The Impact of Urban Sprawl on Air Quality: A Case Study of Hua-Takae Community, Latkrabang District, Bangkok, Thailand

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Abstract — ***The purpose of this study is to investigate the impacts of urban sprawl in the Latkrabang District which directly affects to Hua-Takae Community. Effects of sprawl development were examined to understanding sprawl condition in the district. Calculating a sprawl condition in the district is equal to 33.5 of 100 that shown a low degree of sprawl. Nevertheless, Hua-Takae community are expected to be affected by urbanization and trends of growing population from various sprawl development factors including airport, industrial estates, educational center, and motorway. Lack of public transportation provision in the community by using automobile dependency that resulting air quality. The air pollution analysis based on traffic volume and population growth was found that the major sources were passenger car and pick-up and the major pollutants were CO and PM. The vehicle emissions of mobile sources in 2005, 2010, and 2015, are also found that higher emission standards. The emissions from mobile sources, therefore, it needs to be addressed the related policy for improving air quality of community in future.***

Keywords: ***urban sprawl / transportation/ population/ air quality***

1 INTRODUCTION

Urbanization is a dynamic to urban sprawl development in the suburban areas in many cities. In Bangkok, sprawl has continued along transport routes, it is leading to various environmental problems such as land use conflicts. The urban sprawl of Bangkok has been undergoing the rapid urbanization and industrialization due to the development of the city (BMA, 2003).

1.1 Objective of the Study

- To investigate urban sprawl conditions and their effects on land use changes and air quality in the community.
- To analyze relationships between the environmental impacts of urban sprawl on air pollution situation resulting from motor vehicle.
- To recommend and promote guidelines to reduce air pollution.

2 BACKGROUND

Latkrabang District is one of 50 districts in Bangkok that involved a member of BMA in year 1939. The habitants are mostly original Thai people with traditional living pattern engaged in agricultural activities with land close to canal (Klong). Another portion of the residents with urban lifestyle started to migrate towards this area in 1977 due to the development, economic acceleration (Latkrabang Industrial Estate), and expansion of the urban area. The urbanization led to the conversion of land from agricultural use to overcrowded housing and commercial areas. The inadequacy of infrastructure and facilities are due to the failure to increase urban infrastructure services provision at the rate comparable to land conversion.

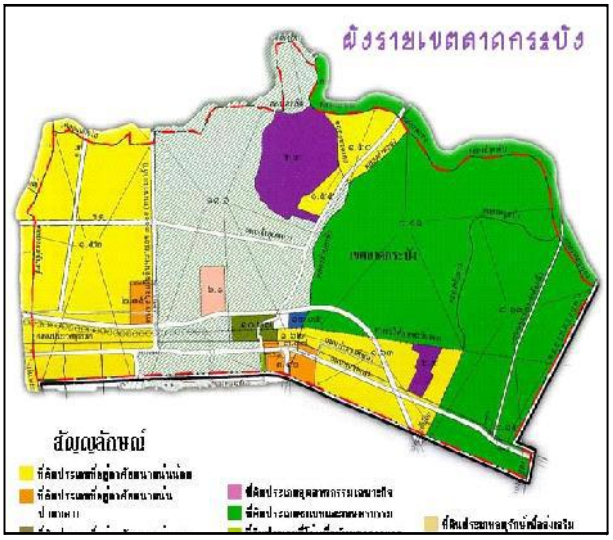


Figure 1. Land use zoning of Latkrabang District (LDO, 2002)

The utilization of land in the district was changed through conversion from agricultural to residential and commercial uses. As shown **Table 1.1**, the residential and commercial area was rapidly increased during 1986 to 1996. Whereas, the agricultural area in district has been lost as the high percentage of land use change all of types in 1986, 1996, and 2000.

Table 1.
Land utilization of latkrabang district (dcp, 2003)

Land use	1986	1996	2000
Type	(ha)	(ha)	(ha)
Residential	864.70	1,240.70	1,646.88
Commercial	35.00	77.24	110.08
Industry	435.00	583.16	468.16
Warehouse	2.50	92.50	85.76
Government	19.50	27.50	52.24
Education	148.60	151.80	151.80
Religion	21.90	21.90	21.90
Recreation	24.40	24.40	24.40
Infrastructure	7.30	11.30	14.35
Road	121.80	253.80	564.16
Agriculture	10,705.2	9,901.60	8604.16
Urban Area	1,680.70	2,484.30	2688.23
Total	12,385.9	12,385.9	12,385.9

Figure 2. Hua Takhe community area.

The effects of sprawl development in Latkrabang District have created high development of housing and commercial area along the major road. Especially, in Hau-Takhe community, the development along Onnuch Road has lead many problems including land use changes, traffic congestion, and air pollution.

From field observation, the sprawl development factors that affect to Hau-Takhe community are listed below:

1) <u>The Second Bangkok International Airport (Suvarnabhumi Airport)</u> *Positive:* Developing economic as the business and commercial center. Providing a transportation network. Improving quality of life such as high income level, job center in suburban area

2) <u>Industrial Estate and Factory</u>
Positive: Driving force of economic development in Latkrabang District. Improving quality of life such as high income level, job center in Latkrabang District.
Negative: Lost of open space and agricultural area from housing demand of employment. High price of housing and land in the community. Air pollution especially from truck and trailer.

3) Education Center (University)

Positive: Improving quality of life as Enhancing education opportunity for people

Negative: Land demand for housing, apartment, and dormitory. Increasing amount of car usage. Air pollution from automobiles. especially in mornings and evenings.

4) Bangkok-Chonburi Motorway

Positive: Providing the transportation linkage between Bangkok and eastern provinces of Thailand. Reducing time traveling between suburban and city

Negative: High land demand for housing to access the motorway. High rate of accidents due to high speed driving. Separating a land parcel and usual route of local people.

3. METHODS AND RESULTS

3.1 Sprawl Measurement

The sprawl condition of Hau-Takhe community could be examined using four factors of sprawl measurement which has applied of Ewing study (1997).

Table 2.
Sprawl Measurement Factors
(Ewing, 1997)

Factor	Sprawl Condition
Residential Density	• Percentage of population living at densities less than 1,500 persons per square mile
Land use Mix	• Percentage of residents with unsatisfactory neighborhood shopping within 1 mile • Percentage of resident with a public elementary school more than 1 mile
Strength of Center	• Unbalance of jobs to residents • Percentage of population living more than 10 miles from the CBD.
Street Accessibility	• Percentage of small blocks

These sprawl factors can show the condition of sprawl in Hau-Takhe community that is going to urban area based on four factors. First, the high residential density of population in the suburban area is about 4,711 persons per Km^2. Second, there are centers of education in the area (9 schools and 1 university in the community within 0.8 – 3 Km); the centers of commerce and market are there also. Third, job place center (Industrial Estate) is established in the north of the community (3 Km). Fourth, the road development (Sub-main Road) to connect public transportation is more 80% covered for traveling.

Furthermore, the sprawl condition of Latkrabang District on population was investigated using lives in high and low density tracts based on sprawl measurement of sierra club. According to Sierra Club (2004), the sprawl index to construct a measure of residential sprawl for metropolitan area is based on the density and concentration dimensions of sprawl. Sprawl index equation (1) was shown below:

$$SI = \frac{[[S\%-D\%] + 1] * 50}{100} \quad \ldots\ldots (1)$$

where,

SI = Sprawl Index for Metropolitan Area

D%= Percentage of the total population in high density tracts

S%= Percentage of the total population in low density tracts

The potential range of values is between 0 to 100. If the value is equal to 100, the people live entirely in low-density tracts indicating the highest level of sprawl. If the value is 0, the people live entirely in high-density tracts signifying the least amount of sprawl.

By using a population data of Latkrabang District Office it can be divided a high density tract and low density tract are 4,675 or 38% and 301 or 4.95%, respectively.

$$\text{Therefore, } SI = \frac{[[4.95\%-38\%]+ 1] * 50}{100} \quad \ldots. (2)$$

$$= 33.5$$

The calculation result of sprawl condition in the district is equal to 33.5 of 100. Thus, this result implies that Latkrabang District does not have a

very high sprawl condition. In addition, the result of above analysis based on four factors in Ewing (1997) indicated a least sprawl situation in the district as it is moving towards urbanization as well as high density population. The result of sprawl measurement confirms that the characteristics of urban sprawl as separated residential, limited street connections, and low population density in the study area, do not appear in the study area. Due to mixture of activities such as job locations, school, commercial, and residential areas located close together, showing a clustered development that creates high density population in the district. However, the lack of public transportation services for people traveling especially to the inner city leads to continuation of sprawl in this district because of the automobile dependency aspect.

3.2 Air Pollution Analysis

The effect of urban sprawl has created a growth of number of vehicles in the community and traffic congestion that directly relates to air pollution and health problems. An increasing automobile dependency will create high air pollutant emissions in the community. The emissions of mobile sources as PM_{10}, CO, NO_x, SO_x, was focused since they are major emission of mobile sources in Latkrabang District (PCD, 2002).

3.2.1 Calculation of Traffic Volume's Emission

The equation for calculation emission from mobile sources by using the emission factor, traffic volume, and travel

$$Q = (Eft(sl)Vl) \quad \text{……..…..(3)}$$

speed data was used below equation (3) as;
Where;

- Q = Quantity of Pollutant of traffic volume
- Eft = Emission Factor of each vehicle type (g/km)
- sl = Travel Speed (Km/hr)
- Vl = Traffic Volume of each vehicle type (vehicles).

Emission Factor:
The emission factor is defined as the estimated average emission rate of a given pollutant for a given class of vehicles that is

Table 3.
Emission Factors (JICA, 1997)

Pollutants	Vehicle Type*	Average Speed (Km/hr)
		9
PM_{10} (g/km)	Small	1.86
	Medium	3.26
	Large	7.51
	MC	9.02
CO (g/km)	Small	146.63
	Medium	3.49
	Large	19.78
	MC	67.52
SO_2 (g/km)	Small	0.53
	Medium	0.78
	Large	1.60
	MC	0.20
NO_x (g/km)	Small	2.03
	Medium	1.84
	Large	21.18
	MC	0.20

useful for emission calculation (Zhongan, 2002). The emission factors in Thailand (JICA, 1997) were used to estimate emission of vehicle in Hau-Takhe community.

Travel Speed:
The result from the observations was found that the travel time during traffic congestion and non-traffic congestion of Onnuch Road (3 Km of road length) in the community that is 20 and 5 minutes, respectively. Therefore, travel speed of vehicles in the community of both traffic and non-traffic congestion period can be calculated below:

$$\text{Traffic period} = \frac{3\text{Km}}{20\text{min}} * \frac{60\text{ min}}{1\text{ hr}} = 9\text{ Km/hr}$$

$$\text{Non-traffic period} = \frac{3\text{Km}}{5\text{min}} * \frac{60\text{ min}}{1\text{ hr}} = 36\text{ Km/hr}$$

mi

The travel speed is 9 Km/hr that was used to calculate emissions as the high emission volume that was found in low travel speed of vehicle (PCD, 2002).

Traffic Volume:

According to DTT (2004), the traffic volume in Hau-Takhe community was composed mainly by cars, pick-ups, buses, trucks, and sam-loe (motorcycle not count of this survey).

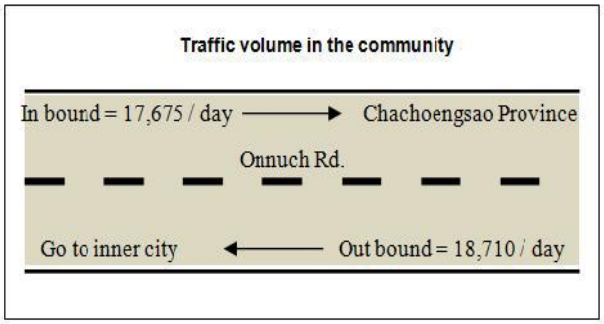


Figure 3. Traffic volume in Hau-Takhe community

Pick-ups were found to be the largest group on Onnuch Road about 42.1%, while buses were found to be only 3.1%. During the peak hours (between 7 am - 9 am) higher amount of vehicle category is pick-up (1,618 cars) that goes to outside of community boundary as regular activities of their work on the major road of community (Onnuch Road). The same day on 4 pm - 7 pm high traffic volume of pick-ups (2,458 cars) that came in the community. Therefore, the high volume of vehicles during peak hours (7 am - 9 am) was used for estimation since the average of vehicles per hour is higher in 9 am - 4 pm than 4 pm-7 pm of period time that also created traffic congestion.

The result of emission calculation of traffic volume in the community was shown in **Figure 4.**

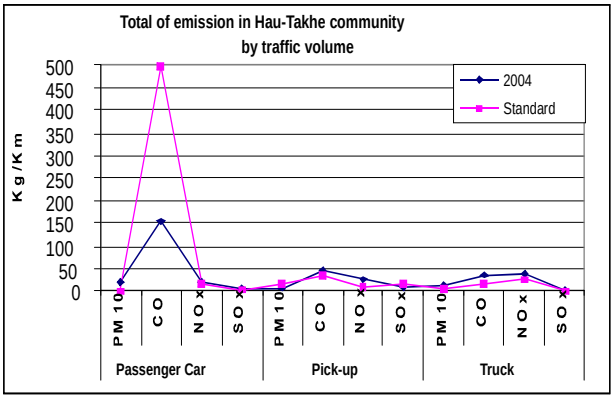


Figure 4. Total of Emission in Hau-Takhe Community by Traffic Volume in 2004

Above figure show the emission of passenger is NO_x, and SO_x that lower than other types of vehicles, but it the major contributors of CO in the community. Trucks and buses pollute high levels of CO and NO_x which also higher than emission standard. Therefore, the high emission volume in the community especially CO and NO_x will affect health of people such as blood and heart problems and headaches. Especially, the people who live near the main road are at risk of health problems due to traffic congestion.

3.2.2 Estimated Emission of Air Pollution from Vehicle

Percentage of vehicle growth from 1990 to 1995 was 3.03, and 6.29 during 1995 to 2000, while the percentage of vehicle growth in 2000 to 2004 was 0.96 (of four years). This would lead to a serious air pollution situation in the future due to population growth which directly increases the automobiles. The rapid population growth in Hau-Takhe community will also be contributing to the growth in the number of vehicles and air pollution in the largest community in the Latkrabang District.

Trends of air pollution in community used the same emission equation in section 3.2.1 However, the trends of number vehicles under the population growth and travel speed in the future need to be analyzed.

Trend of vehicle in community:

Projection population method to estimate the number of vehicles was applied for analysis. According to the statistical report of Latkrabang District Office (2004), the number of population in Hau-Takhe is 10,774 and 18,845 in 1995 and 2003, respectively. Therefore, population projections can be calculated by using Gibbs Method (GM) to find the population and rate of change between 1995 to 2003 below equation (4) and (5):

$$()trPPPt10011+= \text{……..(4)}$$

$$()()()20110001PPtPPr+\times-= \text{……..(5)}$$

where, $P0$ = Population of earlier in the last past
$P1$ = Population of present
t = Time interval
r = Growth rate

From above equation (5), the growth rate of population in community can be calculated as follow:

$$()()()2774,10845,181008774,10845,18+´-=r$$
$$= 6.8\% \text{ per year}$$

Latkrabang District has a development policy based on 5-years plan (LDO, 2003), therefore the population projection corresponded to this plan in order to make it useful for planning in the future. Hence, the 5 year steps to estimate population in Hau-Takhe community are 2005, 2010, and 2015. The population projection in Hau-Takhe community can be represented using the trend of vehicle growth in the community.

According to LTD (2004), the average population per each type of vehicle of Latkrabang District is 6.58, 7.19, 43.00, and 24.58 of pick-up, car, motorcycle, and truck respectively. Therefore, using the average population per each type of vehicle in Latkrabang District can be estimated the number of vehicle in Hau-Takhe community in 2003, 2005, 2010, and 2015 to calculate emission as shown in **Table 5**.

Table 5
Population Projections in Hua-Takhe Community

Type	Pop. 2003	Pop. 2005	Pop. 2010	Pop. 2015
No. of Pop.	18,845	21,407	28,686	38,439
Passenger car	2,862	3,253	4,360	5,841
Pick-up	2,620	2,977	3,990	5,346
Truck	438	497	667	893
Motorcycle	766	870	1,167	1,563
Total	6,692	7,597	10,184	13,643

Travel Speed:

According to OTTPP (2004), the policy of transportation improvement of mass transit system around Bangkok's city as well as to support transportation in suburban area can be efficiently transportation network in the future. Due to airport project locates in western of Latkrabang District especially it near Hau-Takhe community which government provides mass transit to support this project. Therefore the speed average of vehicle in terms of mass transit improvement in community was used to calculate volume's emission from mobile sources. The travel speed during peak hour in suburban area is 18.90 Km/hr.

The result of emission calculation in 2005, 2010, and 2015 in community was shown in **Table 6**.

Table 6.
Estimated Vehicle's Emissions

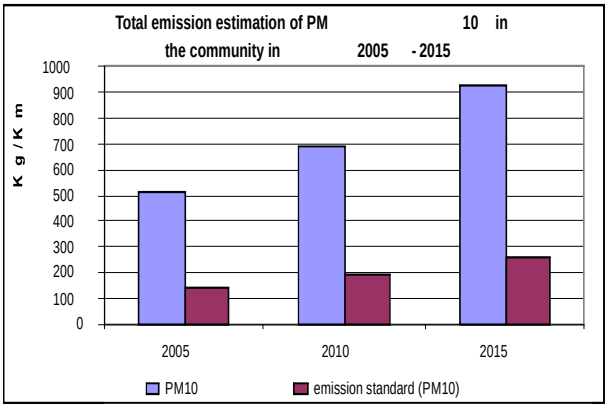
Type	Emission	Year (By using emission factor) (kg/day)		
		2005	2010	2015
Passenger Car	**PM_{10}**	**0.31**	**0.41**	**0.56**
	CO	**24.69**	**33.10**	**44.34**
	NO_x	0.08	0.11	0.16
	SO_x	0.34	0.45	0.61
Pick-up	**PM_{10}**	**0.50**	**0.67**	**0.90**
	CO	**0.53**	**0.72**	**0.96**
	NO_x	0.12	0.16	0.21
	SO_x	0.28	0.38	0.50
Truck, bus	PM_{10}	0.19	0.25	0.34
	CO	0.50	0.68	0.91
	NO_x	**0.04**	**0.05**	**0.07**
	SO_x	0.54	0.73	0.97
Motorcycle	PM_{10}	0.40	0.54	0.73
	CO	**3.04**	**4.08**	**5.46**
	NO_x	0.009	0.012	0.01
	SO_x	0.009	0.012	0.01

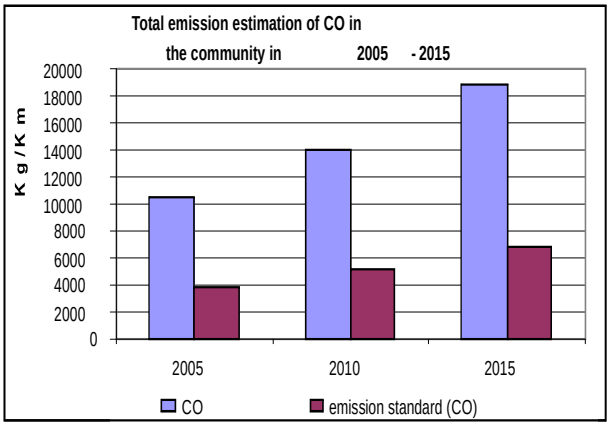
As shown by the emission estimations in **Table 6** (passenger car, pick-up, and motorcycle) is found to be CO, while major emission in terms of volume is NO_x for trucks. In addition, the amount of emission in 2005, 2010, and 2015 from number of vehicle in the community was analyzed while comparing the vehicle emission standards of Thailand in order to identify whether the emission levels exceed the standards or not.

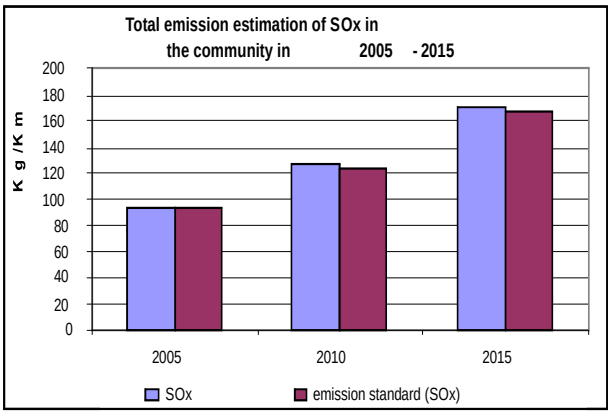
Table 7.
Vehicle Emission Standard of Thailand (PCD, 2002)
(Unit: g/Km)

Vehicle types	PM_{10}	CO	SO_x	NO_x
Passenger car	0.14	47.53	0.33	1.70
Pick-up	1.19	2.40	1.10	0.68
Truck	3.36	9.80	0.86	14.40
Motorcycle	2.20	35.50	0.14	0.11

As shown in **Figure 5.** the total emission estimations of PM_{10}, CO, SO_x, and NO_x in 2005, 2010, and 2015, are higher than the standards. The controlling emission, therefore, needs to be intensively focused. The enforcement of inspection programs of vehicle regulations, and reduction in number of vehicles as well as encouraging people to use public transport services must be encouraged to mitigate air pollution from mobile sources in the community. The high emissions from vehicles will affect the health of the people and the environment in Hau-Takhe community.







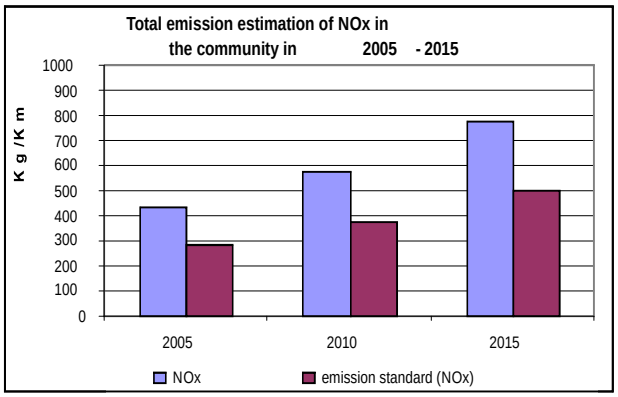


Figure 5. Total of emission estimation of PM_{10}, CO, SO_x, and NO_x in Hau-Takhe Community in 2005-2015.

4. DISCUSSION

As investigation on urban sprawl condition in Hau-Takhe community due to economic development spreading out of metropolitan area of Bangkok such various development projects including the airport, industrial estate, academic institution, and motorway contributed further to population growth, traffic congestion, land consumption, and environmental degradation in the area without insufficiently planning. This phenomenon is normally founded the government policies has tried to promote infrastructure and economic development in the mega urban area to suburban area and inadequately planned development (Downs, 1999).

Even the sprawl condition of the district is not quite high degree of urban sprawl condition, but insufficiency of public transport and using private vehicles are still be one characteristic of sprawl as automobile dependency in the community such McDonald (1998) defines urban sprawl of automobiles utilization for travel to inner city due to lack of public transportation and difficulty to implement mass transit in low density and segregate of land use.

Therefore, to reduce automobile dependency in the district, compact development is an important part of land use management strategies including access management, location efficient development, new urbanism, smart growth and transit oriented development. Compact development can have a variety of equity impacts. Policies that support clustering often involve reducing cross-subsidies for low-density, urban-fringe development (Lenian, 1993). This concept of land use development as well as compact development in suburban area in the case of Hau-Takhe community could be solving the impact of urban sprawl. Especially, Hau-Tahkhe community is currently the community center of Latkrabang District, which need to be promoted and encouraged compact development to support population growth and fulfill the efficient public transportation services as basic mobility for people. Also, to reduce air pollution in the community that can be seen clearly through land use and transport provision as shown in **Figure 6**.

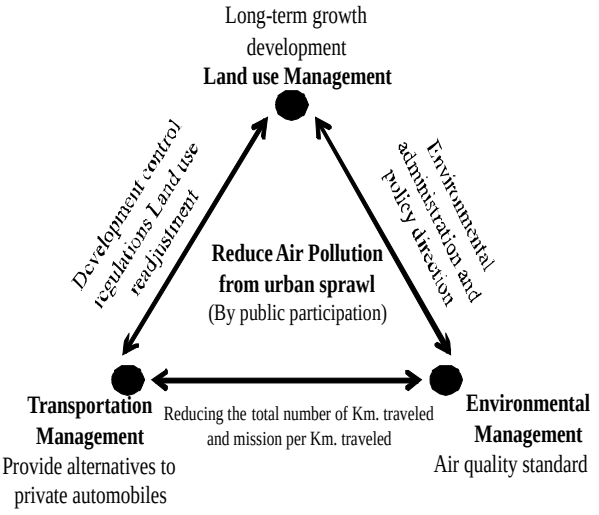


Figure 6. Three principles to reduce air pollution

An emission analysis of vehicles by traffic volume indicates the major polluted emission is from passenger and pick-up cars and the main pollutants are CO and PM_{10}. All these emissions in Hau-Takhe community in 2005 to 2015 are estimated higher than Thai standard for ambient air. This can be one decision-making for local government to implement project and plan for Latkrabang District's five years plan to reduce vehicular emission. Especially, inspection and maintenance vehicle program should be efficiently and more focused on CO and PM_{10} parameters.

Air pollution in the community needs to be controlled and well managed as the local government is working with other stakeholders to set up policies and programs to mitigate the problem. The constraints of local government to implement air quality management in Hau-Takhe community are lack of personnel, with limitedly-skilled officials, and lack of financial support that worsen cooperation with central organizations (Field survey). Lack of preparedness increases dependency in decision-making and budget controlling as financial source is at the central government's stake. Furthermore, public participation in air quality control is not in place especially with the decision-making process.

6. CONCLUSION

The study shows that airport, industrial estate, education center, and motorway are the main factor for urbanization in the community. However, as incomplete compact development in the district and insufficient public transportation in high residential area leads to automobile dependency for people commuting and leading to traffic congestion. This has created air pollution which is harmful to the environment and health of the people in the community. The study of emission prediction shows that the emissions will shortly exceed the standards, especially those pollutants from mobile sources in the community.

Therefore, air quality management is urgently needed, especially with respect to inspection and maintenance of the vehicle program and more focus on long-term air pollution policy. However, regarding to urban planning and development in suburban areas of Bangkok some area is far from the city that requires costly transportation and infrastructure services to support people. At the same time, the contiguous area of Bangkok will continue to sprawl. There is an immediate need to provide the next wave of development into a more coherent and efficient pattern. This is still a problem of urban development in Bangkok for the future

7. ACKNOWLEDGEMENTS

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