Journal of Population and Social Studies, Volume 20 Number 1, July 2011: 25-42

Improving the Quality of Life in Bangkok via Change in City Planning

Tanat Burapatana[1] and William Ross[2]

Abstract

The dream of home ownership is common in modern societies, but a large numbers of house in the suburbs lead to greenhouse gas emissions, trade deficits and social segregation. Suburbanization is often a result of car-oriented city planning, and Bangkok, the capital and socio-economic center of Thailand, has been developing under a car-oriented city model for several decades, thus resulting in severe traffic congestion. The objective of this study is to demonstrate that a change in Bangkok city planning can reduce CO_2 emission and improve the quality of life. Based on the travel diary data, people who live and work in the inner area of Bangkok have the shortest travel time (49 minutes per day); while those living in Bangkok's suburbs spend 109 minutes per day on average in the car. The differences in travel time can be due to the higher vehicle kilometer traveled (VKT) of those living in the suburbs (37 km per day on average) compared to those living in the inner city (9 km per day). Reduction of VKT via improvement of the metro system and increase in mixed land use can decrease CO_2 emission, fossil fuel consumption, diesel fuel subsidies, and conversion of farm land to residential area.

Keywords: suburbanizastion, vehicle kilometers traveled (VKT), travel time, CO_2 reduction, Bangkok

1 Research Fellow, Faculty of Environment and Resource Studies, Mahidol University, 999 Phuttamonthon 4 Road, Salaya, Nakhon Pathom 73170, Thailand. Email: tanatb@gmail.com

2 Associate Professor of Environment and Resource Studies, Faculty of Environment and Resource Studies, Mahidol University, 999 Phuttamonthon 4 Road, Salaya, Nakhon Pathom 73170, Thailand

This research was supported by the grant from the Center of Toxicology, Environmental Health and Management of Toxic Chemicals under the Science & Technology Postgraduate Education and Research Development Office (PERDO), Ministry of Education. The authors gratefully acknowledge Dr. Chamlong Poboon, Dr. Chirapol Singtunawa, Dr. Kwanchai Roachanakana, and Prof. Hermann Knoflacher for their supports and advices on data analysis.

Introduction

Suburbanization or urban sprawl, an expansion of the city and its suburbs into agricultural area, can be found in many large cities around the world especially in the USA. In the suburbanizing city, a large portion of the population choose to move to the suburbs and commute to the central business district in downtown (CBD) for work every day in exchange for home with more space and green areas. However, commuting from the suburbs usually depends heavily on private cars, especially where the infrastructure for mass transit is not efficient. High usage of private cars leads to an increase in fuel consumption and greenhouse gas (GHG) emissions, which contribute to global warming. In addition, the growing of the city especially housing estate into the agricultural areas reduces the land availability for food crops. Thus, suburbanization is not a sustainable development pattern. Beside the unsustainable development pattern, suburbanization often has other characteristics such as 1) migration of population from inner city to the suburbs; 2) high dependence on cars; and 3) single land use in the suburbs, mainly for residential purpose (Frumkin, 2002; Goldberg, 1999; Pope, 1999).

Given the lower price of farm land adjoining the suburbs, real estate developers often convert the farm land into residential estates because there is a constant demand from the general public to have a house with a yard in the suburb. With a growing portion of the population moving to the suburbs, the volume of cars travelling towards downtown rises every year and leads to increased traffic congestion due to the limited road space. Rising numbers of cars comes with higher fossil fuel consumption and greenhouse gas emission, mainly CO_2 from the burning of gasoline. The enhanced greenhouse effect is believed to be the cause of global warming and climate change.

Global climate change affects human quality of life in many ways including an increase in the intensity of flood events and an increase in the frequency of heavy storms (Cunningham, Cunningham, & Saigo, 2005; Kaye, Groffman, Grimm, Banker, & Pouyat, 2006; United Nations Environment Programmme, 2002). Changes in weather patterns are alarming to the agricultural sector, and it results in a decrease in productivity leading to food shortages and higher food prices. In addition, most countries are oil-importers, thus higher consumption of fossil fuels generate a trade deficit especially when crude oil prices can be highly speculated. Providing the infrastructure that a suburbanized city needs, where people have to drive to work every day, the city planning itself causes oil-addiction and converts crude oil from commodity to necessity.

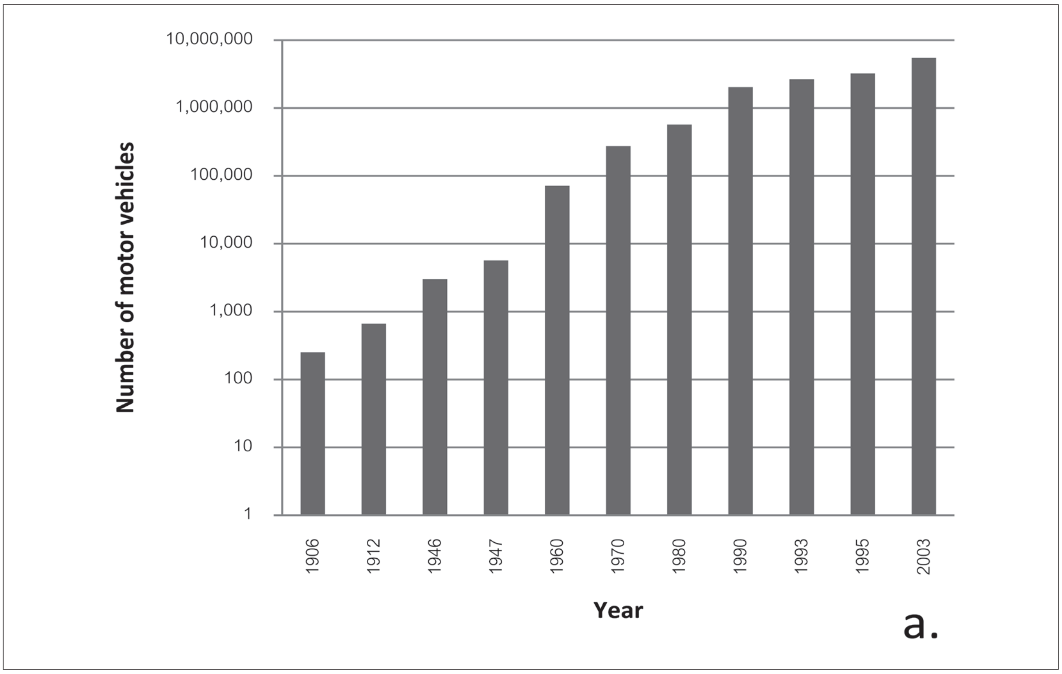
Beside the environmental and economic problems, health and social problems often arise from suburbanization, such as reducing quality of life by increasing obesity and road accidents. Given the nature of having to drive everywhere, people living in the suburbs have less physical activity, and this is strongly linked to obesity. During 1960-1990, suburbanization caused the percentage of overweight Americans to increase from 24 to 33, and doubled the body mass index (Eid, Overman, Puga, & Turner, 2008; Frumkin, 2002). By being overweight, individuals are more prone to diseases such as stroke, hypertension, and ischemic heart disease. Beside the lower physical activity, the rate of road accidents and pedestrian injuries increased as population density decreased (Frumkin, 2002; Litman, 2005). In addition, it was also estimated that 10 minutes of additional time spent in congested traffic leads to 10 percent less quality time that an individual can spend with family or friends (Putnam, 2000). Thus, reducing suburbanization can lead to improving quality of life.

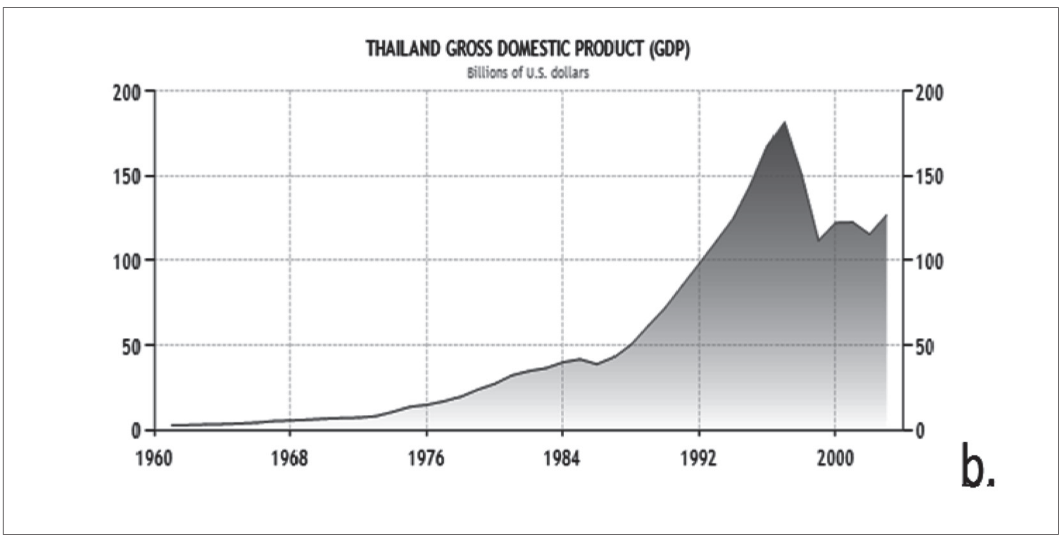
In the past, many governments especially in Asia modeled their major urban development after the US cities. Cities in the US are developed under the premise that every American owns a car, given the car ownership in the US is around 78 percent (United Nations Economic Commission for Europe, 2005). The result is that US cities are highly suburbanized, so that modeling Asian cities after those in the US causes many Asian cities (e.g. Tokyo, Jakarta, Manila, etc.) to suburbanize as well (Murakami, Zain, Takeuchi, Tsunekawa, & Yokota, 2005; Sorensen, 2000).

Bangkok, the capital of Thailand, is home to 9.7 million people (registered population) and is accounted for 43 percent of the Thai GDP (Bangkok Metropolitan Administration, 2009). It was developed in similar manner as the US cities (i.e., very car-dependent with large suburbs). Currently, Bangkok traffic congestion is also as widely known as its tourist destination, and suburbanization is often the root cause of traffic congestion (Ewing, Pendall, & Chen, 2002; Goldberg, 1999; Pope, 1999). Originally, Bangkok transportation was dominated by its canal system, which earned its nickname "Venice of the East". In the past, people lived near the canals or river, and boats were the main mode of transportation. In the old days, Bangkok was similar to other old Asian cities where people lived very close to their workplace. In many cases, people lived upstairs, and the office or shop was on the ground floor. It was not until the middle of the 19^{th} century that the first standard road system was built in Bangkok. However, car was not available at that time; thus, roads were basically used by horse carriages and pedestrians.

During the reign of king Rama V, 45 more roads were constructed in Bangkok. These roads were mainly used by pedestrians, tricycles, horse carriage and rickshaws. In 1906, for instance, there were only 251 cars (Figure 1a). The number of cars in Bangkok increased slowly in the next decades. In 1946, there were only 3,000 cars. In the later part of the 20^{th} century (1960-1997), the number of cars in Thailand started to grow rapidly as the Thai economy rapidly grew as shown in Figure 1b. With the booming economy, people were looking for a better life or "American Dream", so the numbers of cars and houses in the suburb increased rapidly.

Figure 1: a) Number of cars in Bangkok during 1960-2003; b) Thailand Gross Domestic Product during 1960-2003



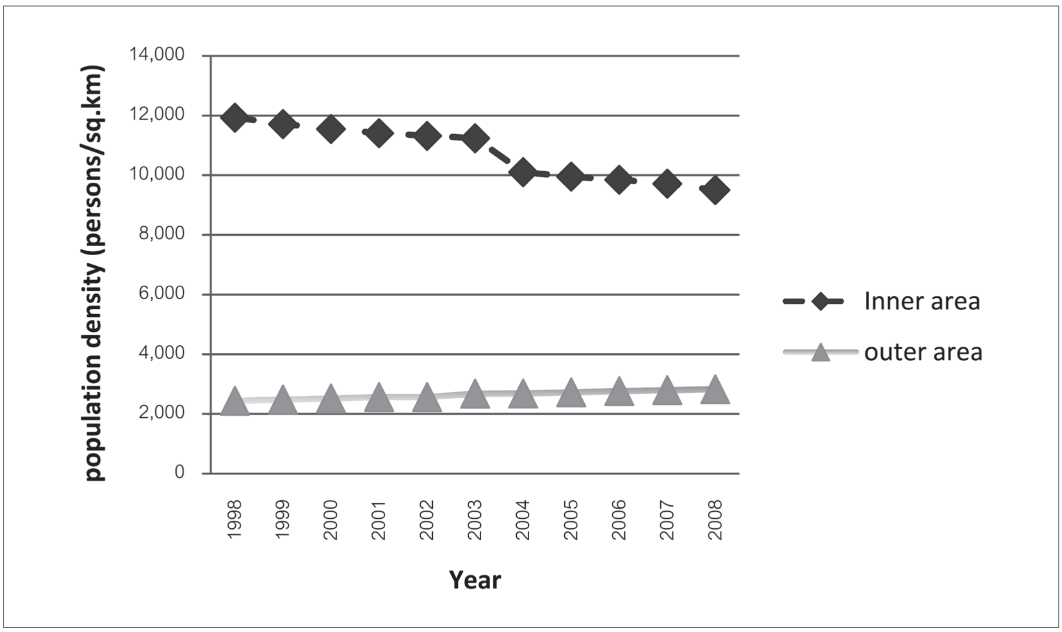


Source: Bongsadadt, 1973; Department of Land Transport, 1993; Trading Economics.com. The World Bank Group, 2011

Thereafter, Bangkok urban development advanced with neither control nor good planning for many decades and this led to suburbanization and poor environmental conditions (Roachanakana, 1999). The increase in the number of people living in Bangkok's suburbs is causing an increase in the number of private motor vehicles. As a result, more than 50 percent of private cars in Thailand are in Bangkok (Bangkok Metropolitan Administration, 2009).

One common characteristic of a suburbanized city is low population density in downtown area and high population density in the suburbs. According to the data collected by Bangkok Metropolitan Administration (BMA), population density in Bangkok inner area has been steadily decreasing in the past decade (Figure 2). From 1998 to 2008, a total of 2,430 persons/km^2 had moved out of Bangkok inner area. On the other hand, Bangkok outer area's population density had been increased by about 390 persons/km^2 during the same period (Bangkok Metropolitan Administration, 2009).

Figure 2: Population density trend in Bangkok during 1998-2008



Source: Bangkok Metropolitan Administration, 2009

On average, population density in inner Bangkok has been decreasing at a rate of 240 persons per km^2 per year. If this trend continues, Bangkok will eventually become similar to most cities in the US where only small proportions of population live in downtown and most people commute from suburbs every day. Considering that resource consumption and pollution emission of the US cities are not sustainable, it is important for Bangkok to change toward a more sustainable form of city development.

Sustainable city development refers to a development pattern that will not leave a long-term environmental impacts in urban areas that affected the future generations to meet their basic needs (Landman, 2000). On the other hand, a compact city is more sustainable due to less resource consumption. For example, people who live in compact city can walk or take a subway or buses to work instead of driving, therefore, the fossil fuel and other resources consumption per capita is less when compared to people who live in the suburbs of a large city. Therefore, sustainable city development may include, but not limited to: 1) efficient mass transit; 2) high population density; 3) mixed land use; and 4) limited parking spaces (Litman, 2009a; Victoria Transport Policy Institute, 2010b; Whitlock, 2003).

If Bangkok can become a more sustainable city, other growing cities in Thailand and in the Southeast Asia region can use Bangkok as a case study for their own sustainable development. Since suburbanization is one of the root causes of high CO_2 emission and traffic congestion, the objective of this study is to determine the difference in commuting pattern for people in the suburbs and those who live in the inner city, and to demonstrate that CO_2 emission from commuting and travel time in Bangkok can be reduced via change in city planning.

Methodology

Travel Dairy Data (TDD)

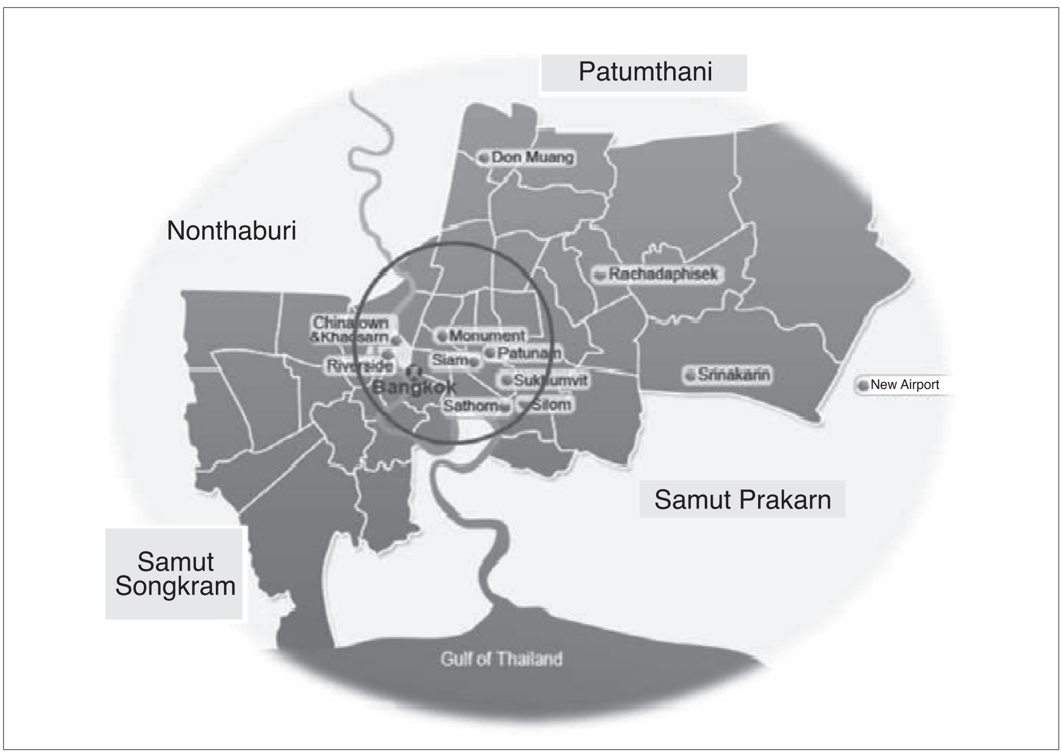
Commuting pattern can be observed by using TDD (Henderson & Mokhtarian, 1996; Yu & Shaw, 2004). TDD contains two parts. In the first part, participants were asked to provide general information such as their age, gender, working status, etc. In the second parts, participants were asked to fill in their destination, times of the day they travel, vehicle kilometer travel (VKT), mode of transport, and the number of passengers traveling with them. Such data are collected every time they travel for 7 days (Henderson & Mokhtarian, 1996; Yu & Shaw, 2004). In this study, all mode of transportation were included in the VKT, and car is often the dominant form of transportation mode in suburbanized city. Since one of the objectives of this study is to determine the difference in commuting pattern for people in the suburbs and those who live in the inner Bangkok, the population according to BMA (9.7 million) was used to calculate the sample size with Taro Yamane's formula (Yamane, 1967). As a result, the minimum of 400 travel diaries were needed.

Around 2,000 travel diaries (hard copy) were distributed in August 2008. The targeted samples were men and women who were in the working age group. The process began with a random selection of the 10 companies from a list of 200 companies located in both the inner and outer Bangkok. The selected companies were then contacted for cooperation in asking their employees to complete the diaries. These sample companies were located in both inner and outer districts of Bangkok Metropolis: Din Daeng, Silom, Sathorn, Pom Prab Sattru Pai, Kan Na Yao, and Nonthaburi. In addition to hard copies, electronic copies were sent to each company to make it more convenient for distribution. Employees of the selected companies were asked to keep the diary of their journey for seven consecutive days. The process of data collection took about 8 months (between August 2008 to April 2009) to obtain the target number of travel respondents.

Zone Division

For analysis and simplicity in demonstrating the differences between inner city and the suburbs, Bangkok was divided into two zones: inner and outer. The inner zone is defined as an area within 10 km radius from the Victory Monument (city center), which is the distance from city center to the farthest metro station, the division between the inner and outer zone are shown in Figure 3. The inner and the outer districts in this study are similar to BMA classification, with 21 inner districts and 29 outer districts. Any parts of Bangkok outside the 10 km radius were considered as outer area. VKT, travel time, and speed of travel between TDD's respondents living in inner and outer area were analyzed and compared by computer software, Statistical Package for Social Sciences (SPSS).

Figure 3: Graphical representation of zone division (the inner and the outer areas) using Victory monument as a base. The center of the zone division is the Victory Monument, which is the center of Bangkok according to the Bangkok Metropolitan Administration (BMA). The circle represents 21 Bangkok inner districts, while the areas outside of the circle are considered as Bangkok's outer area in this study.



Result and Discussion

Approximately 40 percent of the respondents were male, and 60 percent were female. The average age was 37 years for male and 36 years for female. Majority of the respondents (80 percent) lived in Bangkok's outer area, while the rest lived in the inner areas. However, 61 percent of all respondents worked in Bangkok's inner area. According to the BMA, the registered population of Bangkok as of 2008 was around 9.7 million people (Bangkok Metropolitan Administration, 2009). Approximately 7.7 million people or 79 percent of the residents live in the outer area, and only 21 percent of the populations live in the inner area (Table 1). Thus, distribution of respondents in the sample was similar to distribution of Bangkok as a whole. The larger portion of population living in the outer area is the main characteristic of suburbanization (Goix, 2003; Gurin, 1999; Mindali, Raveh, & Salomon, 2004; Zhang & Guindon, 2005). The result from population density analysis and TDD confirmed that Bangkok is in the suburbanization stage.

Table 1: Comparing housing locations of TDD respondents and actual Bangkok population

	Inner Area	Outer Area
TDD respondents	84	316
Percentage (%)	20.1	79.9
Bangkok Population (BMA)	1,972,634	7,742,219
Percentage (%)	20.3%	79.7%

Vehicle Kilometer Traveled in Bangkok

High value of vehicle kilometers traveled (VKT) indicates a high degree of suburbanization and low density development (Frank, Stone, & Bachman, 2000; Chiotti, 2004; Zhang & Guindon, 2005). In general, high vehicle kilometer traveled (VKT) indicates that a large number of people have to travel a long distance between home and workplace every day. In many cases, city where many residents live in the suburb and travel to work in the downtown area has high VKT, but city with large population that live and work in downtown area has low VKT due to shorter distance between home and workplace. City with large population living in the suburb often experiences suburbanization since population growth often push the city to grow bigger. Since people in suburb tend to live in single detached houses, the population density (people per area) is lower than population density in downtown area where people tend to live in a condominium or apartment. Given higher population density in downtown area, condominiums often have grocery or convenient stores nearby as residents of the condominiums are their potential clients. In the outer area, the population density is lower, thus there is less incentive for convenient stores due to lower number of potential clients. This causes the residents to drive to most destinations. In addition, condominium are often located near business districts, thus people travel much shorter distance to their workplaces than those living in the suburbs that have to drive around 20 km to get to their work in downtown area.

According to the information collected from TDD, the average VKT is the lowest (9 km) among people who live and work in inner area (Group I-I). That is, about one fourth of VKT among people in Group O-I (37 km) who live in the outer but work in the inner area (Table 2). Due to more job availability in the inner area, 42 percent of people who live in the suburbs travel to downtown for work. In Bangkok, majority of the office space (80 percent) are located in the inner area (CB Richard Ellis, 2009), therefore, most of the office jobs are in the inner area. Given the larger VKT, CO_2 emissions is likely to be higher for those living in the outer area.

Table 2: Average VKT, travel time, and speed based on commuting direction.

Group	Residential Location	Workplace Location	Respondents (percentage)	Average working day VKT	Traveling time (minutes)	Average speed (Km/hr)
Group I-I	Inner	Inner	18.13	9	49	15
Group I-O	Inner	Outer	2.08	32	79	25
Group O-I	Outer	Inner	42.23	37	109	21
Group O-O	Outer	Outer	37.56	37	73	31

When compared VKT in Bangkok to other suburbanized cities, VKT in Bangkok is higher than in Sydney and New York, but lower than VKT in Atlanta (Table 3) (Ewing, Pendall, & Chen, 2002; Frumkin, 2002). Since VKT is an indicator of suburbanization, this data could imply that Bangkok is more suburbanized than New York and Sydney. In fact, the higher VKT in Bangkok showed that Bangkok residents were living further from the city core when compared to people in New York or Sydney, which indicated higher degree of suburbanization and more severe traffic congestion.

Table 3: Comparing average VKT and travel time per capita in Bangkok to major cities

City	Country	Distance driven (VKT) Km/day per capita	Travel time (minutes)	Population (in Million)
Bangkok	Thailand	~33[1]	~40[1]	9.7
Sydney	Australia	20[2]	40[2]	4.1
New York	US	25[3]	34[3]	8.3
Atlanta[3]	US	54[3]	31[4]	0.54

Source: [1] VKT and travel time based on the data of this study;
[2] Australia Transport and Population centre, 2004;
[3] Ewing, Pendall, & Chen, 2002;
[4] McGuckin & Srinivasan, 2000

Travel Time in Bangkok

Based on the data collected, Group O-I has the longest travel time (109 minutes), while Group I-I has the lowest travel time of 49 minutes (Table 2). Thus, Group O-I travel time is more than double the Group I-I travel time. For residents living in the outer area of Bangkok, the VKT is about the same regardless of the workplace location, but the travel time of those who travel to downtown is about 50 percent higher. This indicates that the traffic in inner Bangkok was more congested than the traffic in the outer area. Since they drive a longer distance, and often at higher speeds, drivers from outer Bangkok have more chance to be in car accidents than drivers from inner Bangkok. Thus, it was documented that long travel time in congested traffic raise driver's aggressive behaviors such as running the red light (Shinar, 1998).

As shown in Table 3, when comparing travel time in Bangkok to other suburbanized cities such as New York (USA), Atlanta (USA), and Sydney (Australia), travel time in Bangkok was higher than in New York and Atlanta and was about the same as in Sydney. Although VKT in Atlanta is higher than in Bangkok, Bangkok travel time is longer, thus Bangkok traffic congestion must be worse than Atlanta. The long travel time means that Bangkok is wasting more fuel than necessary since cars in Bangkok could not travel at an efficient speed to save gasoline.

By dividing VKT by travel time, Bangkok travel speed was estimated in order to reflect the degree of traffic congestion in Bangkok. The average travel speed in the inner Bangkok was 15 km/hr (represented by Group I-I as shown in Table 2), which is slower than bicycle speed (20 km per hour). Traveling within the outer area during the work day had the highest average speed (31 km. per hour as shown in Table 2 as Group O-O). According to Level of Service (LOS) classification, all of Bangkok travel speed fell under F level of service (the lowest level), meaning that the travel time was unpredictable (Victoria Transport Policy Institute, 2009).

Given the slow speed of travel in Bangkok, there would be a high potential in making public or mass transit system more attractive to citizen. But public bus is not very popular among Bangkok citizen who can afford a car because most buses in Bangkok are in poor conditions and lack a dependable schedule. In general, if mass transit system such as subway could get people to their destination faster and at a lower cost, then more people would use the subway instead of driving a private car (Litman, 2009b). In 1999, Bangkok started its light rail system and the number of users quickly rose to half a million people a day (Bangkok Mass Transit System Public Company Limited, 2009). The light rail system in Bangkok provides a good alternative to driving since the light rail system is clean, punctual, and affordable. However, the limited access of Bangkok metro system would make it available to a relatively small group of people who live and work near the rail system (Table 4).

Table 4: Comparison of metro rail system between major cities

City	Country	Rail length (km)	Number of stations	Area (km^2)
Seoul[1]	Korea	312	270	605
Singapore[2]	Singapore	129.7	79	710
London[3]	England	408	275	1572
Tokyo[3]	Japan	292	266	2187
Delhi[4]	India	138	117	1483
Bangkok[5]	Thailand	76	43	1568

Source: [1] Sohn & Shim, 2010; [2] MRTpedia, 2010;
[3] Nieuwenhuijsen, Gómez-Perales, & Colvile, 2007;
[4] Kapoor, 2010;
[5] Bangkok Mass Transit System Public Company Limited, 2009

Bangkok is almost three times larger than Seoul in terms of area, but Bangkok metro system rail length is four times shorter than that in Seoul. Comparing to other developing city such as Delhi, Bangkok is about the same size as Delhi, but the number of stations in Delhi is almost three times more than Bangkok. Although the accessibility of light rail system in Bangkok is limited, many users could still enjoy the extra time saved with their family. Beside the more predictable travel time, BTS and MRT would be the most environmental efficient transport mode due to the lower CO_2 emission per passenger.

CO_2 emission due to commuting

Newman and Kenworthy (1989) described a relationship between petroleum used and population density. In general, low population density would lead to higher VKT and petroleum used since offices, workplaces, hospital, and school were farther apart when compared to high population density area. VKT and fuel consumption were directly related to CO_2 emission since the main emission from cars were CO_2 and H_2O (Frumkin, 2002; Goldberg, 1999). Thus, CO_2 emissions from cars in Bangkok can be calculated by using the following equation suggested by Sperling and Cannon (2006):

GHG Emissions (tons) = LPK * VKT * FI

where:

GHG Emissions	=	Green house gas emission (tons)
LPK	=	Liters of fuel consumed per kilometer per vehicle
VKT	=	Vehicle kilometers traveled (km)
FI	=	GHG intensity of fuel (GHG ton/liter of fuel)

Based on the above equation, the VKT in Bangkok indicated that the average CO_2 emission from cars in inner Bangkok was around 1.1 tons/car/year, while the average CO_2 emission from cars in outer Bangkok was around 3.5 tons/car/year. Thus, cars in inner Bangkok emitted about three times less GHG than cars in outer area due to higher VKT. Annually, the greenhouse gas emission in Bangkok from registered passenger cars (2.1 million) is around 6.5 million tons per year or around 3 tons/car/year, an estimate which is close to the annual estimate GHG emission/car in England (British Broadcasting Corporation, 2001). The absorption rate of CO_2 by one hectare of forest is 0.064 ton per year (Sungsuwan-Patanavanich, 1991). This means that Bangkok would need roughly around 2.4 million hectares of forest (5 percent of Thailand total area or around 16 times the size of Bangkok) to be carbon neutral. But forest takes a very long time and a lot of space to grow, and space is very limited and expensive around the metropolitan area.

On the other hand, if BMA could convince one million residents in Bangkok outer area to move to inner area, GHG emission from VKT in Bangkok could be reduced by 2.4 million tons per year. Thus, if the amount of this reduced CO_2 could be sold as carbon credit, Bangkok could generate more than $48,000,000 of revenue from carbon credit per year (assuming that the average price for carbon credit is $20 per ton). In fact, the difference can be even more dramatic, since the inner city residents will have the opportunity of reducing their CO_2 emission further by switching some of the trips to walking, cycling or mass transit. But the possibility of switching mode for the outer city residents is much more difficult, and often impossible.

A sustainable way to reduce the greenhouse gas emissions in Bangkok would be to address the problem directly by reducing VKT per capita via a change in city planning policy. Change in city planning such as improvement of the light rail system and encouragement of mixed land use can lead to VKT and CO_2 reduction.

Increase accessibility of light rail system

For a more sustainable development, it is crucial for Bangkok to have an efficient mass transit system. At the moment, Bangkok has only 43 metro stations combined, whereas Seoul (relatively 2 times smaller than Bangkok in terms of area) has 270 stations (Table 4). Currently, BMA short term plan is to extend the metro system to the suburbs instead of increasing accessibility of rail system in downtown area. Normally, a mass transit system (such as subway) will be more efficient and economical when serving high population density area. Ironically, high population density areas in Bangkok such as Chinatown have no subway stations. According to the Thai government's plan, the subway to Chinatown (Blue line) will begin operation in 2016 at the earliest, but the subway to the suburb in Nonthaburi (Purple line) will be completed around 2015 (Thongrung, 2011a, 2011b). Extending the subway to these high population and job density areas, such as Chinatown will encourage more people to use the subway since parking in Chinatown is very expensive and extremely hard to find. In addition to Chinatown, the old city of Bangkok where many tourist attractions are located cannot be accessed by subway. Bangkok usually has more than 35 million tourists per year

(Tourism Authority of Thailand, 2010) contributing about 6.5 percent of GDP. Beside the lower CO_2 emission, higher accessibility to the subway will make Bangkok more attractive to tourists.

In Stockholm, the capital of Sweden, using development of high density housing located at the transport nodes, the Swedish government was able to maintain their level of private car usage below 36 percent (Bekele, 2005; Gurin, 1999). A study in California also indicated that easy access to light rail system could reduce private vehicle usage to 32 percent (Victoria Transport Policy Institute, 2010a). Thus, living in a high population density environment with efficient mass transit system would utilize land more efficiently and reduce the use of private vehicles.

Beside the environmental benefits, there are financial benefits in improving metro system in Bangkok. Due to high oil price, Thailand spends a large amount of money supporting fuel price. According to PTT (former Petroleum Authority of Thailand), the subsidies for diesel in Thailand cost the government around $2.3 billion in 2011. In addition, Thailand also spends another $2 billion to support propone (LPG) and compressed natural gas in automobiles (CNG) in 2011 (Wiriyapong, 2011). The money used for subsidies can be redirected to improve the subway and other mass transit system.

Beside the extra money that can be saved, removing the subsidies can discourage people from driving and further reduce CO_2 emission. Currently, Thailand consumes around 50 million liters and 20 million liters of diesel and gasoline per day, respectively, which is equivalent to 181,000 tons of CO_2 per day. If removing subsidies can discourage around 10 percent of the current fuel consumption, 18,100 tons of CO_2 per day can be saved. The expansion of the subway within the inner area is likely to reduce VKT and travel time faster than the current government plan of extending the rail system into the suburbs, because VKT and travel time of the inner area is much smaller than the outer area. Furthermore, if the light rail system to the suburbs has the same speed as using private cars, the travel time of an individual would not change since the VKT still remains the same.

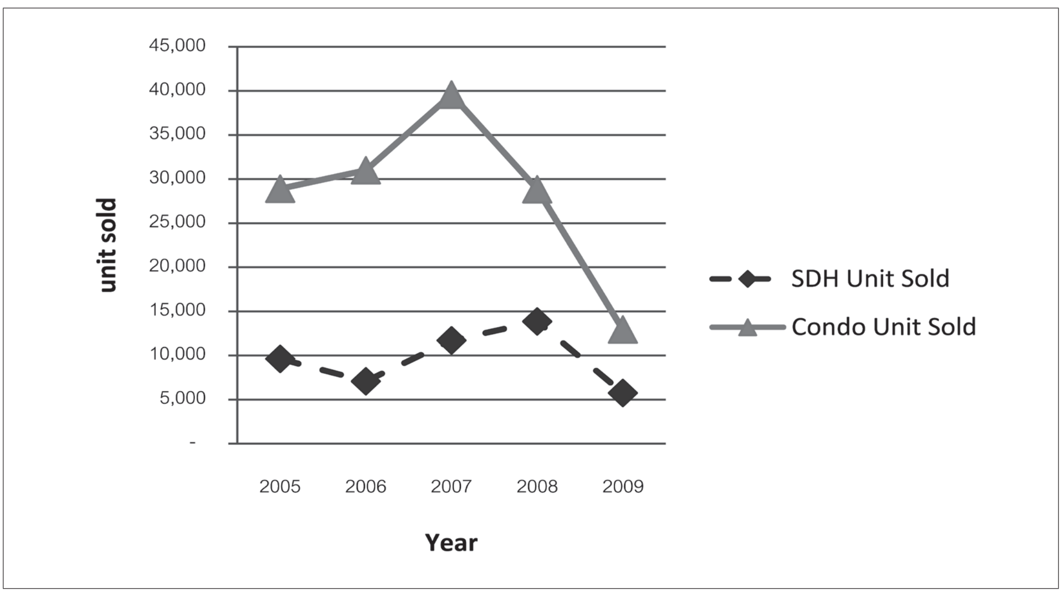
Encouragement of mixed land use

In addition to mass transit improvement, the Thai government could also encourage mixed land use. The mixed land use development should also contain a range of job opportunities, educational and service centers, medical centers, child care centers, retail shops, etc., compactly located in a high population density area. According to the Australian government, a good mixed land use development must be located within walking distances (normally 400 meters) to an efficient mass transit stops (Planning Institute of Australia, 2009). Moreover, sufficient street lightning, good condition footpath, and safe road crossing must be provided in order to encourage people to walk and uses more public spaces (Jacob, 1992; Newman & Kenworthy, 1999; Newman, Kenworthy, & Vintila, 1995; Poboon, 1997).

Currently, mixed land use development in Bangkok occurs around the metro stations. Housing development around BTS/MRT transit nodes were mainly high-rise condominiums due to the expensive land price (CB Richard Ellis, 2009). However, the demand for condominium close to BTS and MRT was also high judging from the fact that 80 percent of the projects were sold out before the construction begins, and the price of properties had tripled during 2004-2008 (CB Richard Ellis, 2009). The development around BTS/MRT stations consisted of well known schools and universities, trendy department stores and popular meeting points. Thus, people who live in these areas often travel shorter distances and had more opportunity to walk or cycle.

By encouraging mixed land use development, more people will travel less due to more availability of goods and services within the mixed land use area, which will reduce the VKT and suburbanization problem. For those who live in outer Bangkok, the increasing number of people living in downtown condominium may not reduce the VKT or travel time but would slow down the increase in travel time. If people who live in downtown condominium decided to live in the suburbs, then the number of cars travel to downtown each day will be more than double since the number of condominium sold (141,247 units) was almost triple the number of houses sold (47,967 units), during 2005-2009 (Figure 4). With more than double the number of cars on the road during rush hours, the traffic congestion would be worsening.

Figure 4: Number of single detached houses and condominium units sold in Bangkok during 2005-2009



Sources: CB Richard Ellis, 2009; Pornchokchai, Khongchantr, & Boonthong, 2009

Victoria Transport Policy Institute (Canada) suggested that a successful mixed land use development can reduce the VKT up to 15 percent (Litman, 2005; Victoria Transport Policy Institute, 2008). Furthermore, the improvement of walking and cycling facilities can reduce car usage. Residents in a walkable community tend to walk 2-4 times more and drive 5-15 percent less than residents in a single used development (Litman, 2005; Victoria Transport Policy Institute, 2008). According to the collected data, the mix land use in inner Bangkok encouraged people to walk. Around 39 percent of people who live in the inner area of Bangkok walk to work, while only 2 percent of the people in the outer Bangkok walk to work. Thus, it is possible to reduce greenhouse gas emission in Bangkok by increasing the mix land uses.

Conclusions

BMA population density data clearly demonstrated that Bangkok is going through suburbanization, resulting in increasing VKT and travel time. The VKT (9 km) and travel time (49 minutes) of those living and working in inner Bangkok (Group I-I) was the shortest among all group in TDD. Comparing to Group (O-I) with the lifestyle of living in the suburb/outer area but work in the inner area, the VKT quadrupled and the travel time increased more than double. Thus, it is more environmental efficient to live in the inner city since most of the work is located in the downtown area. By living close to the workplace, the residents of Bangkok can enjoy cleaner air since the air pollution will be reduced due to lower car usage. Given accessibility to the light rail system, many people can enjoy a more predictable travel schedule and more time with their family instead of getting stuck in traffic.

More family time, better air quality, and less stress from daily commuting are related to quality of life. Therefore, Bangkok citizens can enjoy a higher quality of life by simply changing the city planning toward more compact city development.

References

Australia Transport and Population Data Centre. (2004). *2002 Household travel survey summary report*. Sydney: Department of Infrastructure, Planning and Natural Resources.

Bangkok Mass Transit System Public Company Limited. (2009). BTS Sky Train. Retrieved 10 June 2009, from http://www.btsgroup.co.th/th/mainpage.php

Bangkok Metropolitan Administration. (2009). Bangkok: General information. Retreived, 1 November 2010, from http://www.bma.go.th/bmaeng/body_general.html

Bekele, H. (2005). *Urbanization and urban sprawl.* Stockholm: Royal Institute of Technology.

Bongsadadt, M. (1973). *The analysis of Bangkok and Thonburi transportation*. Bangkok: Theera Press.

British Broadcasting Corporation. (2001). Bangkok to combat traffic congestion. Retreived 15 December 2006, from http://news.bbc.co.uk/2/hi/asia-pacific/1723804.stm

CB Richard Ellis. (2009). *Report on property market in Bangkok 2009*. Bangkok: CB Richard Ellis.

Chiotti, D. Q. (2004). *Toronto's environment: A discussion on urban sprawl and atmospheric impacts*. Paper presented at the Pollution Probe.

Cunningham, W. P., Cunningham, M. & Saigo, B. W. (2005). *Environmental science: A global concern* (9 ed.). New York, United State: McGraw-Hill.

Department of Land Transport. (1993). *Road transport statistics 1993*. Bangkok: Ministry of Transport and Communications.

Eid, J., Overman, H. G., Puga, D. & Turner, M. A. (2008). Fat city: Questioning the relationship between urban sprawl and obesity. [doi: DOI: 10.1016/j.jue.2007.12.002]. *Journal of Urban Economics, 63*(2), 385-404.

Ewing, R., Pendall, R., & Chen, D. (2002). *Measuring Sprawl and Its impacts*. Washington, D.C.: Smart Growth America.

Frank, L. D., Stone, J. B. & Bachman, W. (2000). Linking land use with household vehicle emissions in the Central Puget Sound: Methodological framework and findings. *Transportation Research Part D: Transport and Environment, 5*(3), 173-196.

Frumkin, H. (2002). Urban sprawl and public health (Viewpoint). *Public Health Report, 117*(3), 29.

Goix, R. L. (2003). *Gated communities sprawl in Sourthern California and social segregation.* Paper presented at the International Conference on gated communities, Glasgow.

Goldberg, D. (1999). *Covering Urban Sprawl: Rethinking the American Dream*. Washington, D.C.: Environmental Journalism Center.

Gurin, D. (1999). *Putting the Brakes on Sprawl: Innovative Transportation Solutions from U.S. and Europe*. Boston: Tellus Institute.

Henderson, D. K. & Mokhtarian, P. L. (1996). Impacts of center-based telecommuting on travel and emissions: Analysis of the Puget Sound Demonstration Project. *Transportation Research Part D: Transport and Environment, 1*(1), 29-45.

Jacob, J. (1992). *The Death and Life of Great American Cities*. New York: Random house Inc.

Kapoor, S. (2010). Metro:The Complete Picture. Retrieved 18 January 2011, from. http://epaper.hindustantimes.com/PUBLICATIONS/HT/HD/2010/09/04/ArticleHtmls/Taken-for-a-ride-feel-commuters-04092010004002.shtml?Mode = 1

Kaye, J. P., Groffman, P. M., Grimm, N. B., Baker, L. A. & Pouyat, R. V. (2006). A distinct urban biogeochemistry? *Trends in Ecology & Evolution, 21*(4), 192-199.

Landman, K. (2000). Gated Communities and Urban Sustainability: Taking a closer look at the Future. Paper presented at the Strategies for a Sustainable Built Environment, Pretoria South Africa, 23-25 August 2000.

Litman, T. (2005). *Induced travel impact evaluation*. Montreal, Canada: Victoria Transport Policy Institute.

Litman, T. (2009a). Evaluating criticism of smart growth. 81. Retrieved 18 June 2010, from http://www.vtpi.org/sgcritics.pdf

Litman, T. (2009b). Planning priciples and practices. Retrieved 21 June 2010, from http://www.vtpi.org/planning.pdf

McGuckin, N., & Srinivasan, N. (2000). *Journey to Work Trends in the United States and its Major Metropolitan Areas 1960-2000*. Washington, D.C.: Federal Highway Administration.

Mindali, O., Raveh, A. & Salomon, I. (2004). Urban density and energy consumption: A new look at old statistics. *Transportation Research Part A: Policy and Practice, 38*(2), 143-162.

MRTpedia, E. S. s. (2010). Singapore MRT. Retrieved 12 January 2011, from http://www.exploresg.com/mrt/pedia/

Murakami, A., Zain, A.M., Takeuchi, K., Tsunekawa, A. & Yokota, S. (2005). Trends in urbanization and patterns of land use in the Asian mega cities Jakarta, Bangkok, and Metro Manila. [doi: DOI: 10.1016/j.landurbplan.2003.10.021]. *Landscape and Urban Planning, 70*(3-4), 251-259.

Newman, P. & Kenworthy, J. (1999). *Sustainability and cities: Overcoming automobile dependence*. Washington D.C: Island press.

Newman, P., Kenworthy, J. & Vintila, P. (1995). Can we overcome automobile dependence?: Physical planning in an age of urban cynicism. *Cities, 12*(1), 53-65.

Newman, P. & Kenworthy, J. R. (1989). *Cities and Automobile Dependence: An international sourcebook*. Great Britian: Avebury Technical.

Nieuwenhuijsen, M. J., Gómez-Perales, J. E. & Colvile, R. N. (2007). Levels of particulate air pollution, its elemental composition, determinants and health effects in metro systems. [doi: DOI: 10.1016/j.atmosenv.2007.08.002]. *Atmospheric Environment, 41*(37), 7995-8006.

Planning Institute of Australia. (2009). Design principles-mixed land use. Retrieved 17 January 2009, from http://www.healthyplaces.org.au/

Poboon, C. (1997). *Anatomy of a Traffic Disaster: Towards a Sustainable Solution to Bangkok's Transport Problems.* Unpublished Doctoral Dissertation, Murdoch University.

Pope, C. (1999). American are saying No to sprawl. *PERC Reports, 17*(1), 20.

Pornchokchai, S., Khongchantr, W. & Boonthong, P. (2009). *Bangkok real estate markets, H1/2009*. Bangkok: Agency for Real Estate Affairs.

Putnam, R. D. (2000). *Bowling alone: The collapse and revival of American community*. New York: Simon & Schuster.

Roachanakana, T. (1999). *Bangkok and the second Bangkok international airport.* Canberra: The Australian National University.

Shinar, D. (1998). Aggressive driving: The contribution of the drivers and the situation. [doi: DOI: 10.1016/S1369-8478(99)00002-9]. *Transportation Research Part F: Traffic Psychology and Behaviour, 1*(2), 137-160.

Sohn, K. & Shim, H. (2010). Factors generating boardings at metro stations in the Seoul metropolitan area. [doi: DOI: 10.1016/j.cities.2010.05.001]. *Cities, 27*(5), 358-368.

Sorensen, A. (2000). Land readjustment and metropolitan growth: An examination of suburban land development and urban sprawl in the Tokyo metropolitan area. [doi: DOI: 10.1016/S0305-9006(00)00002-7]. *Progress in Planning, 53*(4), 217-330.

Sperling, D., & Cannon, J. S. (2006). *Driving climate change: cutting carbon from transportation*. Burlington: Academic Press.

Sungsuwan-Patanavanich, S. (1991). *The basis for Thailand response strategies to global warming*. Bangkok: Thailand Development Research Institute (TDRI).

Thongrung, W. (2011a, February 18, 2011). Seven deals move Blue line extension closer. *The Nation*.

Thongrung, W. (2011b, September 15, 2011). Transport firm plans big changes. *The Nation*.

Tourism Authority of Thailand. (2010). Tourism Statistic. Retrieved 2 November 2010, from http://www2.tat.or.th/stat/web/static_tst.php

The World Bank Group. (2011). Thailand Gross Domestic Product. Retrieved 12 September 2011, from http://www.tradingeconomics.com/thailand/gdp

United Nations Economic Commission for Europe. (2005). UNECE trends in Europe and North America 2005-Transport. Retrieved 15 April 2010, from http://www.unece.org/stats/trends2005/transport.htm

United Nations Environment Programme. (2002). *Global Environmental Outlook* (Vol. 3). London: Earthscan Publication Ltd.

Victoria Transport Policy Institute. (2008). Smart growth: More efficient land use management. Retrieved 16 January 2009, from http://www.vtpi.org/

Victoria Transport Policy Institute. (2009). Multi modal level of service indicators: Tool for evluating the quality of transport services and facilities. Retrieved 29 July 2009, from http://www.vtpi.org/tdm/tdm129.htm

Victoria Transport Policy Institute. (2010a). Evaluating rail transit criticism. Retrieved 12 March 2011, from http://www.vtpi.org/railcrit.pdf

Victoria Transport Policy Institute. (2010b). Smart growth: More efficient land use management. Retrieved 12 January 2011, from http://www.vtpi.org/tdm/tdm38.htm

Whitlock, J. (2003). Smart growth: Solving the environmental problems of sprawl or destroying the American dream? Retrieved March 17 2007, from http://www.vjel.org/editorials/ED10040.html

Wiriyapong, N. (2011, 8 September 2011). PTT warns of expanding fuel subsidies. *Bangkok Post*.

Yamane, T. (1967). *Statistics: An introductory analysis*. New York: Harper and Row.

Yu, H. & Shaw, S.-L. (2004). *Representing and visualizing travel diary data: A spatio-temporal GIS approach.* Paper presented at the ESRI International User Conference, San Diego, CA, 9-13 August 2004.

Zhang, Y. & Guindon, B. (2005). Using satellite remote sensing to survey transport-related urban sustainability, Part 1: Methodologies for indicator quantification. *International Journal of Applied Earth Observation and Geoinformation. In Press.*