AN INTERNATIONAL COMPARATIVE STUDY ON LAND USE - TRANSPORT PLANNING POLICIES AS CONTROL MEASURES OF THE URBAN ENVIRONMENT

Yoshitsugu HAYASHI
Professor
Nagoya University
Nagoya - Japan

Yasuo TOMITA
Lecturer
Kobe University
Kobe - Japan

Kenji DOI
Lecturer
Tokyo Institute of Tech.
Tokyo - Japan

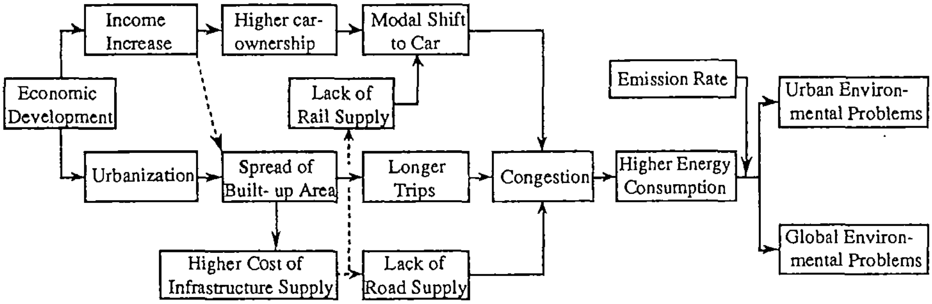
Rithika SUPARAT
Graduate Student
Nagoya University
Nagoya - Japan

INTRODUCTION

Although industrial energy consumption is holding constant or is even decreasing in many countries, transport energy consumption is continuously increasing. On the other hand, air pollution caused by transport has turned worse, cancelling the efforts in engine technology for emissions with a tremendous increase in car ownership and congestion.

Suburbanization is an essential phenomenon which results, over the long term, in wasted energy for transport by expanding trip length, promoting urban sprawl and therefore discouraging rail transit improvement in suburbs. Motorization results in more energy use together with a lack of road infrastructure and a modal shift from rail to car. Suburbanization and motorization are both outcomes of economic development, influencing energy consumption and environmental problems as shown in Figure 1.

Figure 1 Mechanism of the Influence of Transport on The Environment



This paper aims at a) identifying the influences of urbanization on transport and consequently on energy consumption and the urban environment, b) comparing the effects of implemented land use and transport policies for improvement, and c) suggesting some appropriate land use and transport policies for three cities which are in different stages of economic development and urbanization. Greater London (UK), Nagoya (Japan) and Bangkok (Thailand) are selected as the examples.

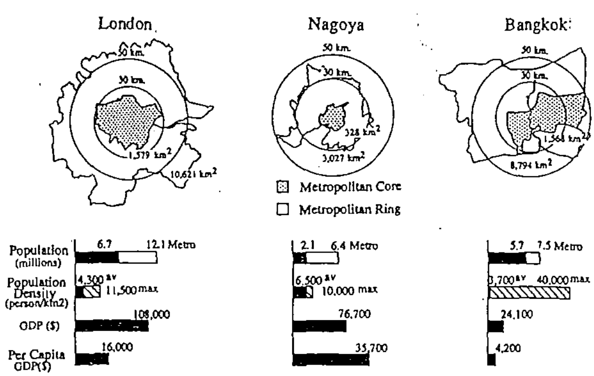
The paper firstly describes some basic background of each city. In chapter 2, economic development and the urbanization process including some environmental evidences are compared. In chapter 3, the influence of spatial development on transport patterns, energy consumption and the environment are analyzed and compared. The implemented land use - transport policies in each city are reviewed in chapter 4. This chapter also includes some suggested policies. Chapter 5 is the conclusion of the paper.

1. CHARACTERISTICS OF STUDY AREAS

Greater London includes the city of London and 32 boroughs. Its population declined after reaching a peak of 8.7 millions in 1940, followed by a decline in employment since the early 1960s. Nagoya is the core city of the third largest metropolitan area in Japan. Its population increased rapidly during the rapid economic development period in the 1950s and 1960s. The population has not changed much since it reached 2 million at the end of 1960s. Bangkok, the capital of Thailand, is a typical developing city due to its rapid economic growth. Its population has been rapidly increasing since the 1950s reaching 6 million in 1990. At present, the population is growing at the rate of around 1.5 % per annum.

Figure 2. shows basic data of each city and its region in 1988. It is obvious that Bangkok's population is very concentrated in the central area as we can see a large gap between average and maximum densities. On the contrary, the small gap in Nagoya implies that the development is spread over the city area. In the case of London, as development is controlled, especially in the suburban areas, the gap of the densities is wider, though the highest density is almost the same as that of Nagoya. Nagoya has the highest value of per capita product which is around twice as high as that of London, and seven times as that of Bangkok.

Figure 2 Basic Data of Cities (1988)



2. ECONOMIC DEVELOPMENT AND URBANIZATION PROCESS

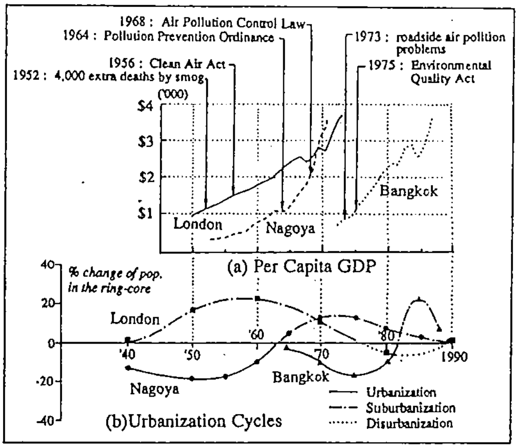
2.1. Economic Development, Urbanization and the Consequent Changes in the Environment

As the changes in energy consumption and the environment of a city are quite dependent upon the stages of economic development and urbanization, it is useful to understand them when searching for appropriate policy measures.

The relationship between environmental problems and per capita GDP suggests, as shown in Figure 3a, that serious environmental problems appeared in the economic development level of around \$1,000-\$2,000 per capita GDP (current prices) in the three metropolises.

Figure 3b shows the occurrence of spatial changes according to stages of urbanization which are represented by the difference of percentage change in population between the metropolitan ring and the core. It can be seen that London began to face severe environmental problems at the middle of its 'suburbanization stage', when population grows mainly in the metropolitan ring, whereas in Nagoya, it occurred at the beginning of the 'suburbanization stage' and in Bangkok at the middle of the 'urbanization stage' when population grows mainly in the metropolitan core. This finding implies that the newer cities generally face severe environmental problems at an earlier stage of urbanization than the older cities. Therefore, in new metropolises, it is necessary to invest in environmental protection infrastructure at an earlier 'urbanization stage'.

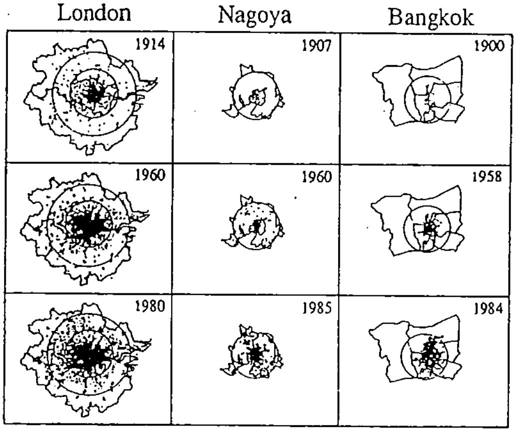
Figure 3 Economic Development, Urbanization and Environmental Events



2.2. Spatial Progress of Urbanization

Figure 4 shows the changes in the built-up areas in the three metropolises during the twentieth century. In London, the built-up area increased rapidly during the first half of the century. However, in the second half, the speed of development has been reduced and appears mainly in the suburban area. In Nagoya, the pattern of spatial development is similar to that of London but the degree of suburban spread in the second half of the century is higher. In Bangkok, the development occurred mainly in the second half of century. Its built-up area in 1984 was almost 9 times as large as that in 1958.

Figure 4 Changes in Built-up Areas



Since the picture of changes in built-up area cannot give clear information on the degree of spatial development, the indices 'r_0' and 'r_1' are introduced as the spread indicators. The index 'r_0' indicates the degree of spatial development in terms of radius when the whole built-up area is shaped in a complete circle, while 'r_1' indicates the average radius of built-up areas from the city centre. These indicators are noted as follows:

$$r_0 = \sqrt{\frac{\sum_{i=1}^{n} a_i}{\pi}}, \quad \text{and} \quad r_1 = \frac{\sum_{i=1}^{n} a_i \, r_i}{\sum_{i=1}^{n} a_i}$$

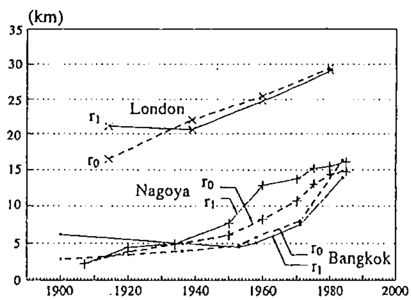
where a_i = area of built-up area r_i
r_i = distance between a_i and the city centre
n = number of built-up areas in the metropolitan area

The bigger 'r_0' is the bigger the total built-up area is, while the bigger 'r_1' is, the more suburbanized the built-up area is.

Figure 5 shows changes in values of 'r_0' and 'r_1' during the twentieth century. In London, 'r_0' has increased continuously while 'r_1', decreased after the introduction of the 'Restriction of Ribbon Development Act 1935' and the 'Green Belt Act 1938' after the 'New Town Act 1946'. However, as development appeared beyond the Green Belt, the radius of the built-up area increased again.

In Nagoya the values of 'r_0' and 'r_1' have increased continually since the start of city urbanization at the beginning of the century. As a result of rapid development after World War II, the built-up area spread rapidly and caused 'r_0' and 'r_1' to increase considerably. The figure suggests that Nagoya suburbanized rapidly during 1950 and 1960, as 'r_1' rapidly increased in this period. The degree of spread has slowdown since the introduction of the "Urbanization Restriction and Urbanization Promotion Areas" in 1968. However, this countermeasure could only reduce the speed of sprawl.

Figure 5 Changes in Spatial Development Indices



The changes in 'r_0' and 'r_1' in Bangkok show that rapid development began in 1950 and has continued up to the present. Before 1950, development had been concentrated in the inner area which resulted in a decrease of 'r_1'. However, since 1960 the value has increased considerably as the result of rapid urbanization. It can be seen that the development speed (slope of the curve) in Bangkok during the 1970s is similar to that of Nagoya in the 1950s, which was a period of rapid urbanization.

Comparing the values of 'r_0', we can see that at present, the size of the built-up area of London is around twice as large as those of Nagoya and Bangkok. Moreover, the calculation of changes in 'r_1' between 1970 and 1985 found that the built-up area in Bangkok is spreading at a higher rate than those of London and Nagoya by around 2.3 times and 3 times respectively.

3. INFLUENCES OF LAND USE DEVELOPMENT AND TRANSPORT ON THE URBAN ENVIRONMENT

3.1. Influences of Suburbanization on Transport

3.1.1. Increase of Trip Length

Suburbanization causes changes in transport patterns through longer trips and higher car use. The right hand side of Figure 6 shows that the total trip length increases more than a linear relation to 'r_1'. This is because in the suburbs there are less dense public transport systems and thus the number of car trips is higher. This tendency is most remarkable in Bangkok and least in Nagoya as it can be seen in Table 1 that in Bangkok 'r_1' increased 2.27 times while trip length increased 4.46 times or almost twice that of 'r_1'. Moreover at the same 'r_1', veh-km in Bangkok is also higher implying that the energy consumption intensity should be higher. This topic will be discuss in section 3.2.2.

Figure 6 Development Radius, Veh-km and Road Energy Consumption

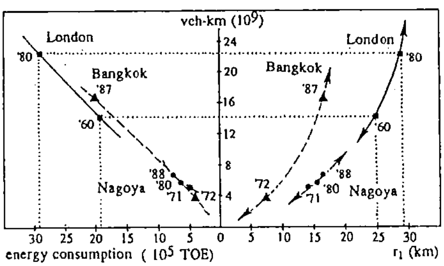


Table 1 Comparison of Changes in r1, Veh-km and Energy Consumption

	Development Radius (r_1)	Veh-Km	Energy Consumption
London (1960-1980)*	1.16	1.57 (1.35)	1.51 (1.30)
Nagoya (1971-1988)*	1.18	1.29 (1.09)	1.52 (1.29)
Bangkok (1972-1987)*	2.27	4.46 (1.96)	4.75 (2.09)

( )* calculation period, ( ) elasticity of r_1

3.1.2. Modal Shift and Increase of Trip Rate

Figure 7 shows that due to economic development and suburbanization, shares of passenger car use in motorized trips have increased at the expense of public transport shares especially bus transport in all cities. The percentage share of passenger car use in London increased around 1.0% per year compared with 1.4% in Nagoya, the highest rate, and 0.6% in Bangkok. The decline in public transport patronage reduces revenue from fare, which generally results in higher fare rates. The higher fare will in turn contribute to more car use. This relation will be discussed in section 3.2.3.

Figure 7 Changes in Modal Split

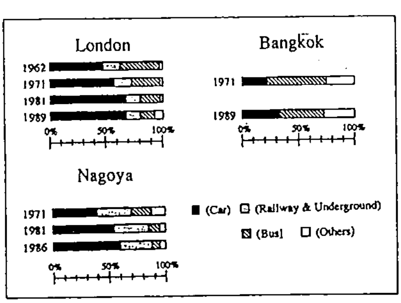
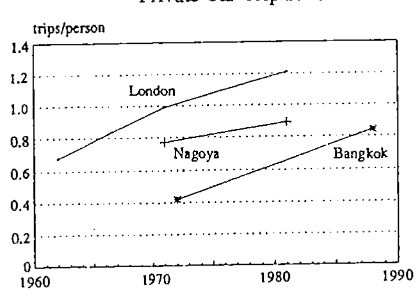


Figure 8 Changes in Per Capita Private Car Trip Rate



On the other hand, Figure 8 shows the changes in per capita private car trip rate. In 1981, the per capita private car trip rate (total trips by private transport/total population) in London was around 1.5 times as high as that in Nagoya and twice as that in Bangkok. The slopes of the curves suggest that in London and Bangkok private transport trips are increasing at a higher rate, 0.27 trips per 10 years, than that in Nagoya, which shows only 0.12 trips per 10 years. The higher growth rate of private transport in London seems to be the outcome of employment decentralization, which encourages more car trips in the outer area, and the relatively high public transport fare (discussed in section 3.2.3). Whereas in Bangkok, the rapid increase in car ownership (between 1981 and 1988 car ownership increased almost 2.5 times) and the poor public transport system are the major contributors to higher car use.

3.2. Effects of Suburbanization on Energy Consumption

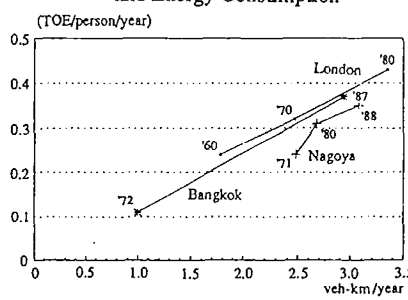
3.2.1. Increase of Trip Length and More Energy Consumption

According to the higher rate of increase in trip length and passenger car use, veh-km in Bangkok is increasing at the highest rate. The left hand side of Figure 6 shows that within around a 20 year period, vehicle-km in Bangkok increased around 4.5 times whereas in London it increased 1.6 times and only 1.3 times in Nagoya.

As a consequence of higher veh-km, road transport energy consumption is also increasing. In the same period, Bangkok's energy consumption increased almost 5 times, while the consumption increased around 1.5 times in London and Nagoya (see Table 1). It can be seen that the increased rate in energy consumption in Bangkok and Nagoya is higher than that in veh-km. This is because in Nagoya there is a considerable increase in truck movement especially in the 1970s. Whereas in Bangkok, higher congestion is a major cause of higher consumption. The rapid increase in road energy consumption has caused rapid deterioration in roadside air quality in Bangkok.

On the other hand, Figure 9 shows that within the same period per capita veh-km in Bangkok increased by 3 times whereas in London it increased almost twice and 1.2 times in Nagoya. Meanwhile, Bangkok's per capita energy consumption increased 3.4 times while the consumption increased around twice in London and 1.4 times in Nagoya. It can be seen that the increased rate in energy consumption in Bangkok and Nagoya is higher than that in veh-km. This is because in Nagoya there is a considerable changes in size of cars especially in 1970s. Whereas in Bangkok, higher congestion is a major cause of higherconsumption. The rapid increase in road energy consumption has caused rapid deterioration in roadside air quality in Bangkok.

Figure 9 Changes in Per Capita Veh-km and Energy Consumption

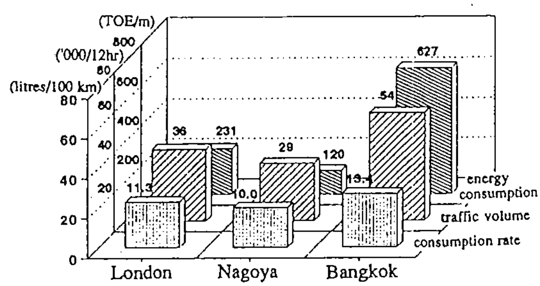


3.2.2. Energy Consumption Inefficiency due to Congestion

If attention is paid to energy consumption per km, Figure 10 suggests that the energy consumption rate per unit mileage is highest in Bangkok followed by London. The higher consumption rate in Bangkok seems to be a result of the lower travel speed and usage of aged cars. The average peak hour speed is as low as 14 km/hr in Bangkok compared with 27 km/hr in London and 24 km/hr in Nagoya. Although travel speed in Nagoya is lower than that in London, the energy consumption per km is lower. This may be because the energy consumption efficiency of vehicle engines in Nagoya is higher than that in London.

Figure 11 shows the trends in the relationship between car ownership and road length per car. Bangkok's car ownership in 1988 reached that of Nagoya in 1972 but the level of road infrastructure supply for Bangkok in 1988 is almost one-fourth of that of Nagoya in 1972. We can understand how serious the situation in Bangkok is and that it will become worse considering the fact that the road length per car in Nagoya decreased about half between 1972 and 1988. As shown in Figure 11, road infrastructure supply is really the bottleneck behind congestion and consequently, energy consumption and air pollution.

Figure 10 Section Traffic Volume and Energy Consumption Intensity



3.2.3. Energy Consumption and Energy Price

Comparison of the type of energy consumption in Figure 12 suggests that the percentage share of diesel consumption in Nagoya and Bangkok are relatively high. Moreover the shares in both cities have been increasing rapidly. The high diesel share in Bangkok is mainly contributed by the consumption in bus transport. In Nagoya, the high share is caused mainly by a wide gap between gasoline and diesel prices as shown in Figure 13. In Japan, gasoline price is around 1.7 times higher than diesel in terms of normalized price by GDP, whereas the difference is only 1.1 times in UK and 1.4 times in Thailand.

According to Figure 13, it can be clearly seen that fuel price in Nagoya is the lowest. The lower fuel price generally contributes to higher energy consumption. However, in the cases of London and Nagoya, though the fuel price in Nagoya is higher, energy consumption is lower. This is because the use of passenger cars in Nagoya is less than that in London (see Figure 8).

Figure 11 Motorization and Infrastructure Supply

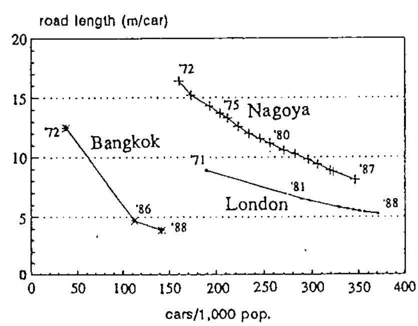


Figure 12 Changes in Percentage Share of Diesel

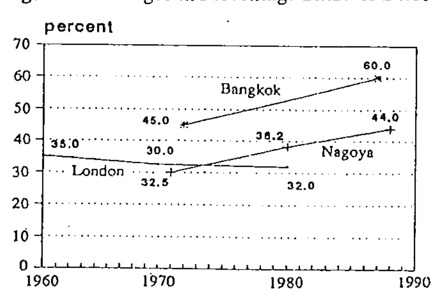


Figure 13 Gasoline and Diesel Prices (1988)

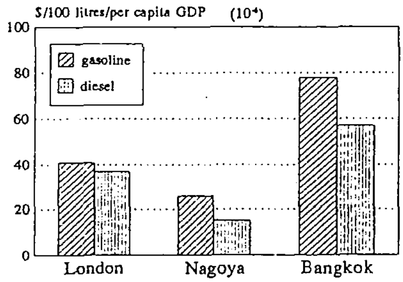
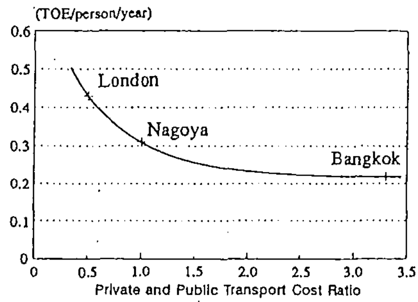


Figure 14 Transport Cost and Per Capita Energy Consumption (1980)



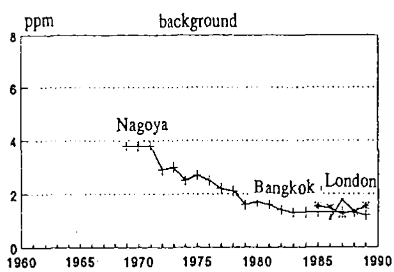
Since car use is also influenced by the competitive level of public transport, the relationship between per capita road transport energy consumption and the ratio of fuel cost in car use to public transport fare modes in the three cities are plotted as shown in Figure 14. It can be seen that per capita consumption decreases as the ratio of fuel cost to fare increases. This implies that higher public transport fare in London is one of the contributors to high car use and high per capita energy consumption.

3.3. Influences of Suburbanization and Transport on Air Quality

Economic development, urbanization and lack of infrastructure supply are the major causes of higher energy consumption and air pollution problems as well. The problems appear in urban, regional and global levels. However, the paper discusses only the problems in urban level. The changes in concentration of CO and NO_2 both in terms of background and roadside concentrations are shown in Figure 15 and 16 respectively.

In London, as the transport energy consumption is increasing, both background and roadside concentrations of CO and NO_2 show the upward trends. The gap between background and roadside concentration represents the extent of car traffic contribution to air pollutants. The roadside CO concentrations are around 3 times higher than those of

Figure 15 Changes in Annual Mean Concentration of CO



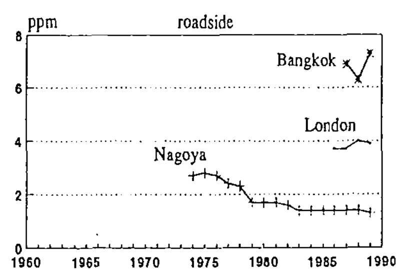
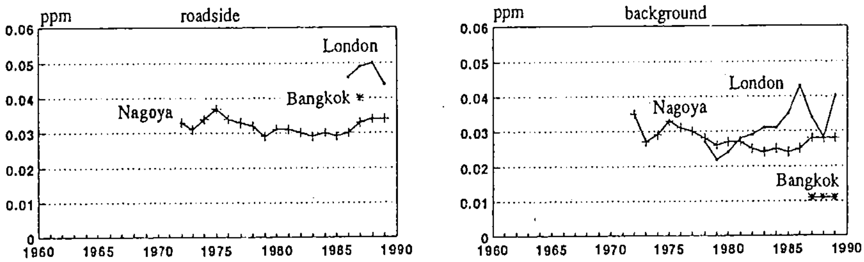


Figure 16 Changes in Annual Mean Concentration of NO_2



background values, while in the case of NO_2 concentrations, the difference is around 1.5 times. It must be noted that although the percentage share of the diesel trend has decreased, NO_2 concentration has increased. This is because the reduction of NO_2 emissions because of lower light oil consumption is smaller than the increase due to higher gasoline consumption.

In Nagoya, both background and roadside concentrations of CO have decreased since 1975. The roadside concentrations were only 1.2 times higher than those of background levels. This implies that the road traffic contribution is low. This is a result of the introduction of very strict CO emission standards for gasoline vehicles in 1975. On the contrary, though stricter NO_2 standards were also introduced, the concentration of NO_2 has not decreased and seems to have increased in recent years. This is caused by the additional emissions from higher diesel consumption which are higher than the reduced emissions from the stricter standards.

In Bangkok, the concentration of the roadside CO level is almost 5 times higher than that of the background level. Though diesel accounted for around 60% of road transport energy consumption, the concentration level of roadside NO_2 was not as high as it should be. The Thai National Environmental Board suggests that since the travel speed in Bangkok is very low, vehicles emit lower NO_2 but higher CO and smoke. Moreover it is also due to favorable meteorological conditions in Bangkok.

The figures also suggest that background CO levels are not very different between cities but they are clearly different in the case of roadside concentration. The roadside CO concentration in Bangkok is around twice and 4.5 times higher than those in London and Nagoya respectively. The higher roadside CO concentration in Bangkok is mainly a consequence of higher energy consumption of traffic on the road. The comparison of energy consumption per km length of road in Figure 11 (section 2.2) shows that the consumption in Bangkok is 2.7 times as high as that of London and 5 times as high as that of Nagoya.

Since the traffic in Bangkok emits CO rather than NO_2 as described above, the roadside NO_2 concentration is not as high as in the case of CO. Roadside NO_2 concentration is highest in London. The concentration in London is around 1.4 times higher than Nagoya while the energy consumption per road length is twice as high. This is because the percentage use of diesel in London is lower than that in Nagoya.

4. LAND USE AND TRANSPORT POLICIES FOR IMPROVEMENT OF THE URBAN ENVIRONMENT

4.1. Major Causes of Environmental Degradation - executive summary of findings from comparative analysis

The findings from the comparative analysis in the previous chapters suggest that suburbanization is one of the major contributions to longer trip length. The built-up area in Bangkok is spreading at a higher rate than those of London and Nagoya, around 2.3 times and 3 times higher respectively. Moreover, the analysis in section 3.1.1 also suggests that the sensitivity between the spread of the built-up area and veh-km is the highest in Bangkok (see Figure 6 and Table 1). In this sense the problem is the most serious in Bangkok.

Higher car use and transport energy consumption are found in all three cities but the major causes seem to be different. In London, higher car use is remarkable in the suburbs due to lower public transport service and its relatively high fare. These result in the highest per capita energy consumption for road transport. In Nagoya, the increase rate of vehicle trip length is the lowest among three cities because the total length of underground had become 2.5 times during 1871 - 1989. In Bangkok, the lack of transport infrastructure supply and rapid increase of trip length due to tremendous suburbanization make higher rate of energy consumption both in terms of consumption rate and per capita consumption. The per capita road transport energy consumption is almost equal between Nagoya and Bangkok, though the economic development levels are very different due to the above reasons.

In Bangkok the very high intensity of energy consumption along the road together with low quality vehicles causes severe air pollution problems along the road, while in Nagoya, as the result of the lower intensity of energy use and stricter emission standards, the roadside pollutant concentration is not so high. However, due to a wide gap of prices between gasoline and diesel, the rapid increase in diesel consumption shows a trend of continuing and this will cause a higher degree of problems. In London, the high roadside NO_2 concentration, which is a consequence of high gasoline consumption, is a major air pollution problem.

4.2. Comparison of Implemented Land use - Transport Policies and Comments for Environmental Improvement

Table 2 compares the major land use-transport policies which have been recently implemented for encouraging environmental improvement in each city.

The comparison suggests that in London development management and control policies are the major measures for environmental protection and improvement, while not many countermeasures have been introduced for controlling usage of the cars which is a major cause of high energy consumption, especially in suburbs.

In Nagoya vehicle emission control is a major countermeasure against air pollution problems. Though the influence of suburbanization on veh-km is comparatively low due to the improvement of underground system, suburban spread seems to continue occurring (see Fig.6). This phenomenon suggests that in order to control an increase in veh-km and energy consumption, Nagoya must pay more attention to development control.

Table 2 Comparison of Implemented Land use - Transport Policies

Policy Category	London	Nagoya	Bangkok
Development Management and Control	- Green belt - Redistribution of industry to other regions - New town development	- Urbanization restriction area - New town development	- Building control
Infrastructure Supply	- Underground and British Rail - Ring road - Light rail transit	- Underground and private rails - Urban expressway	- Urban expressway - Construction missing links
Traffic Management and Control	- Heavy lorry ban during night - Bus lane - Parking restriction	- Exclusive central lanes for bus - Parking restriction	- Heavy lorry ban during day time - Bus lane - One-way and reversible lane - Parking restriction
Pricing and Taxation	- Travel card	- Travel card	
Emission Control and Technology Innovation	- Stricter standard	- Very strict standard - Inspection of in-use vehicles	

In Bangkok, the measures are mainly concentrated on traffic management, which aim mainly at reducing traffic congestion. However, the evidence of suburbanization degree and changes in veh-km and energy consumption show that the past measures could not tackle the rapid changes. As the effect of suburbanzation on the increase of veh-km and energy consumption is the highest, development control together with infrastructure supply both of road and rail should be the major measures for environmental protection and improvement.

5. CONCLUSION

In this study, we have illustrated the quantitative relations between suburbanization, trip length and the consequent energy consumption. Using these functions, necessary land use-transport policies can be better examined. We believe that by comparing the metropolises which are in different stages of economic development and urbanization, interpretations of policy effects can be more generalized.

Comparing the three cities as a whole, land use control is one of the most essential measures because it determined the basic level of energy use in a metropolis through total trip length. In long-term control of land use, London has been most successful for a megalopolis. On the contrary, Bangkok is most behind in suburban land use control, and it is clearly suggested in this study that the environment will become much more seriously impaired without introduction of stricter regulations at this stage of urbanization.

The following policies seem to be necessary for each metropolis;

1) London should concentrate on reducing the use of private transport especially in suburban areas, by increasing the cost of car use in order to bring about higher use of public transport. Moreover, stricter emission standards, especially for NO_2, should also be introduced.

2) In Nagoya, the policies should pay attention to stricter land use control in suburbs and the reduction of diesel consumption in the city. The increase of diesel tax, lorry bans and traffic diversion by ring roads are considered appropriate policies.

3) In Bangkok more effective development control and transport infrastructure supply are the most important measures needed for improving the urban environment. In addition, stricter vehicle emission standards and an in-use vehicle inspecting system will considerably reduce the amount of emitted pollutants.

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