PROMOTING TRAVEL DEMAND REDUCTION IN TRANSPORT SECTOR IN CITIES OF ASIAN DEVELOPING COUNTRIES: CASE OF BANGKOK

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Abstract

Urban land use observably induces and generates traffic particularly where segregation among categories of land uses are distinct. Zoning in land use that distinguishes residential and commercial zones would create the needs of motorized transport due to journey to works and other purposes, provided that the proximity between residential and commercial zones is absence. In Bangkok, this state exists because of significant residential developments in the suburban areas. Bangkok has been sprawling into various directions particularly to North, Northeast, East and Southeast to form Bangkok Metropolitan Region. This experience makes motorized travel demand increasing, and reducing it would be indispensable from the environment and energy viewpoints. This paper explores the current conditions of land use and transportation relationship in Bangkok that affects urban air quality.

With the growing number of population of Bangkok and insufficient integration of transit systems, the number of private vehicles operating on road is increasing every year. Since vehicles predominantly use fossil fuels this trend has lead to the degradation of air quality until 1996. However, with synergistic efforts in both urban development and transport sectors that commenced in 1997, the air quality in Bangkok is considerably improving. A number of solutions had been adapted to cope with the problem of air quality. While urban planners introduced strategies to promote poly-centric development of the city and thereby dispersing the traffic to limited areas, the transport planners employed a series of measures to reduce the vehicular emissions. The cumulative effects of these strategies are evident by the improving air quality in terms of most indicators. The paper suggests to create pedestrian friendly environment in inner city areas that could further improve urban air quality since it encourages non-motorized travel.

Keywords: land use, transport, air quality, transport modes, passenger-kilometer traveled.

1. Introduction

Urban growth is usually associated with environmental problems. It is true that urban areas in developed countries are encountering less environmental problems. This is because this group of countries has sufficient technological and financial capability to cope with the problems. Developed countries are able to provide better urban environmental management than their counterparts in developing countries. Irrespective of the status of development, air pollution exists in both groups of countries. However developing countries are confronting with worse situations than developed countries. This can be explained by looking deeply into inverted *Kuznet Curve* (inverted U-shape) as shown in a cross country study undertaken by World Bank in 1992 (World Bank, 1992; Field, 1997). The Curve signifies that level of environment degradation will amplify up to a certain point of gross national product (GNP) of a country and then it will decline beyond that point when GNP increases. This phenomenon is also valid in the case of air pollution as an environmental problem.

Air pollution has been a concern in many urban areas in developing countries since it leads to adverse impacts particularly on human health. This paper tries to explore the correlation among three urban parameters viz; land use, traffic and air quality in some Southeast Asian Cities. It attempts to look into

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fundamental comprehension on the impacts of land use on urban physical mobility, and at the end how it affects the urban air quality.

Transportation is one of the important functions in urban dynamics. Need for transportation increases in line with the growth of urban area as well as growth of urban economy. On the other hand, urban growth is characterized by the change of land use, thus there is a close correlation between change of land use and change in transportation needs. The relationships between transportation and land use have been investigated by many researchers. Many descriptive and analytical models have been developed, each providing a dimension of investigation and explanatory elements in the urban spatial structure (Carter, 1995).

Coping strategies to reduce air pollution problems can be viewed in terms of three components, which are transportation infrastructures, modes of transport and road users. The provision of adequate capacity of roads to cater the maximum traffic loads can reduce air pollution by creating free flow of traffic. At the same time it encourages people to have private cars. Creating the conditions that encourages the use of mass transportation system can directly improve urban air quality. Reduction of air pollution caused by vehicular traffic can be accomplished by modifying travel pattern (e.g. reducing needs of motorized travel by creating the proximity of origin-destination up to the level of walking distance).

In addition to those direct means, some indirect means to reduce air pollution with respect to land-use can also be introduced by creating the proximity of Origin (O) and Destination (D). With the closeness of O and D, the need for motorized travel will also be reduced. Moreover, inter-categorical links of land use may indirectly minimize the impact of air pollution. These approaches will probably be achieved through the modification of land use. These arguments postulate a linear causality between air pollution, transportation and land-use. In the rest of the paper, it is attempted to examine the land-use, transport and air quality nexus in a city of South East Asia.

2. Bangkok, Thailand

Bangkok, the capital city of Thailand, was once a notoriously congested and polluted city. This was mainly attributed to the high dependency on private vehicles for transportation. In other words, Bangkok epitomized a highly car depended metropolis. However with synergistic efforts since early 1990s, air quality in Bangkok has significantly improved. Among other attributes, the urban development strategies introduced by the Bangkok Metropolitan Administration have significantly contributed to improve the air quality.

2.1. Land Use in Bangkok

Present land use in Bangkok Metropolitan is identified within two broader zones, comprising the inner city districts within 10 kilometers of the Rattanakosin Area which is the main concentration area for government offices, commercial activities, educational establishments and living quarters. The outer bound is defined as the next 10 kilometers ring functioning as the new central business district accommodating outward increase in the numbers of businesses and commercial activities. Presently, the key government operations and businesses and commercial activities are concentrated in these inner city bounds and it continues to be the major employment areas. Intensification of economic activities and continued demand for centrally located sites is the main reason for the rise in land price in these locations. The outer part of Bangkok is defined as the 20-40 km ring from the centre. These areas are linked to the center by a set of roads radiating northwards and southwards to Nonthaburi and Samutprakarn Provinces and eastwards and westwards to Chachoengsao and Nakhon Pathom Provinces respectively (see Figure 1). Around 25 percent of these suburban areas were classified as residential areas. The remaining 75 percent of land are utilized for manufacturing and commercial activities while large parts of the land remain under agricultural production. The outward expansion of economic activities together with the economic and environmental factors is likely to intensify land use in these fringe areas. Though linked with the inner city by expressways and arterial roads, inadequate distributor roads and access roads and poor urban amenities are said to be the prevalent problems of these areas.

The pattern of urban land use in the outer metropolitan areas has been mainly influenced by private developers due to weak enforcement of planning and control measures. During the early 1980s, population density increased rapidly on the eastern side of the city. Although lower in density, the Urbanization on the western part of the city was mainly at the expense of losing agricultural land. The recent completion of the outer ring road circling Bangkok will expedite urban sprawling to almost all sides

of the city including the adjacent provinces. The present trends indicate that the city is sprawling to the Pathumthani province in the north and Nonthaburi and Nakhonpathom provinces in the west with new residential developments.

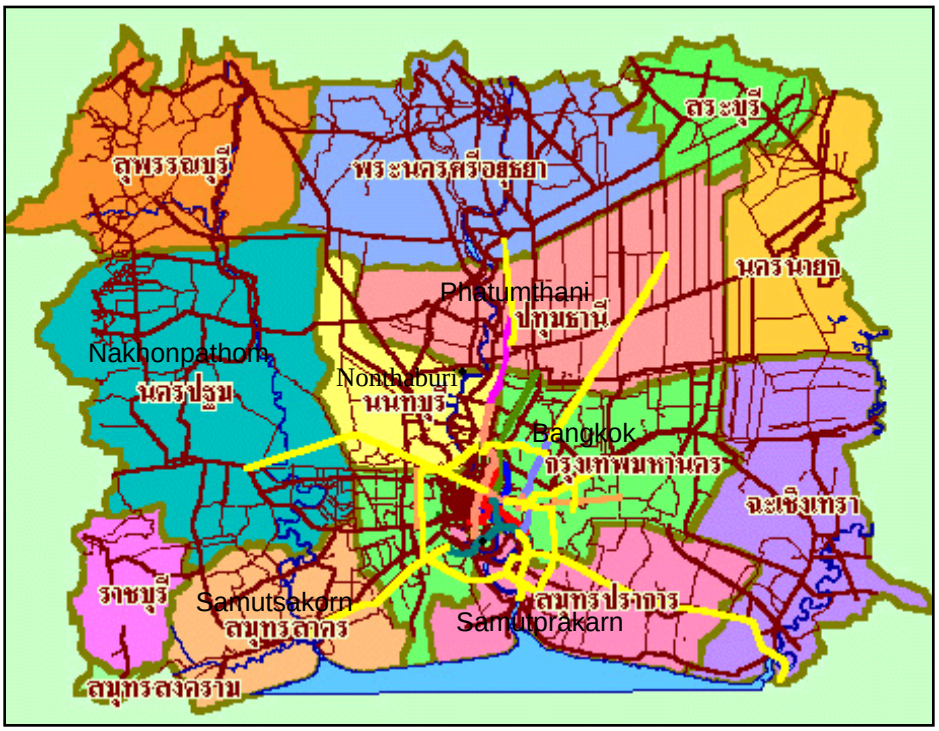


Figure 1. Bangkok and Adjacent Provinces

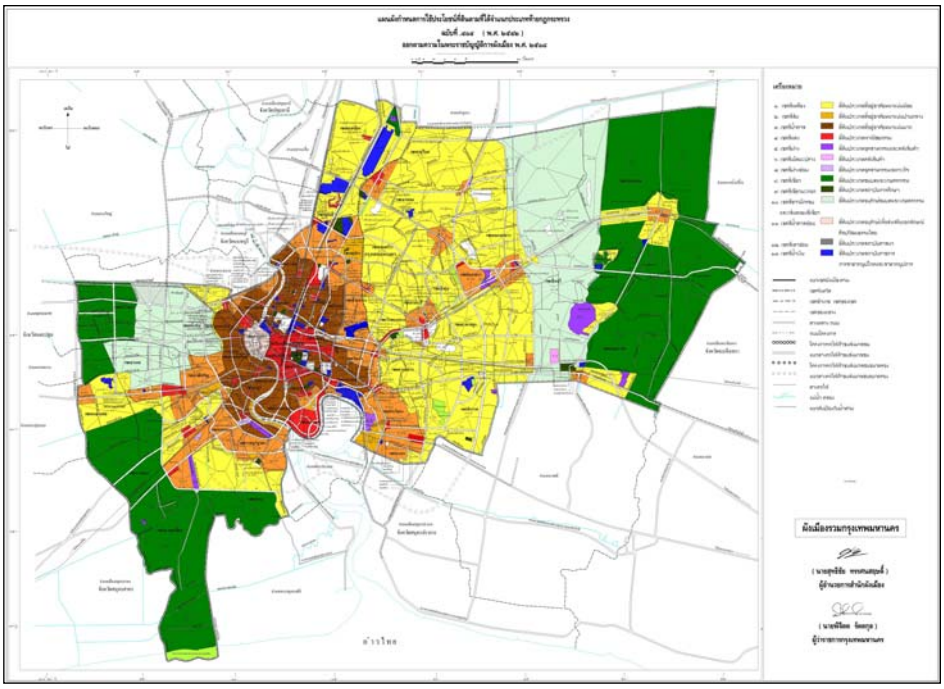


Figure 2. Bangkok Metropolitan Comprehensive Land Use Plan
Source: Bangkok Metropolitan Administration (http://www.bma.go.th)

Figure 2 depicts the first Revision of Bangkok Metropolitan Land Use Plan of 1999. However with current needs of development, the plan has been revised for second time in 2006. The Second Revision of Bangkok Metropolitan Land Use Plan was promulgated in May 2006. Significant changes in the revised plan include an emphasis on developing a multi-nodal metropolitan with a ring of sub-centers. This is an attempt to reduce the significance of CBD areas. While the city center remains as the commercial and financial hub, the sub-centers are promoted as growth centers to attract new investments and new housing. The urban planning strategies that contribute to improve the air quality in Bangkok are outlined in section 2.2.

2.2 The Bangkok Comprehensive Plan of 1999

Bangkok Metropolitan Administration has planned and made Bangkok Metropolitan Comprehensive Plan (1st revised edition) in 1999 and made it effective by the enactment of Ministerial Regulation Number 414 BE 2542 (1999), which was released under the City Planning Act 1975 and announced in the government gazette the royal decree edition 116 section 57 on 5th July 1999. The comprehensive plan has the objectives to guide Bangkok Metropolitan urban development and peripheral conservation and preservation for the purpose of comfort and better life of the citizen. Five broad objectives of the plan are:

- To conserve the historical and cultural heritages and to maintain the national identity.
- To preserve valuable natural and environmental resources, and simultaneously improve the quality of life;
- To create technological information based economy which is essentially centered by excellent administration and communication;
- To improve the city's accessibility by improving an efficient mass transit system;
- To achieve more efficient land use plan in order to accommodate future growth of the metropolitan.

To achieve these objectives, the Bangkok Metropolitan Administration promoted following strategies:
Strategy 1. To develop polycentric city by strengthening existing business centers which are located in the city center (hatched area as shown in Figure 3) and develop other commercial and residential areas scattered in the outskirt areas (shown as red-shaded areas).

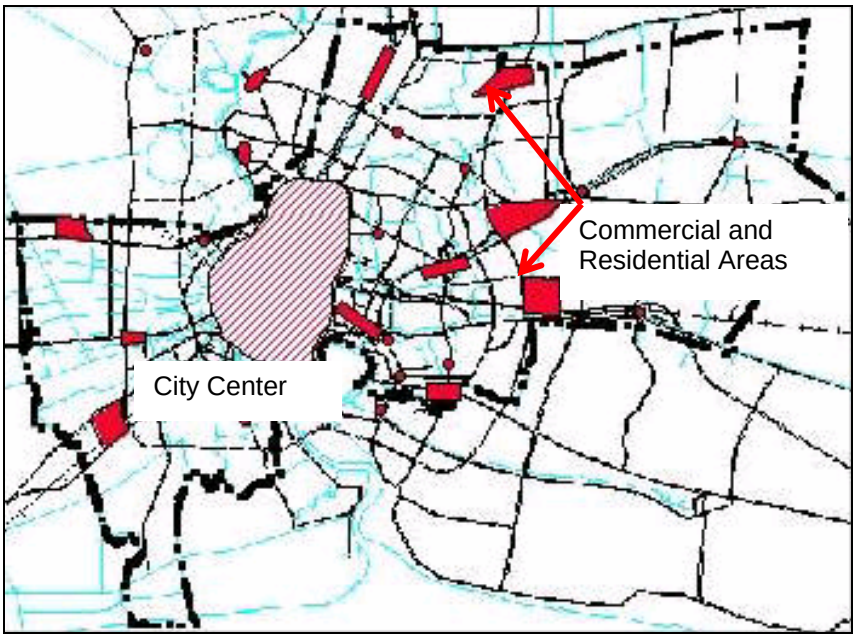


Figure 3. Implementation of Strategy 1
Source: City Planning Dept, BMA

Strategy 2. To preserve and conserve cultural heritages in the areas around and nearby Rattanakosin Island, as shown by thick outlined area in Figure 4. This strategy is mostly implemented by means of building control.

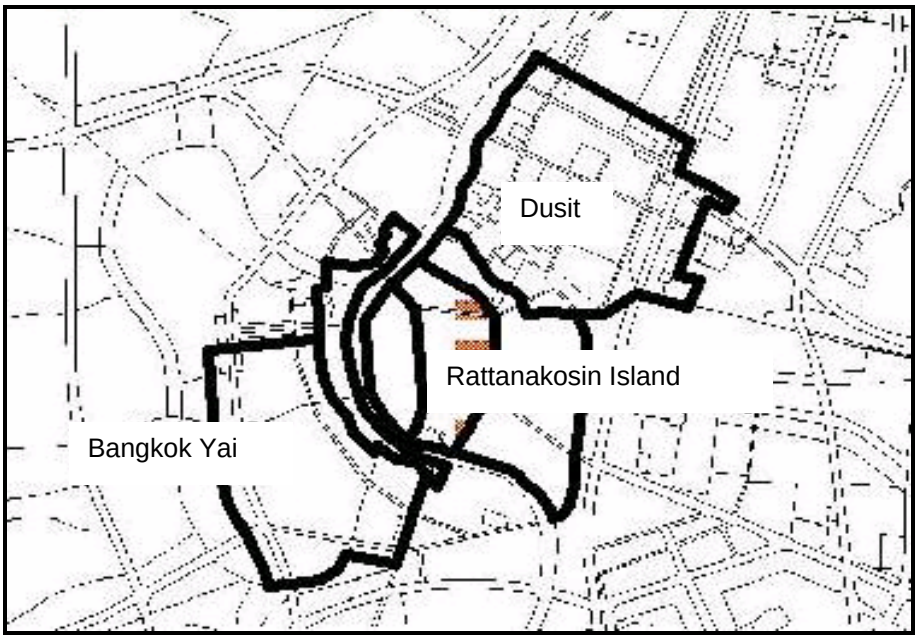


Figure 4. Implementation of Strategy 2
Source: City Planning Dept, BMA

Strategy 3. To set up effective land use for future public transportation networks, and other public utilities and infrastructure nearby public transportation nodes/stations. These are shown in Figure 5 below, as represented by red dots.

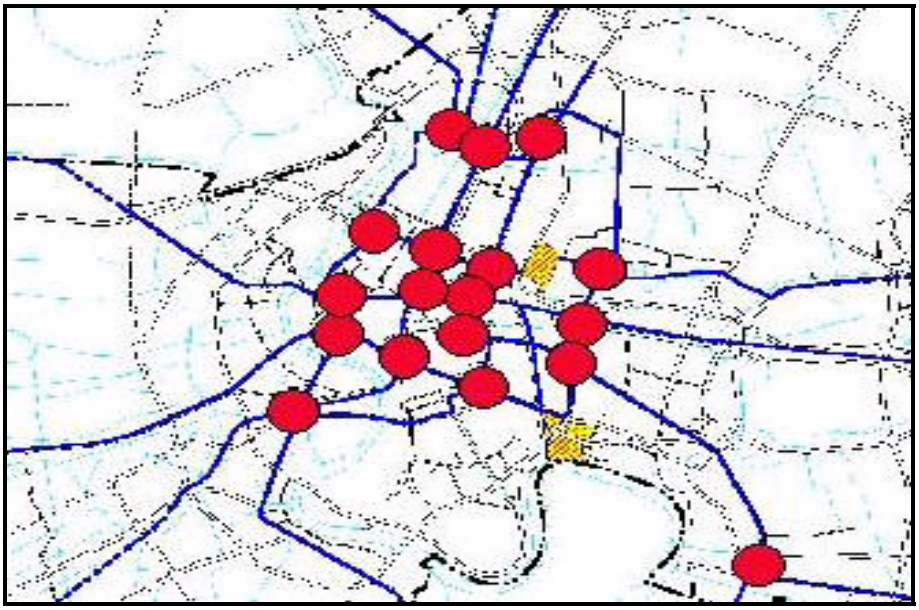


Figure 5. Implementation of Strategy 3
Source: City Planning Dept, BMA

Strategy 4. To set up the special development areas (Chaeng Wattana Government Center, Bangsue Commercial Center, Rama III Special Development Area. as shown in Figure 6) to reduce the pressure on central business district.

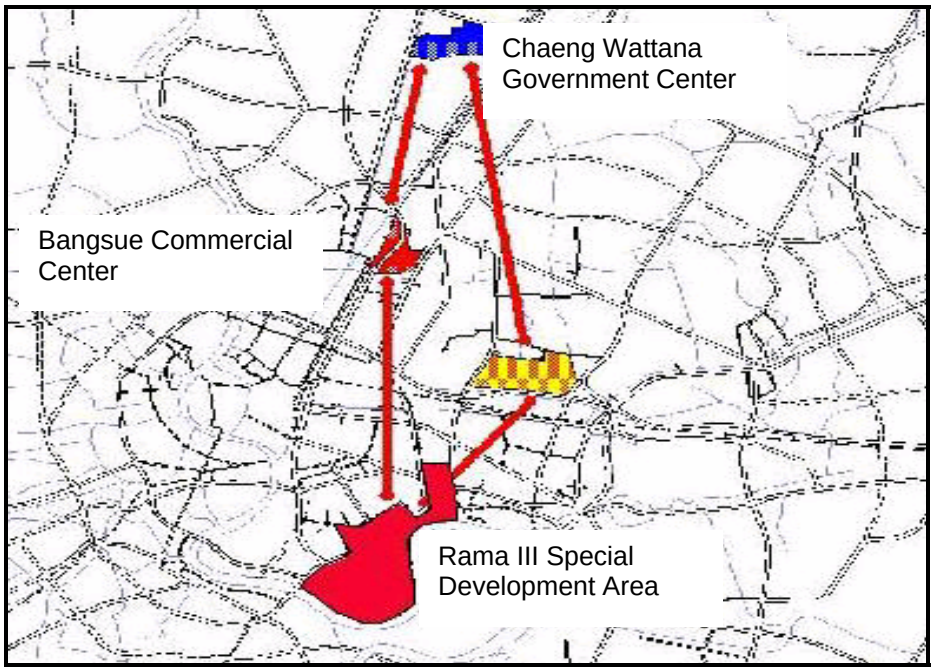


Figure 6. Implementation of Strategy 4
Source: City Planning Dept, BMA

Strategy 5. To adjust the travel convenience by integrating all urban transport modes in Bangkok, through smooth transit system as shown in Figure 7.

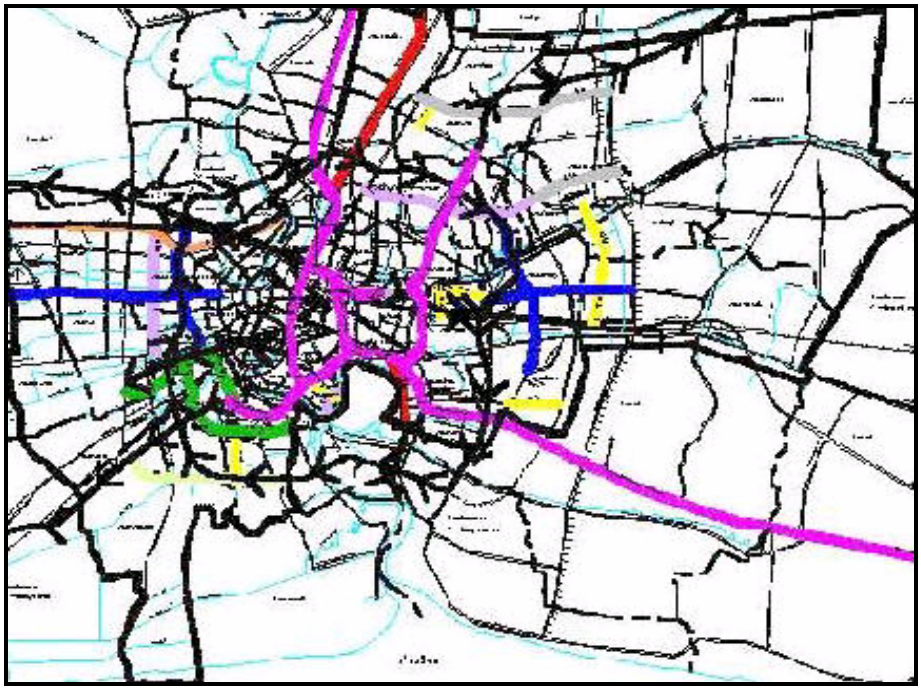


Figure 7. Implementation of Strategy 5

Strategy 6. To promote the urban environment by encouraging urban parks, reducing air and water pollution, and undertaking appropriate solid waste management, as shown by green-dot in Figure 8.

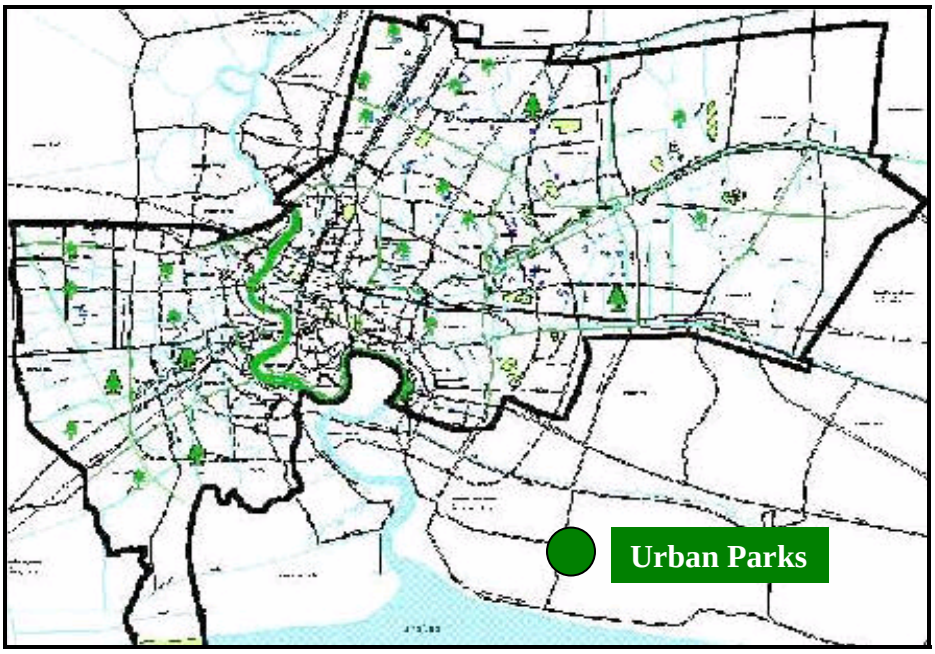


Figure 8. Implementation of Strategy 6
Source: City Planning Dept, BMA

Strategy 7. To promote the balance between workplaces and residential zones, by promoting mixed land uses, as shown by yellow hatched area in Figure 9.

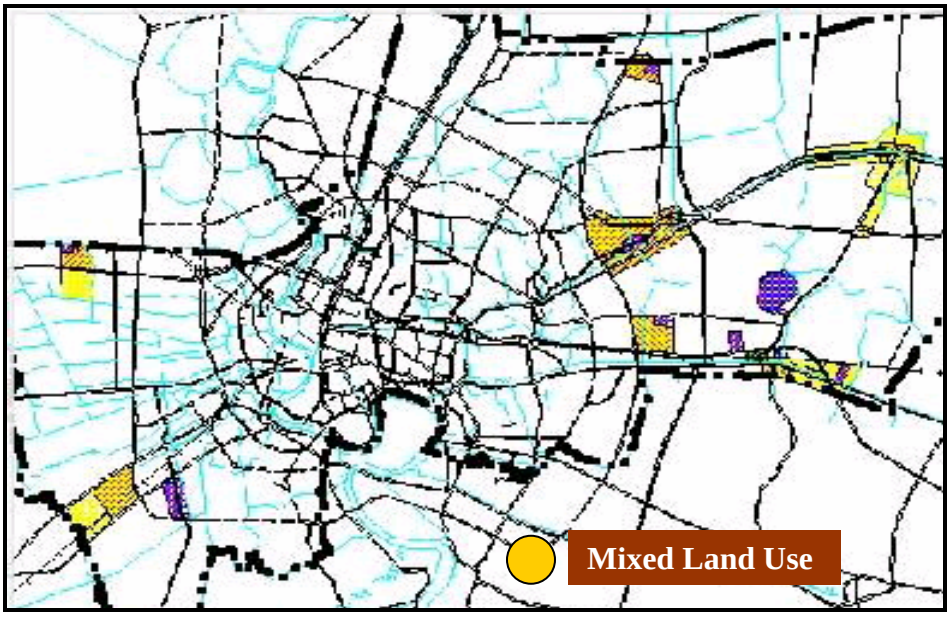


Figure 9. Implementation of Strategy 7
Source: City Planning Dept, BMA

Strategy 8. To promote urban containment in order to reduce urban sprawl by encouraging major developments are undertaking inside the outer ring road frame. This is shown in Figure 10.

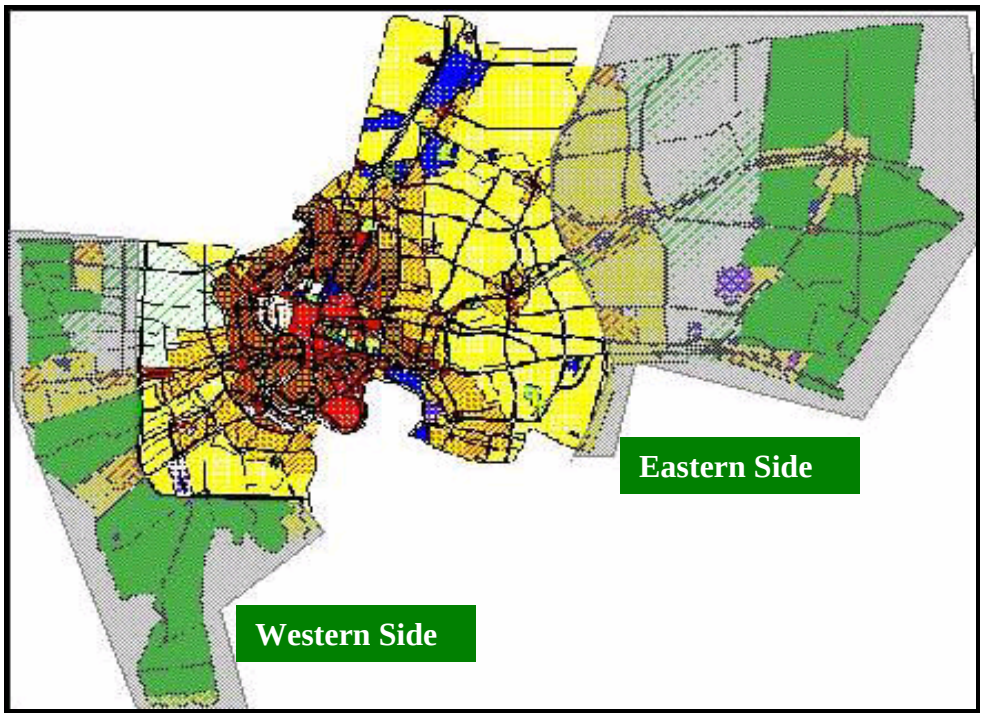


Figure 10. Implementation of Strategy 8
Source: City Planning Dept, BMA

These strategies indicate that there had been a great emphasis on developing a poly-centric city so that people and traffic are not converging into the city center. In other words BMA has been very conscious in solving the traffic problem that plague the city and thereby reduce the air pollution level through a series of land-use planning and urban development strategies. The strategy 5 above tries to adjust the efficiency of the transportation system by integrating all urban transport modes in Bangkok, through smooth inter-modal changes.

2.2. Current Status of Transportation in Bangkok

Bangkok has been expanding from Bangkok as a city (BKK) to Bangkok Metropolitan Area (BMA) and also expanded physically to be the Bangkok Metropolitan Region (BMR). The BMR consists of Bangkok Metropolitan Area (BMA) and its five peripheral provinces, viz; Samutprakarn, Nonthaburi, Pathumthani, Nakhon Pathom and Samut Sakhon, covering 7,758 km^2.

There are various public transport modes available in BMA. In terms of approximate contribution to passengers kilometer traveled, city buses are the largest contributors. Thereby this transport mode contributes significantly to either improvement or degradation of the urban air quality in Bangkok. Improvement of urban air quality would be accomplished with appropriate policies on city buses. In the same fashion, private cars are the biggest contributors in terms of vehicle-kilometer traveled. This indicator signifies that private cars play an important role in the improvement of urban air quality in Bangkok Metropolitan. The passenger-kilometers traveled and vehicle-kilometer traveled of different transport modes in 2005 are shown in Table 1.

Table 1. Passenger-kilometer Traveled and Vehicle-kilometer Traveled per Year for Various Transport Modes in Bangkok of 2005

Transport Mode	Capacity (Passenger)	Number of Fleets	Vehicle-kilometer Traveled per Year	Passenger-kilometer Traveled per Year
Taxies	4	53,000	286,200,000	572,400,000
Tuk-tuk	3	7,500	20,286,000	40,500,000
BTS Sky train	1,000	40	2,032,380	1,728,000,000
City Buses	35-60	8,177	288,036,000	6,623,370,000
Microbus/Van	12	5,519	238,400,000	2,384,208,000
Express Boat	100	47	472,320	28,350,000
MRT-Subway	1,000	44	1,944,000	972,000,000
Motorcycle Taxis	2	50,000	28,800,000	57,600,000
Private Cars	4	1,700,000	1,834,560,000	3,672,000,000
Motorcycles	2	2,300,000	1,490,400,000	1,490,400,000

Source: Thanaprayochsak, 2005

Passenger-kilometers traveled (PKT) and Vehicle-kilometer traveled (VKT) are illustrated in Figure 11 and 12. Figure 11 shows that city buses contribute to the total PKT in BMR for about 37.7 percent, while private cars as the second largest contributor has 20.9 percent share. In terms of vehicle-kilometers traveled as shown in Figure 12, private cars contribute about 43.8 percent and motorcycles 35.5 percent. The phasing out of leaded gasoline, the use of CNG for private cars and taxis, limiting the age of taxis to 3 years, converting some fleet of public busses to NGV vehicles, and banning of two-stroke motorcycle engines have all significantly contributed to the improvement of urban air quality in Bangkok.

From the figures 11 & 12 it is apparent that city buses and private car users are potential shareholders to be handled for alleviating congestion problems and air quality issues. Prior to take this action, expansion of excellent but affordable public transport and integration of all public transport modes with smooth transit system are indisputable to compensate the comfort that has been sacrificed by private cars users. The elevated light rail and the subway have shown encouraging signs that some car uses have changed these transport modes. This is very visibly indicated by popularity of the park and ride facilities near some rail stations. Therefore, the park-and-ride system needs more promotion and expansion to attract more car users to mass transit systems.

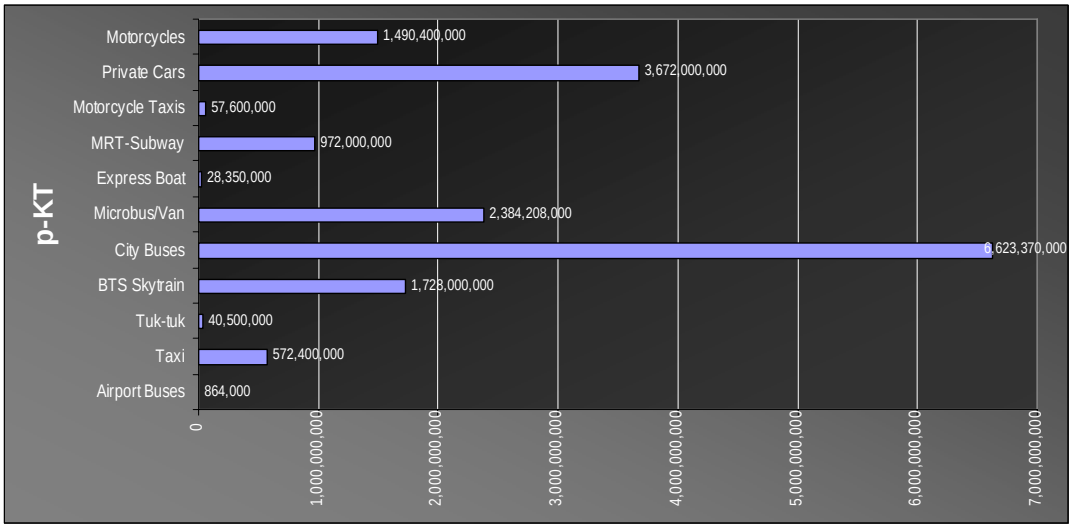


Figure 11. Passenger-Kilometer Traveled per Year in Bangkok in 2005

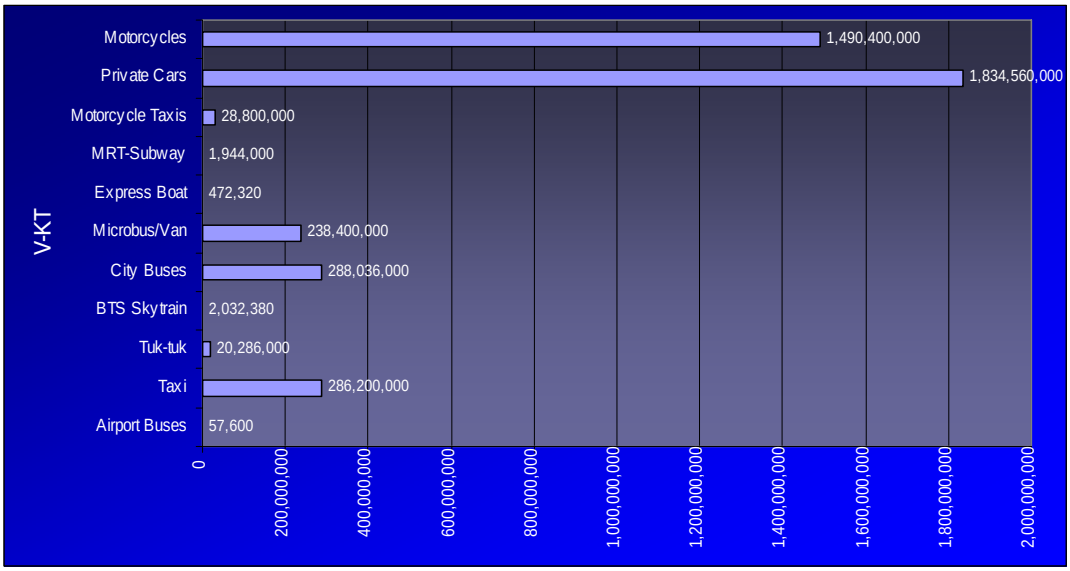


Figure 12. Vehicle- Kilometer Traveled per Year in Bangkok in 2005

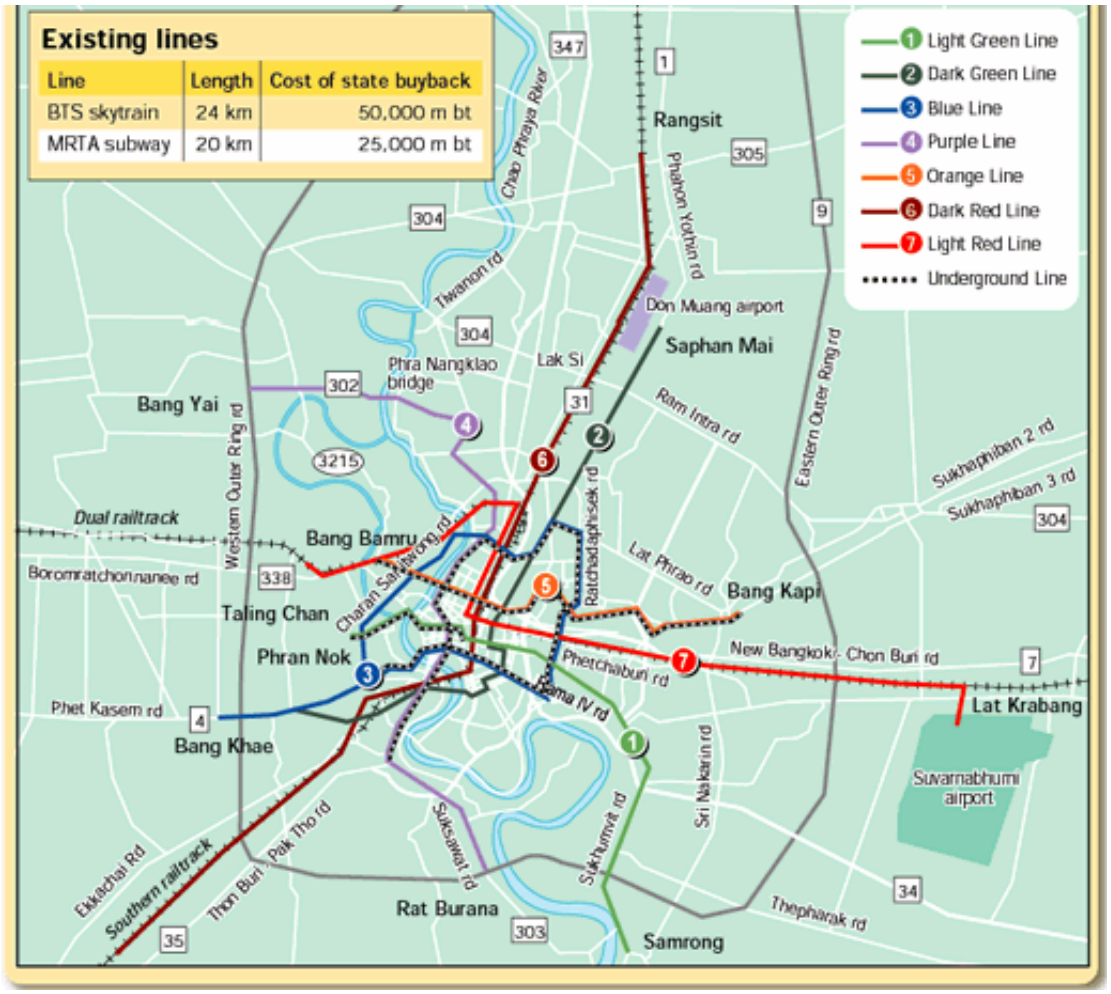


Figure 13. Bangkok Transportation Network
Source: www.bangkokpost.com

The Transportation Network in Figure 13 shows different types of transportation modes either planned or existing. The Bangkok Transport Network is back-boned by BTS sky-train that serves two lines: Sukhumvit Lines and Silom Lines with total length is 24.0 km. While Chaloem Rachamongkhon Line MRTA subway connects Bangsue and Hua Lamphong, with total length of 20 km. As shown in table 1, city buses, both air conditioned and non-air conditioned, are the most contributors of transport modal splits in terms of passenger kilometer with more than 6.6 billion passenger kilometers in a year. Microbus Van and BTS sky-train are the second and third largest contributors of public transport in Bangkok Metropolitan Region. With the introduction of five more LRT lines, BMA is expecting to reduce traffic congestion further. Presently one of the existing lines is extended while a new route linking the new airport and the city center is under construction (No.7 line).

Public transport system in Bangkok was drastically changed when the Bangkok's first subway was opened on July 3, 2004; while in the same year on December 5, the sky train (BTS) celebrated its fifth anniversary. The sky train's ridership is currently around 380,000 per day, and is expected to top 500,000 trips per day, in order to attain minimum number of passengers for break even point. However, passenger volume has risen steadily from 150,000 a day in its first year. Proceeds from the operator's fare-boxes and advertising have also climbed steadily and are now sometimes as high as eight million baht a day compared with just about three million baht when it was launched.

There is a proposal to reintroduce a bus transit system as feeder system for the LRT and MRT. Some existing bus transport routes, especially the routes served by micro (van) busses serve that purpose now. These routes have become more popular due to the variety of routes they offer and the links they make with the BTS sky-train or MRT subway. These public transport modes are key determinants on the state of urban air quality in Bangkok; thereby continuous improvement of public transport towards smooth transit systems in Bangkok would eventually reduce the use of private cars and then lessen air pollution generated by these sources.

Presently, it seems that continuous improvement of quality and variety of public transport services does not directly reduce the use of private cars. It is because of the following reasons: development plan that prioritizes road investment that encourages citizens to have their own private cars, high affordability of the citizens with relatively inexpensive price of the cars, non-existence of smooth inter-modal transit systems, absence of pedestrian friendly environment, and discouragement of non-motorized transport.

Provisions of good public transports and investments on road construction are competing with the increase of number of vehicles in Bangkok. The growing numbers of vehicles would release more emissions. This situation would eventually lead to the degradation of urban air quality. To what extent transportation sector affects urban air quality? The following section elaborates air quality and transportation nexus in Bangkok.

2.3. Urban Air Quality in Bangkok

It is indisputable that transportation is one of the potential sources of urban air pollution. The pollutants related to transportation that causes air pollution include Nitrogen Oxides, Ozone, Carbon Monoxide and Sulfur Dioxide. Other important emissions generated by transportation and directly affect air quality in Bangkok are PM_{10}, TSP, and Lead. The Pollution Control Department has regular monitoring activities to assess the extent of those pollutants. The records during the last ten years indicate gradual decrease in concentration as discussed below.

Nitrogen Oxides: Nitrogen oxides, including NO_2, are mainly produced by fossil fuel combustion in urban areas. They play a major role in the formation of ozone, PM, and acid rain. Short-term exposure, even less than three hours, to low levels of NO_2 may lead to changes in lung function in individuals with pre-existing respiratory illnesses and can increase respiratory illnesses in children. Long-term exposure to NO_2 may increase susceptibility to respiratory infections and cause permanent alterations in the lung. Some transport modes, particularly diesel-powered vehicles, are some of the major contributors to NOx emissions in urban areas. Emissions from power generation and industry are also significant sources in Thailand (Thailand Environment Monitor, 2002).

In 2000, ambient and roadside measurements of NO_2 in Bangkok were typically 20 percent of the national standard. As shown in Figure 14, from 1999 to 2001, ambient NO_2 measurements were somewhat stabilized. NO_2 concentration levels in Bangkok's suburban provinces were similar to those recorded in the city. This achievement is due particularly to cumulative effect of the improvement of urban transportation systems. The change of fossil fuel to natural gas has also significant impact to the air quality improvement in Bangkok Metropolitan.

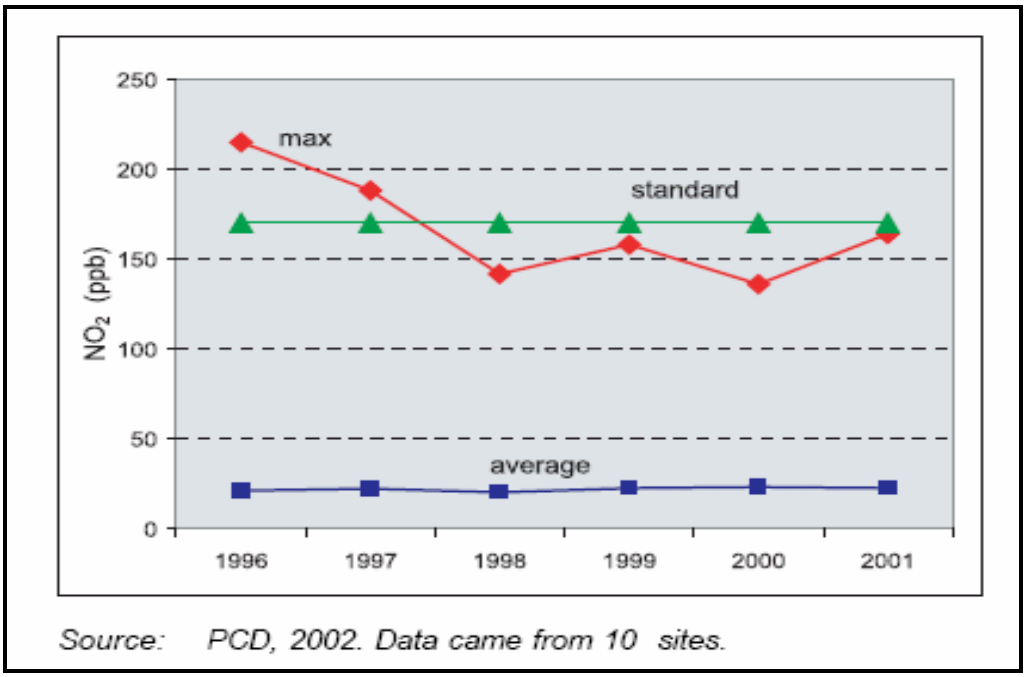
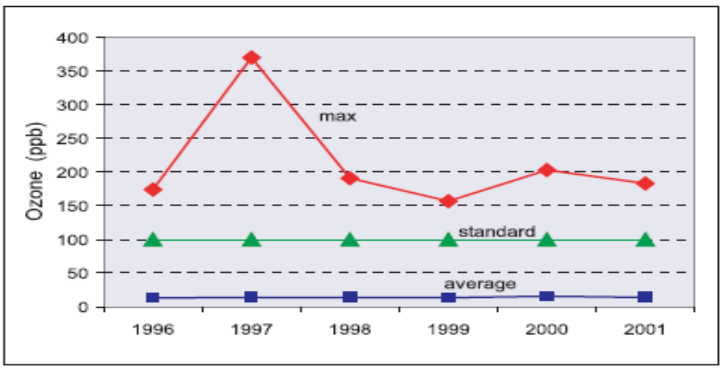


Figure 14. Concentration of NO_2 in Bangkok (all sites combined)

Ozone: Ozone is a highly reactive gas formed by the reaction of Volatile Organic Compounds (VOCs) and NO_x in the presence of heat and sunlight. Ozone can cause a range of acute health effects including eye, nose and throat irritation, chest discomfort, coughing and headaches. Children who are active outdoors when ozone levels are high are most at risk. Ozone also affects vegetation and ecosystems, decreasing yields of commercial crops and plantations and lowering the aesthetic value of national parks. In 2000, measurements of ambient ozone in Bangkok showed that while average concentrations are low at all monitoring stations, maximum values exceeded the standards significantly and frequently, as shown in Figure 15. High ozone concentrations are normally observed in the suburban areas downwind from center of Bangkok. Similar trends have been observed in Bangkok's adjoining provinces and throughout other urban areas in Thailand. Rising emissions of VOCs and NO_x, which are precursors for O_3 along with meteorological conditions, are causes of increasing maximum levels downwind of urban centers. However, several studies indicated that O_3 problem in Bangkok is controlled by VOCs not by NO_x. This means that VOCs emissions will have to be reduced in order to lower the levels of O_3 (Thailand Environment Monitor, 2002).

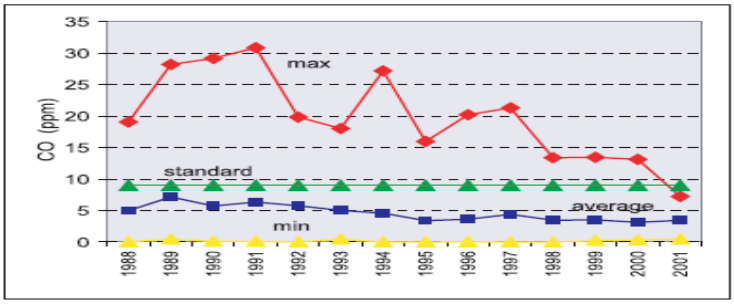
Carbon Monoxide: Carbon monoxide is an odorless, invisible gas, formed when carbon in fuel is not burned completely. The inhalation of CO can disrupt the supply of essential oxygen to the body's tissues thus posing a major health risk. Those who suffer from cardiovascular disease are most at risk. At high levels of exposure, CO can be fatal. Automobiles are the largest source of CO emissions. Lesser sources include industrial processes, non-transportation fuel combustion, and natural or manmade fires. Peak CO concentrations typically occur during the colder months of the year, when automotive CO emissions are greater and nighttime inversion conditions are more frequent. Roadside measurements from 1988 to 2001 show a steady reduction in CO over the 13-year period as shown in Figure 16. In Bangkok's adjoining provinces, average concentrations were similar to those observed in Bangkok. This decline is due to the catalytic converters on automobiles, which were mandated in 1993 after introduction of un-leaded gasoline (Thailand Environment Monitor, 2002).



Average and Maximum 1-hr Ambient Ozone at All Sites in Bangkok 1996-2001 (ppb)

Source: PCD, 2002. Data came from 8 sites.

Figure 15. Average and Maximum Ozone Concentration at All Sites in Bangkok

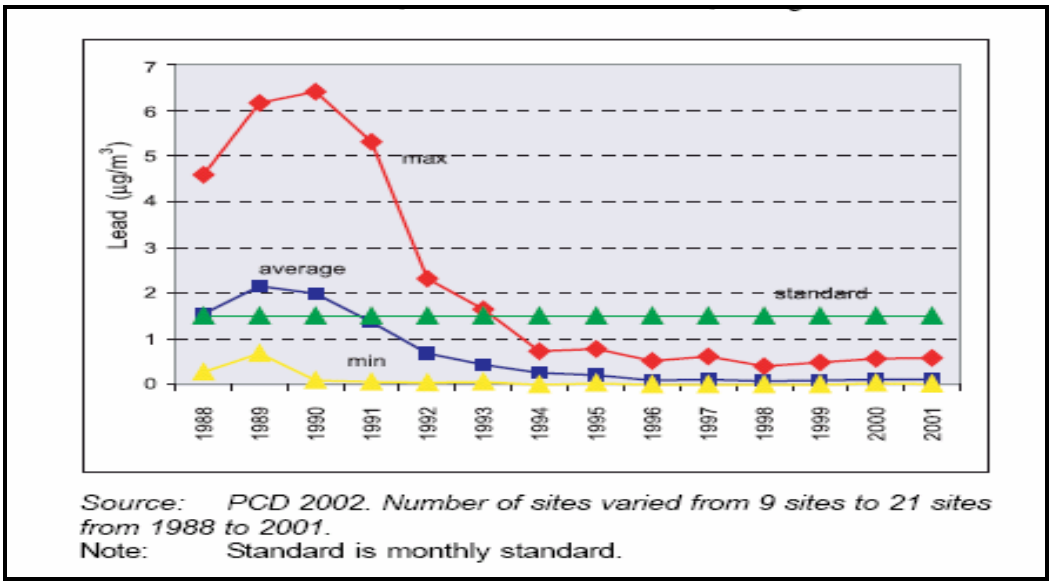


Roadside CO (8-hr average) All Sites Combined in Bangkok 1988-2001 (ppm)

Source: PCD 2002. Number of sites varied from 10 sites to 21 sites from 1988 to 2001.
Note: Standard is 8 hr average standard.

Figure 16. Concentration of Roadside Carbon Monoxide at All Sites in Bangkok

Lead: Lead is a highly toxic element that can result in damage to the brain, kidneys, blood, central nervous system, and reproductive system. Children who are exposed to high levels of lead may experience slowed cognitive development, reduced growth, and other health effects. Lead in ambient air is not an issue in Thailand any more, since Thailand's complete phase-out of leaded gasoline at the end of 1995, observed lead levels have fallen to almost nil, as shown in Figure 17. A recent study found that since the early 1990s, there has been a statistically significant decrease in blood lead levels in school children and traffic police, two groups that face the risk of lead exposure (Thailand Environment Monitor, 2002).



Source: PCD 2002. Number of sites varied from 9 sites to 21 sites from 1988 to 2001.
Note: Standard is monthly standard.

Figure 17. Roadside Lead (24-hr average) in mg/m^3 1988-2001 All Sites Combined, Bangkok

3. Concluding Remarks

The improvement of air quality in Bangkok is attributed to the introduction of various synergistic policies and strategies since the late 1990s. Along with the land use and urban planning policies, the following strategies have greatly contributed to the improvement of air quality in Bangkok.

- Shifting from leaded to unleaded gasoline in Thailand, and fully phased out in 1995. This program has contributed to the purity of urban air quality by diminishing toxic substance from the air.
- Introduction of van transit system for ride sharing in 1995. This system has contributed to the improvement of air quality through the reduction of number of vehicles on road.
- Shifting from two to four-stroke engines of motorcycles program in 1997 nation-wide. This program has a significant impact to the improvement of air quality in Bangkok and in other cities in Thailand, since motorcycles are predominant mode of transport with respect to number.
- The use of low emission fuels e.g. NGV for vans and buses and LPG for taxis and other private transport. This program has been able to remarkably reduce carbon monoxide, nitrogen-oxides, and sulfur-dioxides from urban air, and improve Bangkok air quality.
- Operation of Sky-train (BTS) to provide full capacity of services for public transportation system in 1999. This program is able to reduce the use of private transportation.
- Introduction of park-and-ride system to complement BTS operation in 1999. This program has reduced traffic congestion, improve energy efficiency used by transportation, and improve air quality.
- Operation of subway (MRT) to complement integrated public transportation system in Bangkok in 2004.
- Construction of elevated toll-ways and expressways to improve the travel speed and reduce congestion.

Air quality in Bangkok has been remarkably improving due to the synergistic programs of urban development and transport sector improvements. The compatibility of National and city level policies are important to ensure the sustainability and consistency of the program implementation.

Despite the improvement of urban air quality, Bangkok is indisputably car-dependent city. Despite the improvements in both transport sector and air quality, Bangkok is still known for its chronic traffic congestions. The efforts to improve urban air quality in Bangkok would be exceptional if car-dependency is reduced. Continued improvement of air quality would invariably contribute to achieve the sustainable city that Bangkok aspires to be.

4. References

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