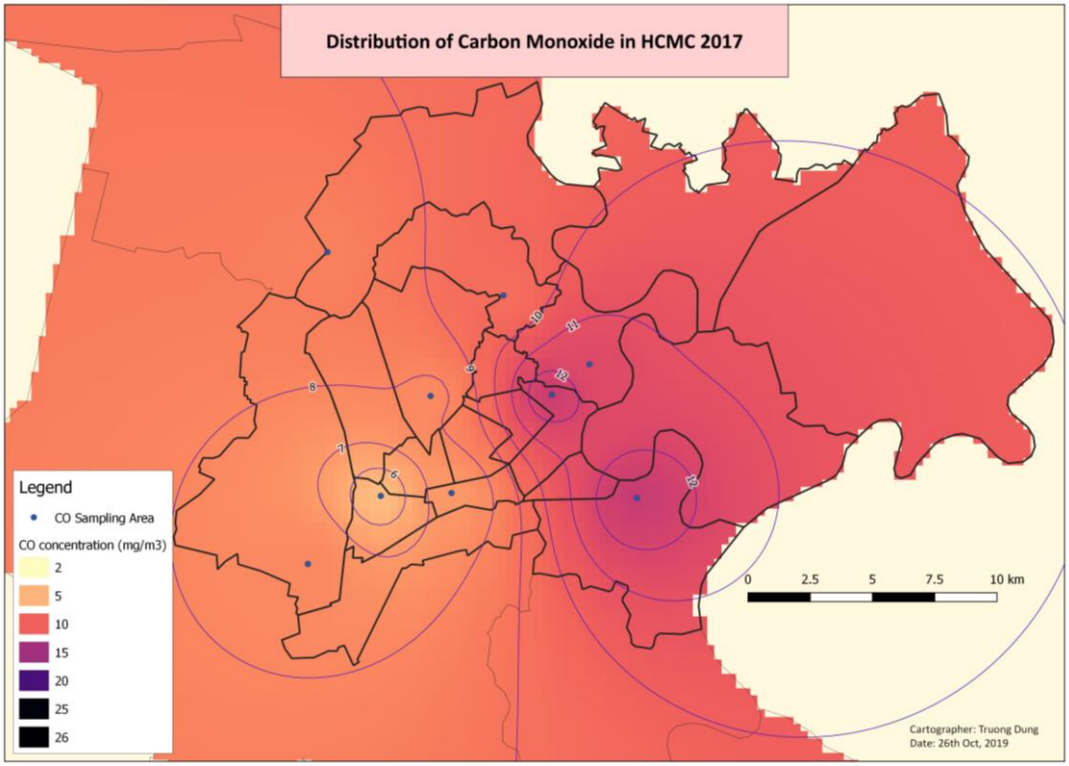


Figure 15 Distribution of carbon monoxide 2017

4.1.2 Distribution of nitrogen dioxide 2007 – 2017

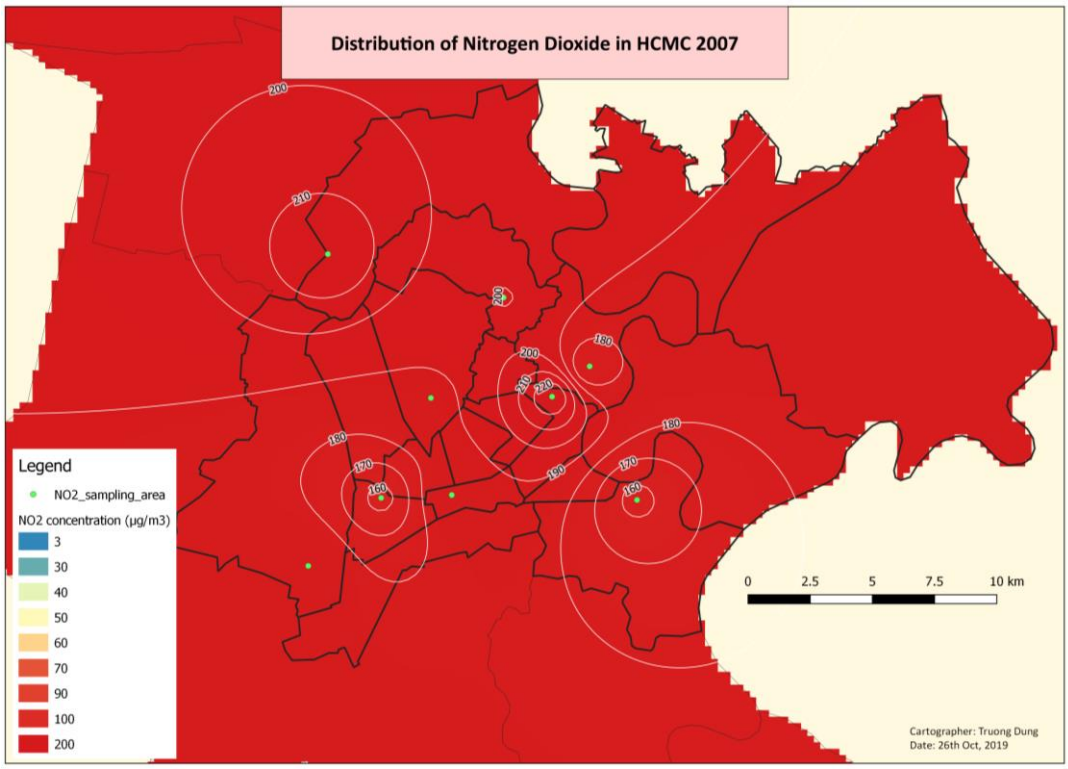


Figure 16 Distribution of nitrogen dioxide 2007

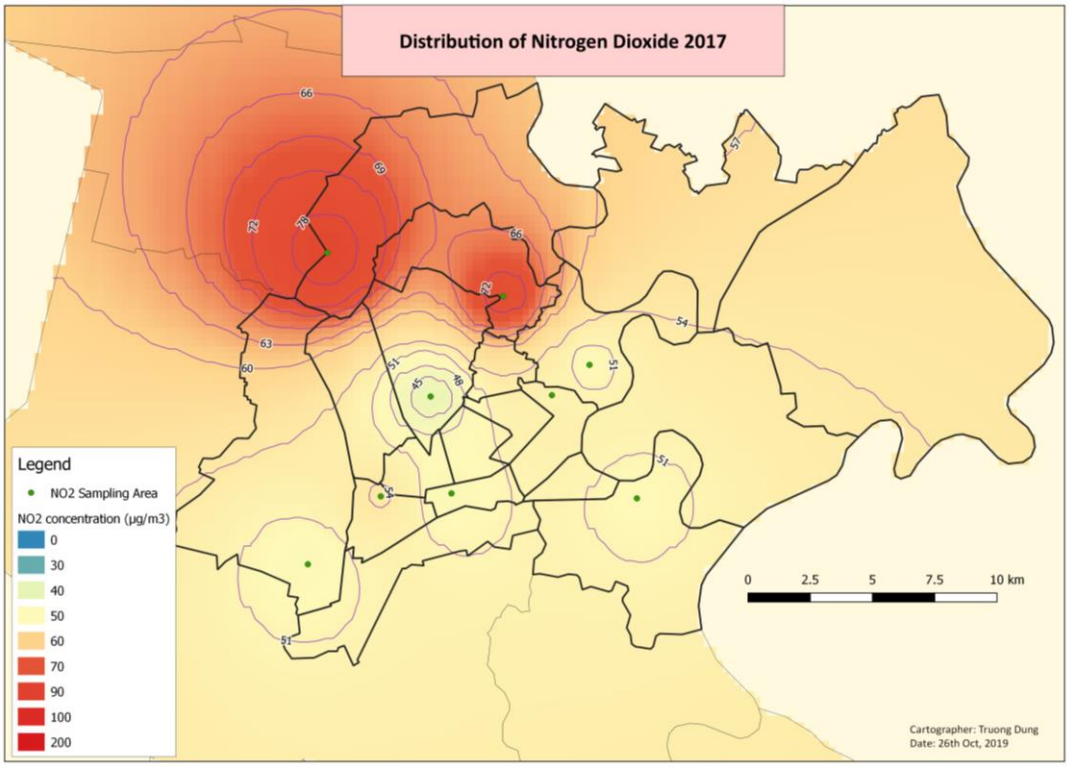


Figure 17 Distribution of nitrogen dioxide 2017

4.1.3 Distribution total suspended particles 2007 – 2017

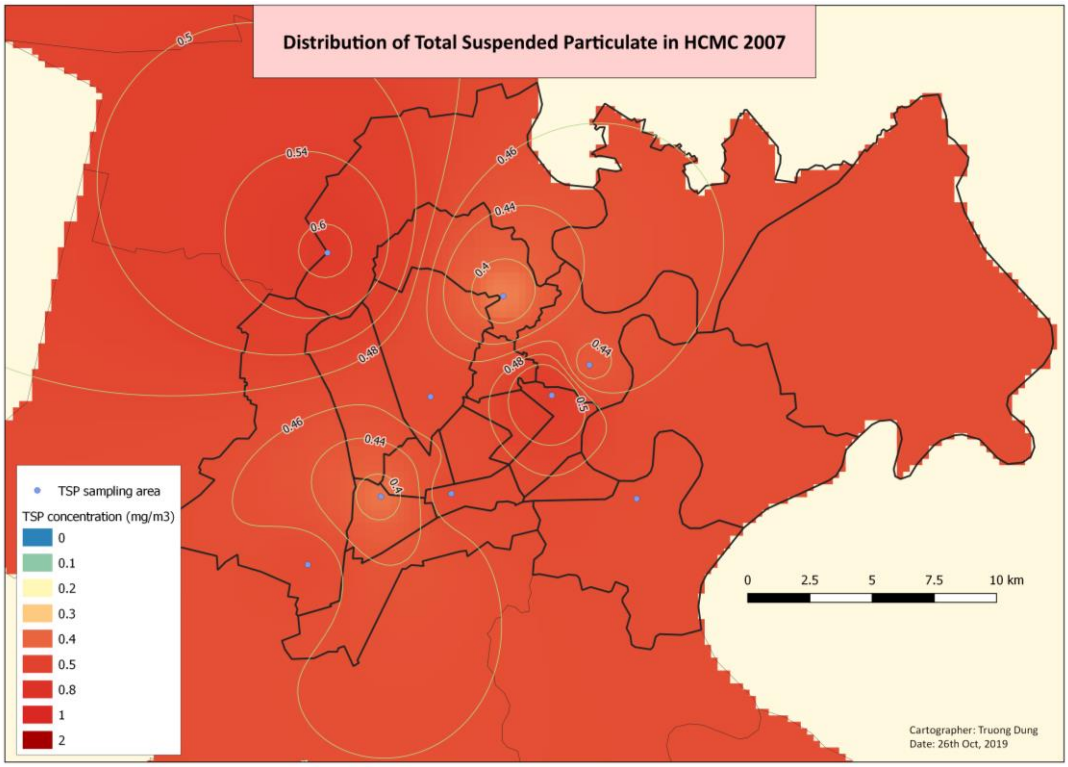


Figure 18 Distribution total suspended particles 2007

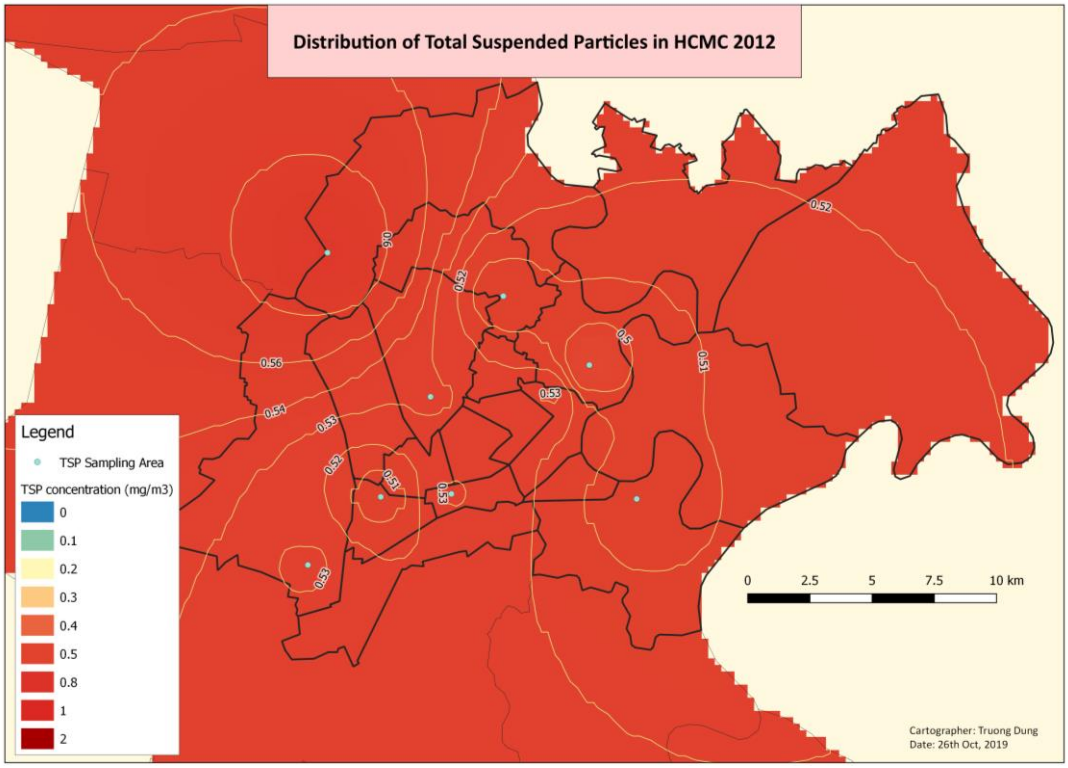


Figure 19 Distribution total suspended particles 2012

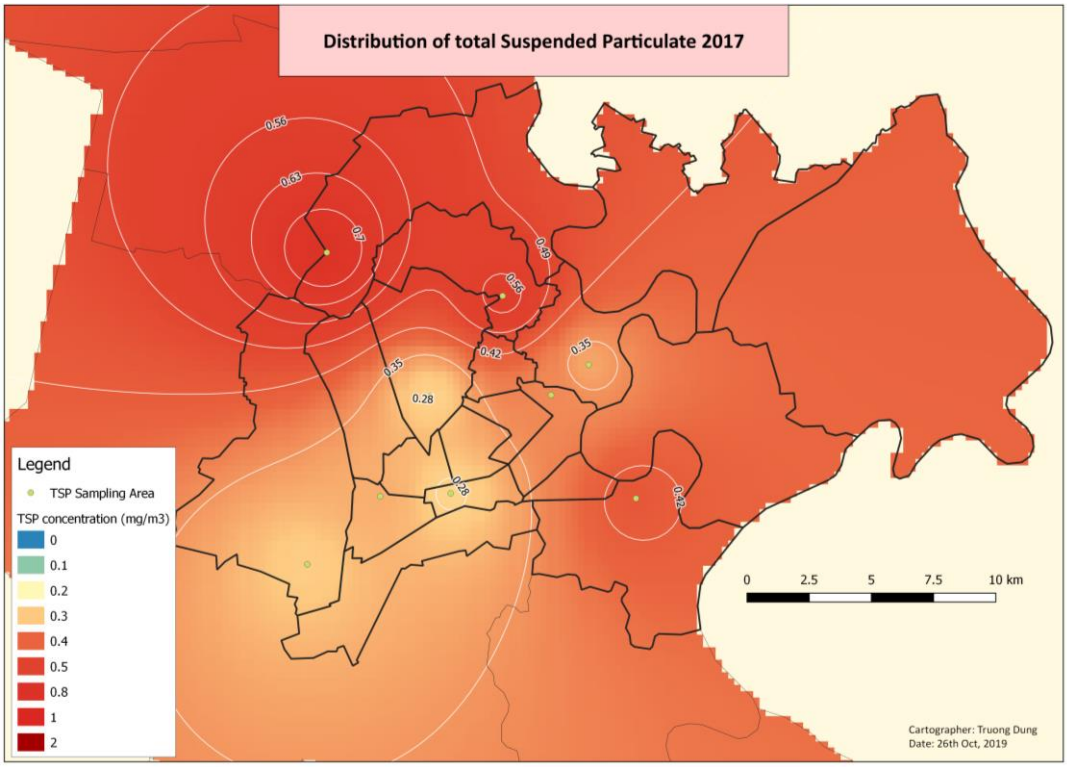


Figure 20 Distribution total suspended particles 2017

4.1.4 Levels of noise in HCMC 2009 – 2017

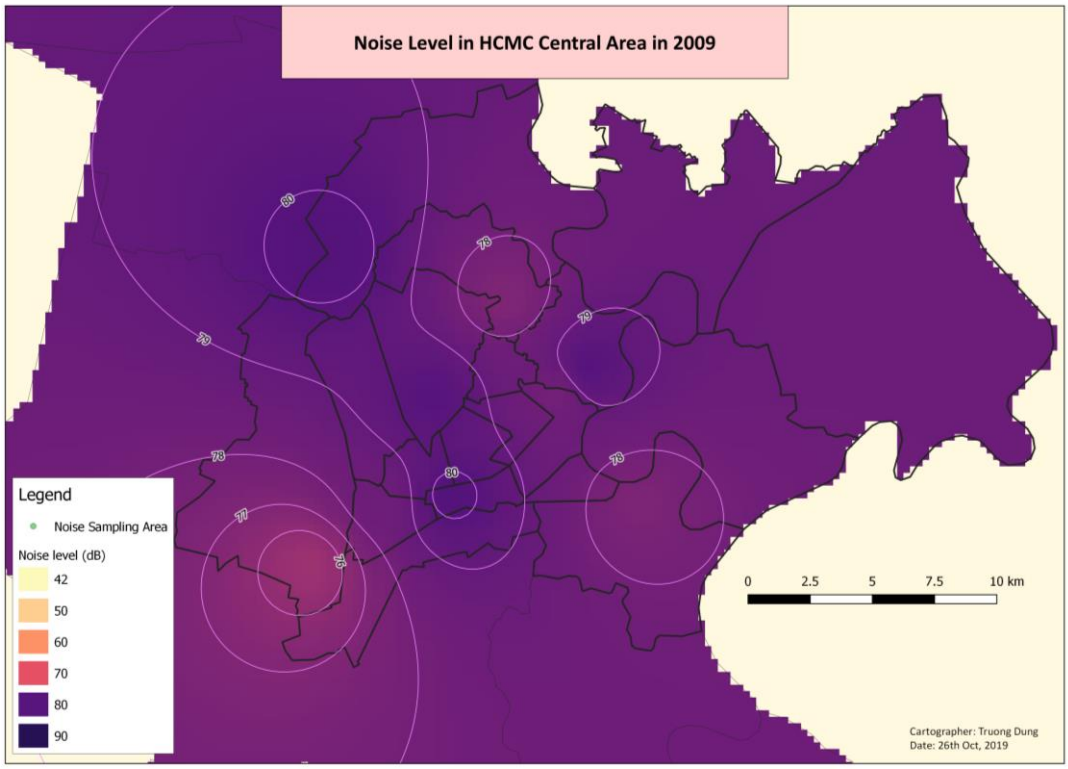


Figure 21 Noise level in HCMC 2009

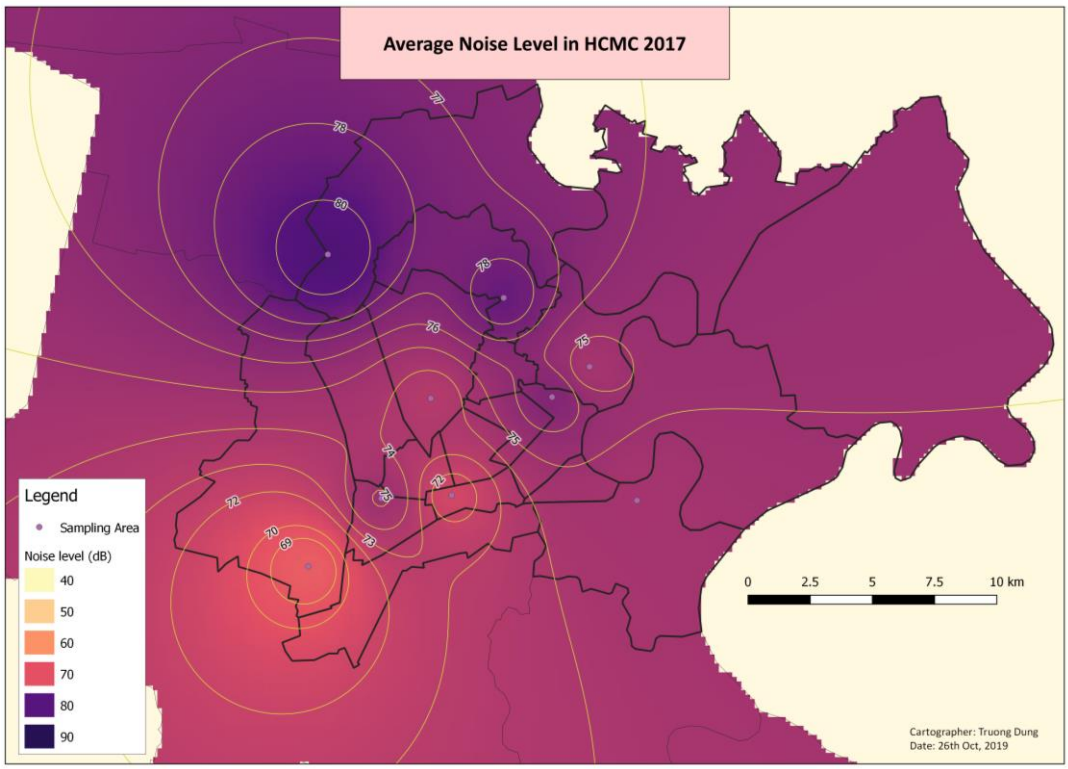


Figure 22 Noise level in HCMC 2017

4.2 Future levels of air pollution in HCMC

4.2.1 Forecasted future concentrations of CO

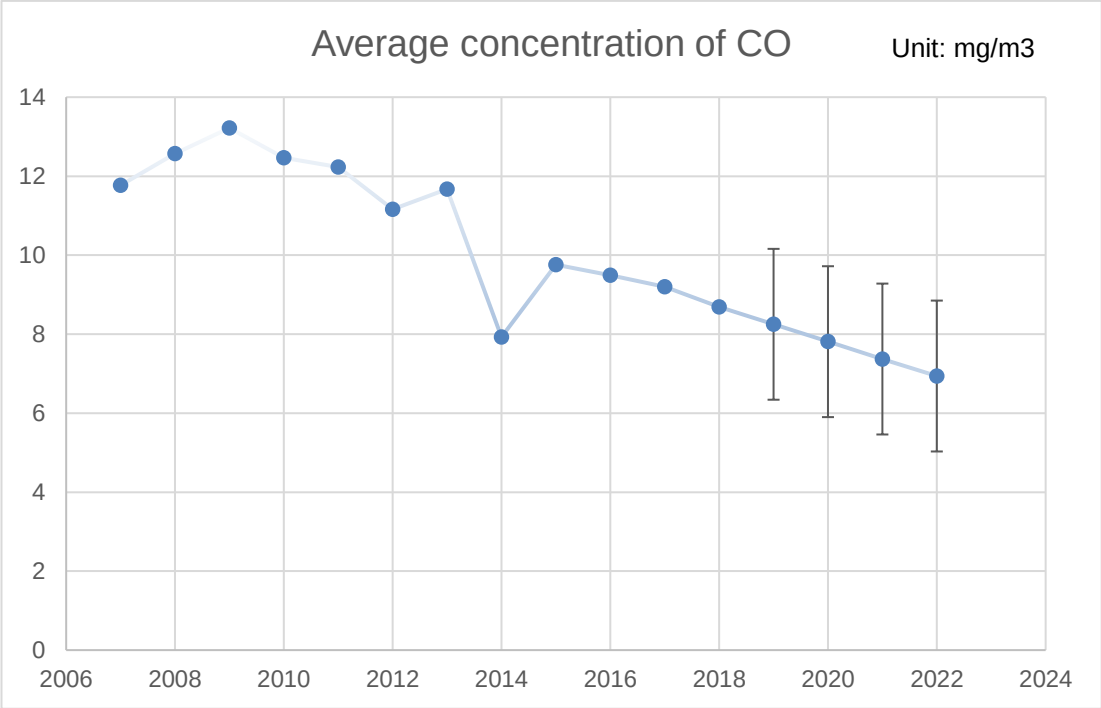


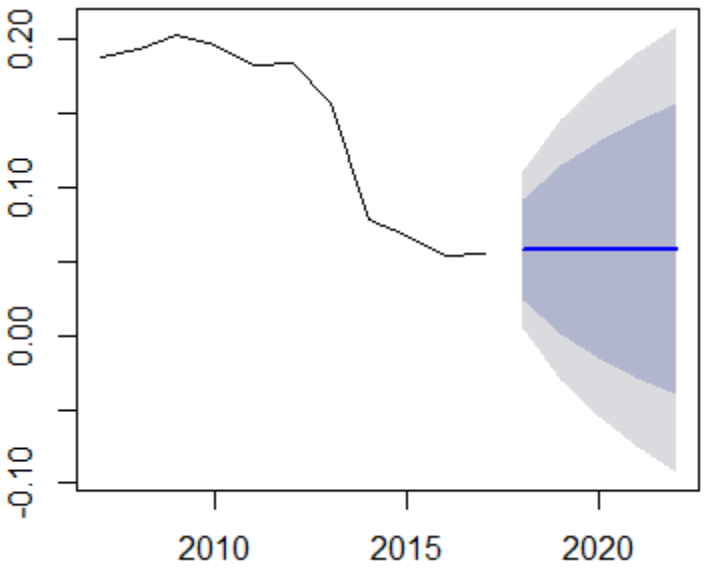
Figure 23 Predicted annual average concentrations of CO 2018 – 2022.

Average concentrations of CO in the next 5 years were predicted to experience a promising downward trend. The concentration is expected to reduce from 9.2 mg/m3 in 2017 to 6.9 mg/m3 in 2022 with standard error remaining stable at 1.91mg/m3

Table 7 Predicted future concentrations of CO. Unit: mg/m3

	Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
2018	8.689807	7.440535	9.939080	6.779210	10.600404
2019	8.251856	7.002576	9.501136	6.341247	10.162465
2020	7.813905	6.564519	9.063290	5.903135	9.724674
2021	7.375953	6.126024	8.625882	5.464352	9.287555
2022	6.938002	5.686750	8.189254	5.024377	8.851627

4.2.2 Predicted future concentrations of NO_2



Unit: µg/m3

Figure 24 Predicted annual average concentrations of NO_2 2018 - 2022.

NO_2 average concentration's standard deviation was predicted to increase gradually, 0.052, 0.088, 0.1129, 0.1331and 0.1506 µg/m3 respectively, however, average concentration of NO_2 dropped significantly from the peak of 0.2 µg/m3 in 2009 to 0.05 µg/m3 in 2016, we could expect a down trend of NO_2 average concentration in the future.

Table 8 Predicted future concentrations of NO_2 Unit: µg/m3

	Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
2018	0.05820758	0.0237569232	0.09265824	0.005519845	0.1108953
2019	0.05820758	0.0006932038	0.11572196	-0.029753070	0.1461682
2020	0.05820758	-0.0154738916	0.13188906	-0.054478509	0.1708937
2021	0.05820758	-0.0286832426	0.14509841	-0.074680468	0.1910956
2022	0.05820758	-0.0401340229	0.15654919	-0.092192925	0.2086081

4.2.3 Predicted future concentrations of TSP

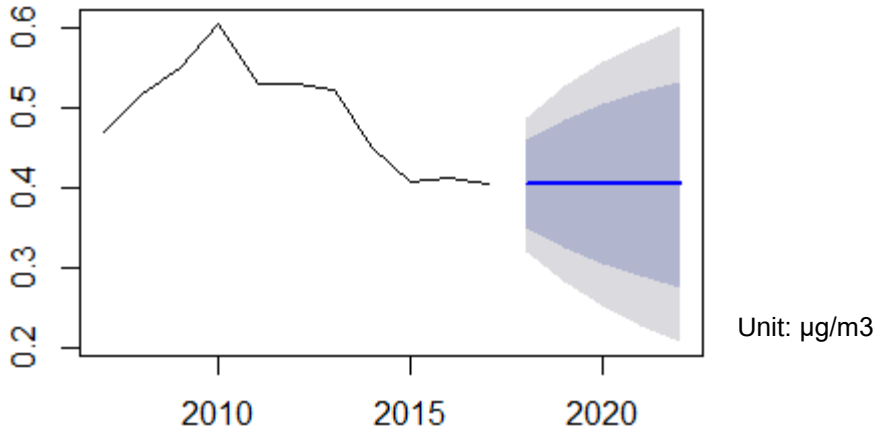


Figure 25 Predicted annual average concentrations of TSP 2018 - 2022.

TSP average concentration's standard deviation was predicted to increase gradually, from 0.08 to 0.2 mg/m3; however, average concentration of TSP in the atmosphere has considerably decreased since 2010. Predicted values of average TSP concentration within HCMC central area would remain as 0.40421 mg/m3 in the next 5 years.

Table 9 Forecasted results of future concentrations of TSP Unit: mg/m3

	Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
2018	0.40421	0.3491780	0.4592420	0.3200458	0.4883741
2019	0.40421	0.3237542	0.4846657	0.2811635	0.5272564
2020	0.40421	0.3046221	0.5037978	0.2519035	0.5565164
2021	0.40421	0.2886144	0.5198055	0.2274218	0.5809981
2022	0.40421	0.2745684	0.5338516	0.2059402	0.6024797

4.2.4 Forecasted future levels of noise

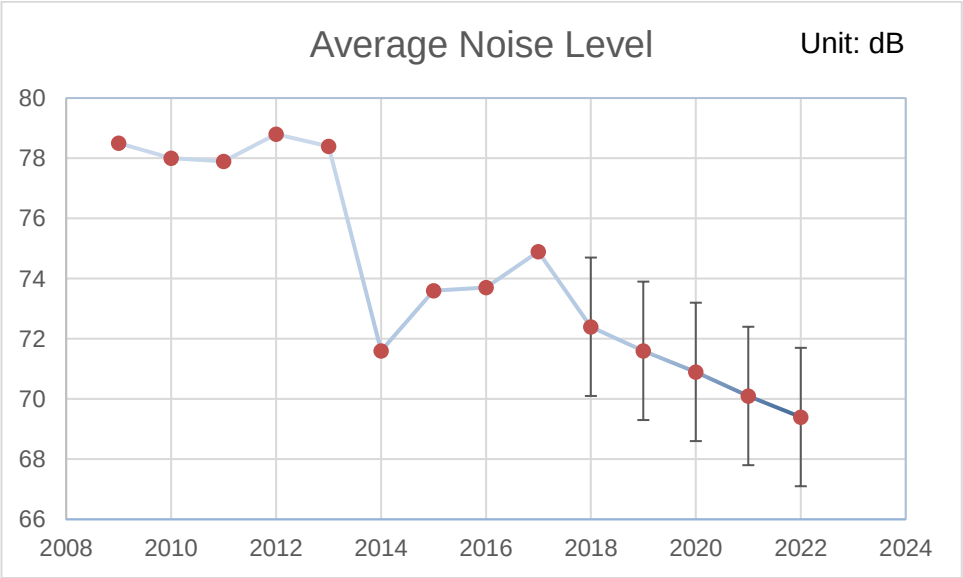


Figure 26 Predicted annual average noise level 2018 - 2022.

The average noise level in HCMC was predicted to gradually reduce in the next 5 years, from 74.9dB in 2017 to 69.4dB in 2022 with standard error remains stable at 2.3dB.

Table 10 Forecasted results of future noise level. Unit: dB

	Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
2018	72.38382	70.14731	74.62032	68.96338	75.80426
2019	71.63430	69.39735	73.87126	68.21318	75.05543
2020	70.88479	68.64740	73.12218	67.46299	74.30659
2021	70.13528	67.89744	72.37311	66.71281	73.55775
2022	69.38576	67.14750	71.62403	65.96263	72.80889

4.3 Evaluation

Generally, both the concentrations of air emissions and noise pollution, collected at 9 different traffic points within HCMC central area, had been significantly reduced from 2007 to 2017. The historical performances support prediction of further reductions of toxic ambient air and noise pollution caused by traffic activities. However, this reduction has not yet brought HCMC a cleaner atmosphere and less noise, since the concentration of CO and TSP in the atmosphere is still considered as poor to unhealthy in HCMC central area, as well as average noise levels are high.

5 Conclusion

In order to reduce air pollution in the future, Vietnamese government needs a synchronous implementation solution from policy, enforcement to monitoring and evaluation, for example, promote the establishment of institutions, laws, and environmental policies, to create regulations, environmental standards, discharge standards, technology standards on which pollution is controlled. In addition, it is necessary to gradually improve the mechanisms and policies to promote the socialization of environmental protection activities and develop environmental services.

Strengthen the planning management: re-approving the urban development and management plans according to environmental-friendly construction criteria; paying special attention to investment in developing urban technical infrastructure such as transportation, drainage, domestic wastewater treatment, and solid waste treatment.

Regularly inspect the work of ensuring environmental sanitation at construction sites, periodic vehicle inspection and need to have more stringent conditions for vehicles.

Increase the number of environmental observations in large cities, populated areas, traffic hubs, industrial estates and environmentally sensitive areas.
Urban air pollution has a significant contribution from industrial waste sources. In order to effectively control and manage these sources, creating a database of waste sources according to inventory of emissions is necessary.

The data stream used in this thesis project merely contains annual average data of 10 years from 2007 to 2017; therefore, the regression model is not certainly close to reality. As a result, calculated forecast data has a relatively accuracy level. The objective of the thesis project stops at the application of GIS in environmental forecasting, management and protection.

The limitation in number of monitoring points within HCMC central area resulted in the inefficiency of the calculation of surface interpolation when conducting IDW interpolation in a wide area. The author of the thesis believes that with better supports to accessing the necessary data, longer data streams, larger number of monitoring points and more thorough factors affecting air pollution, would produce more accurate results.

The results of this thesis project form a basis for further researches.

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