3.5.1. Development of environmentally sustainable transport systems in urban areas

3.5.1.1. Introduction

The transport sector provides vital services in urban areas, but at the same time causes serious urban problems. The negative effects of urban transport activities include air pollution, accidents, congestion, noise from road transport, energy consumption, and consumption of land and other natural resources for the production of vehicles and infrastructure. In addition, urban transportation is one of the most significant sources of carbon dioxide (CO_2) emissions, which cause climate change. These negative effects persist and will worsen in many urban areas in the Asia-Pacific region if the current trend of urbanisation continues.

The most serious environmental effect of transportation is air pollution. The transport sector has been the fastest-growing source of most air pollutant emissions, and the high prevalence of two- and three-wheeled vehicles with two-stroke engines further aggravates the local air pollution in cities in Indonesia, Malaysia, and Thailand, and increasingly in China, India, Vietnam, and other countries in the Asia-Pacific region (ESCAP, 2001). Plans to reduce these negative effects within these cities of the region are needed urgently.

This research aims to collect good practices in the area of transport and to propose strategic policy options (SPOs) to develop systems for environmentally sustainable transport (EST), that is, effectively integrated policy instruments for cities in the Asia-Pacific region, focusing mainly on passenger transport, although not to the total exclusion of freight transport.

This study also aims to develop packages of SPOs reflecting the real situations of the cities, and to assess the SPOs and instruments as applicable by conducting scenario analysis in a number of cities in the Asia-Pacific region, namely, Bangkok (Thailand), Beijing and Taiyuan (China).

3.5.1.2 Research framework

(1) Research objectives

It is now generally accepted that the most appropriate transport strategies for urban areas are integrated strategies that combine a range of policy measures and achieve synergy between them (May et al., 1999). This research aims, therefore, to propose strategic policy options (SPOs) to develop systems for environmentally sustainable transport (EST), that is, effectively integrated policy instruments for cities in the Asia-Pacific region, based on good practices. This study also aims to develop packages of SPOs reflecting the real situations of the cities and to assess the SPOs and instruments as applicable by conducting scenario analysis in a number of cities in the Asia-Pacific region, namely, Bangkok (Thailand), Beijing and Taiyuan (China).

(2) Research scope

This research focuses on the effects of the transport sector on the environment, especially air pollution and climate change, and does not consider other factors such as safety issues or the infrastructure of roads. In addition, the main focus of this research is on passenger transport, although the transport sector consists of both passenger transport and freight transport and the research does not totally exclude the latter.

(3) Research methodology

This research was conducted in four steps: (1) collecting good practices; (2) developing a framework of EST strategies in the Asia-Pacific region; (3) identifying and developing strategic policy options; and (4) developing scenarios for target cities and assessing the policy options/scenarios (Figure 3.5-1).

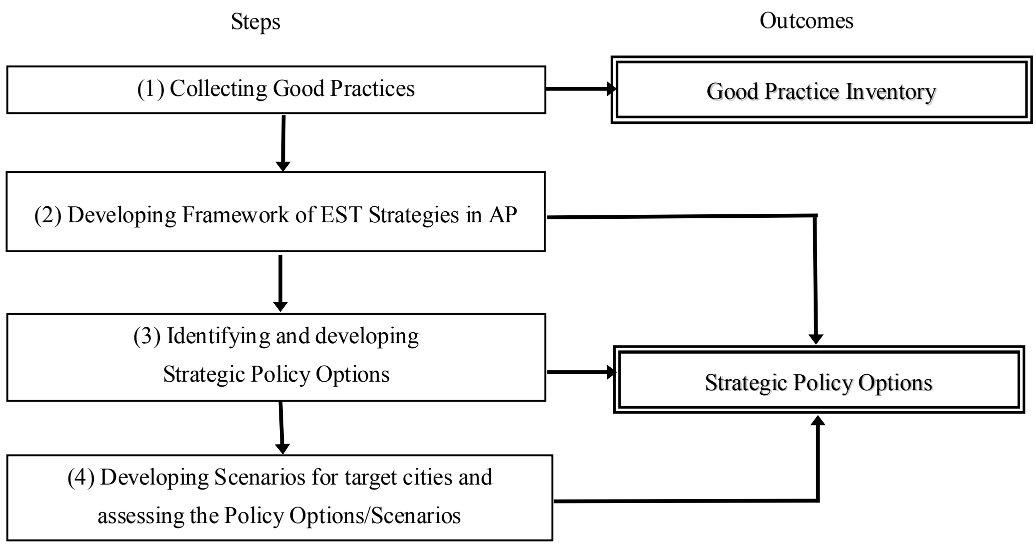

Figure 3.5-1 Research procedure

1) Collecting good practices

Information on good practices, including critical instruments, effects, lessons learned, and potential for application of the practices, was compiled in the Good Practices Inventory based on literature review and interviews with experts and the people concerned. In addition, a workshop was held in Bangkok to receive comments from the policy-makers on the good practices information. Good practices were selected so that various areas of sustainable transport are covered. This work was carried out in collaboration with international institutes including the Asian Institute of Technology, the Energy Research Institute of China, and the UNEP Collaborating Centre on Energy and Environment (UCCEE).[73]

2) Developing the framework of EST strategies in the Asia-Pacific region

To identify the SPOs for EST, three strategies to tackle major factors of transport that cause environmental problems were identified by tracking the causal chains among socio-economic factors, transport, and environmental problems. The basic framework of those three strategies was developed at an experts meeting for the Asian EST scenarios held in July 2004.[74]

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[73] The name of UCCEE was changed to the UNEP Risoe Centre on Energy, Climate and Sustainable Development (URC) in 2003.

[74] The participants included: Prof. Hideo Nakamura (Institute for Transport Policy Studies), Mr. Senro Imai (Institute for International Cooperation, Japan International Cooperation Agency), Mr. Naomi Kamioka, (Coalition of Local Government for Environmental Initiatives, Japan), Prof. Yoshitsugu Hayashi (Graduate School of Environmental Studies, Nagoya University), Prof. Jun Fujimoto (Research Centre for Advanced Science and Technology, University of Tokyo), Dr. Kiyoyuki Minato (Japan Automobile Research Institute), Prof. Tsuneyuki Morita (National Institute for Environmental Studies), and Prof. Masaharu Yagishita (Graduate School of Environmental Studies, Nagoya University).

3) Identifying and developing Strategic Policy Options

Under each strategy, the changes needed to achieve the strategy and the objectives for those changes were identified, and policy options which are expected to meet those objectives were identified as the SPOs. A draft list of the changes, objectives, and SPOs was developed, based on the framework from the experts meeting in July 2004. Twenty-three SPOs were identified after receiving feedback through academic and international conferences,[75] and after discussions among the participating researchers. "Innovative" SPOs were selected from the identified SPOs by using the criteria common to all sub-themes of RISPO, developed by the Overall Analysis team. For each innovative SPO, analyses on criteria instruments, effects of the instruments selected, implementation issues, and applicability and limitation, were conducted, based on the collected good practices in the Good Practices Inventory and literature review. In documenting the SPOs, the possibility of integration with other policy options is considered.

4) Developing scenarios for target cities and assessing the policy options/scenarios

Two mega cities and one large city were selected as the target cities for the scenario analyses. Bangkok (Thailand) was chosen as one of the major cities in the Asia-Pacific region which for many years has suffered from high environmental pollution due to transportation. Beijing (China) was chosen as a mega city going through rapid economic growth and vehicle population increase. Taiyuan (China) was selected as a large city with serious air pollution yet with low vehicle population. For each city, scenarios were identified through interaction with policy-makers, and the energy consumption and emissions of CO_2 and air pollutants for each scenario were estimated by using the Asia-Pacific Integrated Model (AIM) in collaboration with the Integrated Environmental Assessment sub-project of APEIS.

3.5.1.3 Strategies and SPOs

(1) Status of transport in the Asia-Pacific region

1) Background: Rapid urbanisation trend in the Asia-Pacific region

Urbanisation is one of the most significant issues facing the Asia-Pacific region, where cities have some of the highest urban densities compared to other regions in the world (Kenworthy and Laube, 2000). Figure 3.5-2 shows the urban population in the 22 Asia-Pacific countries in 2001. Among the approximately 3.3 billion population in those countries, more than one fifth of people live in urban areas in the two highest-populated countries, China and India. When we look at the urbanisation rate, nine countries show an urban population rate higher than 50% (Figure 3.5-3). On average, one in three people in this region lived in an urban area in 2000, compared to one in five in 1960. This urbanisation trend is still progressing rapidly. It is estimated that half of the population of the developing economies in the Asia-Pacific region may be living in urban areas by 2025. Almost all of the increase in population over this period will be absorbed by urban areas, with the population in the rural areas remaining more or less at the current level (ESCAP, 2001).

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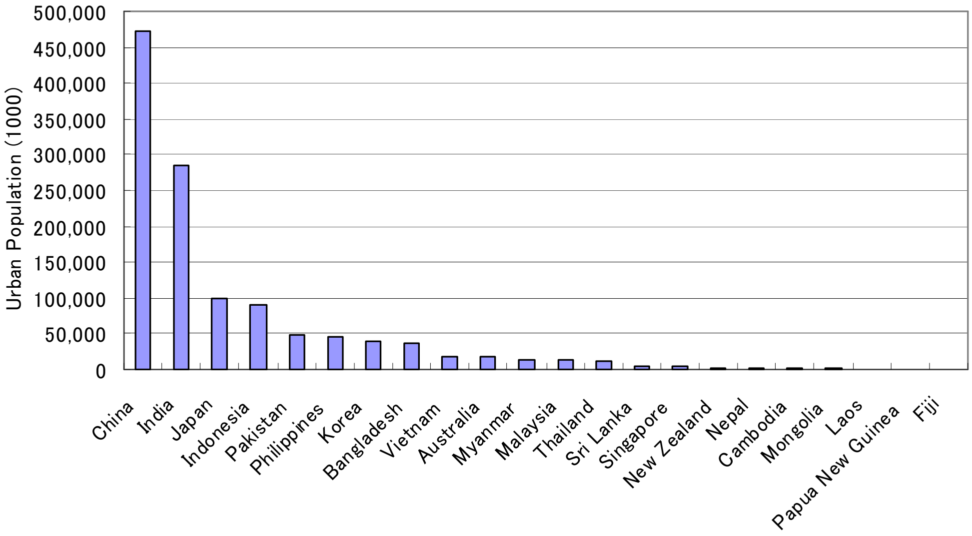
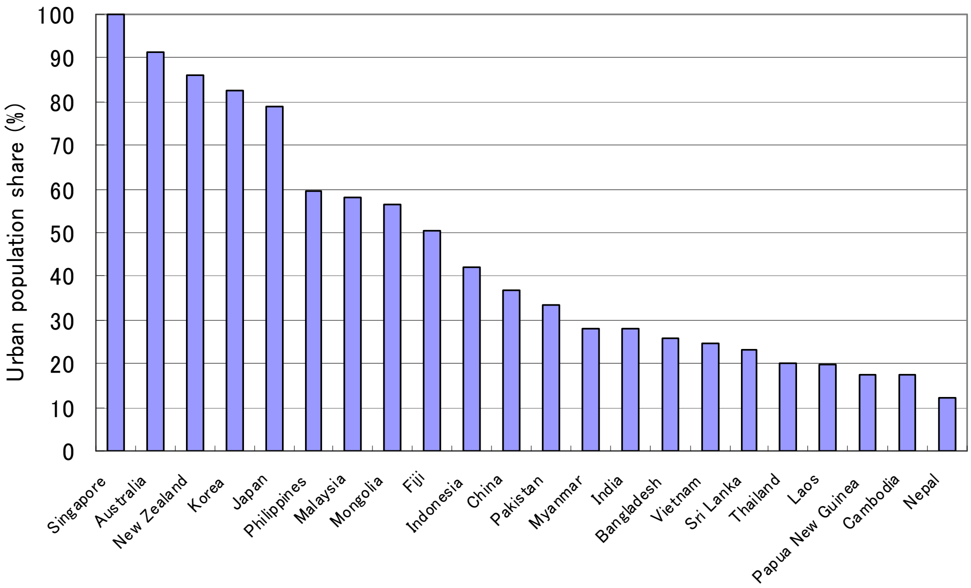
[75] The conferences included: Society for Environmental Economics and Policy, September 27-28, Tokyo; Better Air Quality 2003, December 15-17, Manila; and Mega City Workshop, January 28-30, Hayama.



(Source: United Nations Population Division 2002)

Figure 3.5-2 Urban population in the Asia-Pacific countries in 2001



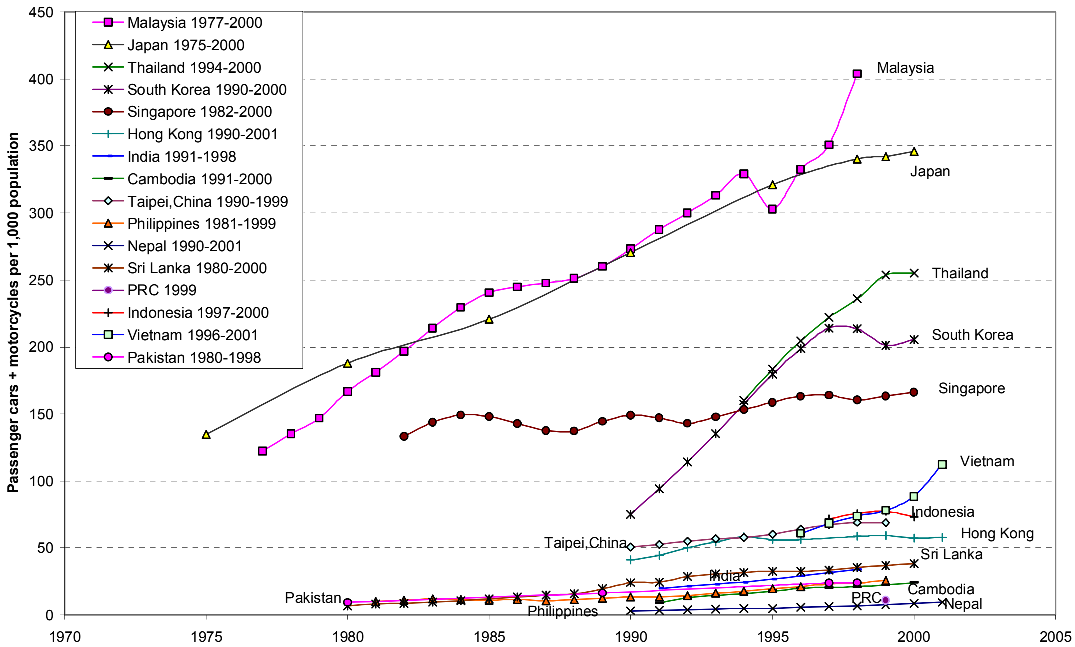
(Source: United Nations Population Division 2002)

Figure 3.5-3. Urban population share in the Asia-Pacific countries in 2001

2) Motorisation trend and environmental effects in the Asia-Pacific Region

The growth of urban population as well as the economic growth in the region induces an increase in the travel activities of people and goods. As a result, the number of vehicles in Asia is increasing as shown in Figure 3.5-4. The rate of motorisation is different from country to country. However, an overall increasing trend can be observed for most countries.

As the number of vehicles and travel distances grow, negative effects intensify such as air pollution, global warming, accidents, congestion, noise, energy consumption, and consumption of land and other natural resources for the production of vehicles and infrastructure. Figure 3.5-5 shows the average annual air quality in 15 mega cities in Asia from 1990 to 1999, in relation to the World Health Organisation (WHO) air quality standards and the United States Environmental Protection Agency (US EPA) standards for particulate matter of less than 10 microns (PM_{10}). This figure shows that many cities fail to meet those standards, especially for suspended particulate matter and PM_{10}, meaning that residents of many cities are exposed to a risky level of air pollutants. Health effect studies have shown the relationship between the air pollution level and health effects such as cardiovascular disease, asthma, and other respiratory diseases. For example, the WHO estimated that about 800,000 people each year die prematurely because of exposure to urban outdoor air pollution, and 500,000 of those are believed to be in Asia (ADB, 2003).[76]

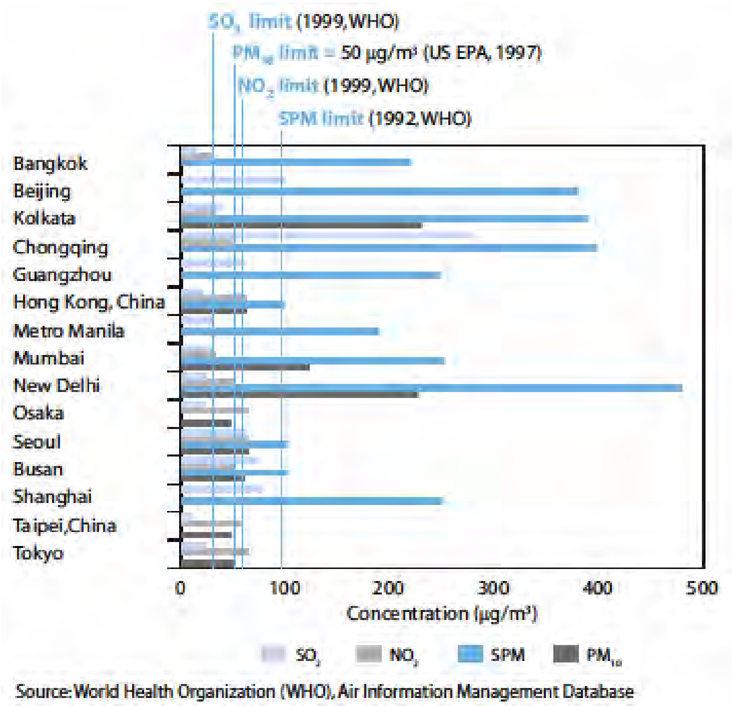


Notes
1. Motorisation includes registered private cars and motorcycles
2. Vehicle registrations in some developing countries are known to overstate actual in-use fleet. In Thailand, for example, the in-use fleet was half of the 1999 registered fleet.
Sources: Cambodia Ministry of Public Works and Transport; Hong Kong, China Transport Department website; Paper on “Modelling Anthropogenic Emissions from Energy Activities in India: Generation and Source Characterization” of the Ohio Supercomputer Centre website; Indonesian Police Department (Ditlantas Polri); Japan Statistics Bureau and Statistics Centre website; Malaysian Roads General Information 1999 of Malaysia Road Transport Department; Nepal Department of Transport Management; Pakistan Statistical Yearbook 2000, Federal Bureau of Statistics; Philippines Department of Transportation and Communication; PRC “World Development Indicators 2001” of World Bank website; Statistical Yearbook 2001 of Republic of Korea Ministry of Construction and Transportation; Singapore Land Transport Authority website; Sri Lanka Ministry of Transport; Taipei, China, Department of Transportation website; Thailand Department of Land Transport, Ministry of Transport and Communications; “Transport Statistics Great Britain: 2002 Edition” of United Kingdom Department of Transport website; Vietnam Register; Population statistics for all countries from University of Utrecht website

(Source: Asian Development Bank 2003)

Figure 3.5-4 Selected motorisation trends

[76] Studies on the health effects of air pollution are very limited in Asia due to weak capacity to undertake such research (ADB 2003).



(Source: Asian Development Bank 2003)

Figure 3.5-5 Average annual pollution concentrations, by city (1990-1999)

It is likely that, with the growing economies and population in the Asia-Pacific region, motorisation will be accelerated. To address and mitigate this trend, policies to reduce the negative environmental effects from the transport sector are urgently needed.

(2) Strategies

1) Framework of strategies

As the first step to identifying the SPOs for EST, strategies to tackle major factors of transport that cause environmental problems were identified by tracking the causal chains among socio-economic factors, transport, and environmental problems as shown in Figure 3.5-6. The following three factors were identified.

Factor 1: Increase in travel demand

With economic growth and increased urban population (Figure 3.5-2 and 3.5-3), the city areas tend to expand (urban sprawl), which leads to longer trips. In addition, growing economic activities induce more frequent and longer trips of people and goods. This can be categorised as the issue of ***quantity***.

Factor 2: Increase in vehicle ownership and use, and lack of alternatives

To meet the increasing travel demand, people buy cars and drive. Income growth and population increase stimulate the increase in vehicle ownership and use. The rate of ownership and use of automobiles are expected to grow, especially in sprawling areas. Alternatives to automobile use are public transport and non-motorised transport (walking and cycling). If good systems of public transport and non-motorised transport are provided, the need for automobile ownership and use could decrease. However, the reality is that many Asian cities suffer from the lack of such good alternatives and allow the ongoing motorisation, as shown in Figure 3.5-4. Tendencies to look upon automobiles as status symbols are also observed in many cultures. As a result, the combination of increase in vehicle ownership/use and low availability of public transport to meet the increasing travel demand leads to more vehicle kilometres travelled. This category of factors can be called the issue of ***balance***.

Factor 3: High environmental impact due to vehicle use

Vehicles consume energy, and emit air pollutants and greenhouse gases to an extent depending on the travel distances and traffic conditions. Another major factor defining the total environmental burden is the energy efficiency and emission rate of each vehicle. While developed countries have been making progresses in the energy efficiency and emission control technologies of vehicles, old and ill-maintained polluting vehicles are still seen in the traffic in many developing countries. Those issues are arising due to the problem of ***quality***.

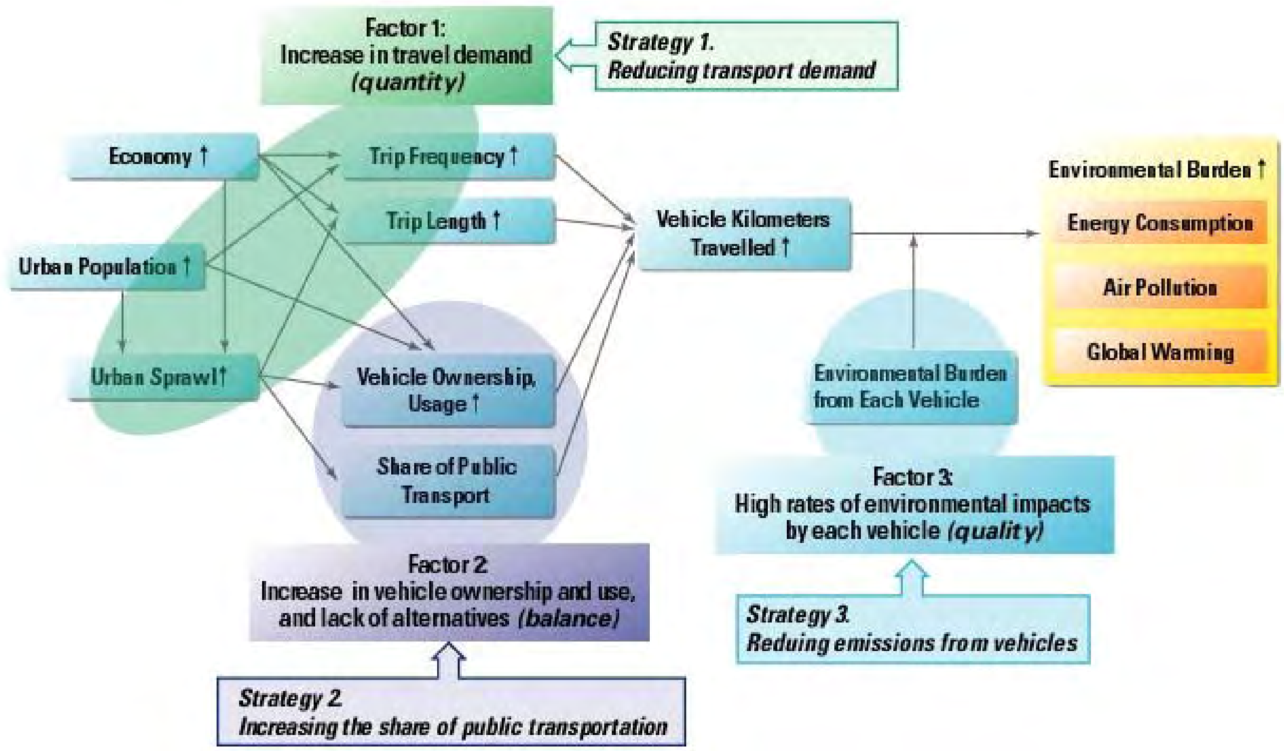


Figure 3.5-6. Factors of environmental burden due to transport related activities and strategies

To address these factors, three strategies, each focusing on quantity, balance, and quality, were selected as shown in Figure 3.5-6. Those strategies are: reducing transport demand, increasing public transport, and reducing emissions from vehicles.

Under each strategy described above, the changes needed to achieve the strategy and the objectives for those changes were identified. Policy options which are expected to meet those objectives were identified as the SPOs (Table 3.5-1).[77]

[77] The lists were developed based on the framework developed by the expert meeting, feedback received at academic and international conferences, and discussion among the participating researchers.

Table 3.5-1 List of SPOs for each strategy

Strategy 1: Reducing transport demand

Change	Objective	SPO Title	Related GP
Land use change for shorter length of trip	Avoiding urban sprawl	**Creating regional systems of cities**	
		Promoting compact cities and smart growth	Singapore, Curitiba
Travel behaviour (frequency of trip)	Reducing necessity of trips	**Using IT-based communications and services to reduce transportation need**	

Strategy 2: Increasing the share of public transportation

Change	Objective	SPO Title	Related GP
Modal shift	Improving public transport (providing alternatives to automobiles)	**Promoting rail-based mass rapid transit (R-MRT) through innovative mechanisms to address high initial costs**	Beijing, Curitiba, Bangkok
		Promoting Bus Rapid Transit (BRT)	Curitiba, Bogotá, Quito
		Improving bus routes and services	
		Using community vehicles	Bangkok, Kathmandu
	Improving NMT	**Promoting special lanes for pedestrians and cyclists**	Beijing
		Creating car-free zones	Bangkok
	Reducing ownership and use of automobiles	**Introducing number plate bidding systems**	Singapore, Shanghai
		Promoting car sharing	Fukuoka
		Regulating entrance to the city centre (number plate regulation)	
		Introducing a parking policy	
		Introducing high occupancy vehicle lanes	
		Using road pricing to control vehicle use	Singapore, Seoul
		Using a travel awareness initiative for wise use of automobiles	Sapporo

Strategy 3: Reducing emissions from vehicles

Change	Objective	SPO Title	Related GP
Low emission vehicle technology	Reducing emissions from conventional fuel vehicles (including hybrids)	**Introducing vehicle emission standards and inspection/maintenance systems**	Bangkok, Beijing, Shanghai
		Introducing vehicle fuel standards	Bangkok
		Greening fuel taxes	Bangkok, Bogotá
		Promoting the spread of high efficiency vehicles	Beijing, Shanghai
	Introducing alternative fuel vehicles (bio-fuel, CNG, LPG, EV, fuel cells)	**Promoting alternative fuel vehicles**	Beijing, Shanghai, Kathmandu
Smooth traffic flow	Reducing loss due to bottlenecks/congestion	Introducing Intelligent Transport System (ITS)	Beijing
Good driving practice	Reducing emissions due to driving practice	Raising public awareness of environmentally friendly driving	

- SPOs in bold: SPOs meeting at least one of the two sets of components of the 'criteria for innovative policies for developing countries' and considered feasible and important in such countries.
- Related GP means the Good Practices compiled in the Good Practices Inventory.

The innovativeness of each SPO was assessed based on the 'criteria for innovative policies for developing countries' developed by the RISPO Overall Analysis group. Innovativeness is defined *as new ideas, methods, and devices that can make changes.* Two kinds of criteria are identified, each of which consists of a set of components, and a policy option is considered innovative if it satisfies at least one component of both criteria. The first criterion is "basic ideas" which has two components: (a) policies that turn burdens into opportunities and weakness into strength; and (b) policies that can introduce new ideas and mechanisms that can prove to be effective. The second set, "specific suggestions", has four components: (a) policies that utilise market mechanisms; (b) policies that will promote the enabling and catalytic roles of governments; (c) policies that improve the use of existing capacities for the betterment of the environment (infrastructure, institutional mechanisms); and (d) policies that harness the synergy of the various stakeholders and countries. This sub-project selected the SPOs which meet any components of either set of criteria and, among the policies selected, seventeen policy options were identified as priorities based on their feasibility and importance in developing countries (as shown bold in Table 3.5-1. See Table 3.5-2 for evaluation of innovativeness of each SPO based on the criteria). For those SPOs, analyses of criteria instruments, effects of instruments selected, implementation issues, and applicability and limitation, were conducted based on the collected good practices identified in the Good Practices Inventory and literature review.

Table 3.5-2 Evaluation of innovativeness based on the 'criteria of innovative policies for developing countries' context

Strategy 1: Reducing transport demand

SPO Title	Evaluation of Innovativeness		
	Basic idea (1) Policies that turn burdens into opportunities and weakness into strength (2) Policies that can introduce new ideas and mechanisms that can prove to be effective	Specific suggestions (1) Policies that utilise market mechanisms (2) Policies that will promote the enabling and catalytic roles of governments (3) Policies that improve the use of existing capacities for the betterment of the environment (infrastructure, institutional mechanisms) (4) Policies that harness the synergy of the various stakeholders and countries	Meeting both criteria?
Creating regional systems of cities	1: Development of a regional system of cities changes a densely populated huge urban centre into a manageable one 2: This is a new concept of city development	4: This can be applied with close cooperation among national and local governments, infrastructure developers, and local people	Yes
Promoting compact cities and smart growth	1: Congested and sprawled cities can become environmentally sustainable and livable cities if appropriate planning is introduced	4: Same as above	Yes
Using IT-based communications and services to reduce transportation need	2: Teleworking, teleshopping, etc., are new ideas for utilising new IT technology	3: Huge investment in terms of urban transport infrastructure is not required, although investment needed for IT infrastructure	Yes

Table 3.5-3 Evaluation of innovativeness based on the 'criteria of innovative policies for developing countries' context (cont'd)

Strategy 2: Increasing the share of public transportation

SPO Title	Evaluation of Innovativeness		
	Basic idea (1) Policies that turn burdens into opportunities and weakness into strength (2) Policies that can introduce new ideas and mechanisms that can prove to be effective	Specific suggestions (1) Policies that utilise market mechanisms (2) Policies that will promote the enabling and catalytic roles of governments (3) Policies that improve the use of existing capacities for the betterment of the environment (infrastructure, institutional mechanisms) (4) Policies that harness the synergy of the various stakeholders and countries	Meeting both criteria?
Promoting rail-based mass rapid transit (R-MRT) through innovative mechanisms to address high initial costs	1: Congested streets can become important arteries served by high capacity rail systems	1: Market mechanisms are utilised if innovative financing schemes are introduced or if value capture due to MRT is reflected 4: Development of R-MRT induces new area development which involves developers, retailers, and citizens	Yes
Promoting Bus Rapid Transit (BRT)	1: Congested roads can be turned into public transport arteries	3: Existing roads can be used as busways without replacement with railways	Yes
Improving bus routes and services		3: This does not require changes in road infrastructure	No
Using community vehicles	2: This system bridges the gap between public and private transportation modes	3: Existing road system could be used	Yes
Promoting special lanes for pedestrians and cyclists	2: Special lanes for walking and cycling are a new concept	3: Human feet and bicycles are measures which require smaller investment compared to other modes of transportation	Yes
Creating car-free zones	1: Traffic-congested and polluted areas can be transformed into environmentally better areas where people can enjoy various activities	3: Implementation of this option may not involve significant cost 4: Cooperation between local government and local people is necessary for car-free day Car-free days enhance communication among them through the activities taking place in the car-free zones	Yes
Introducing number plate bidding systems	1. Government can utilise the burden of increasing cars as a funding and control tool 2. Number plate bidding is a new mechanism for many cities (current examples are only Singapore and Shanghai)	1. An auctioning system, a market mechanism, is used as the key to this option	Yes
Promoting car sharing	2: The concept of shared ownership is new, starting in the late 1980s	1: Users pay according to the time and/or distance they drive 4: Car sharing organisations collaborate with various stakeholders including governments, private companies, public transport operators, and citizen groups	Yes
Regulating entrance to the city centre (number plate regulation)		3: This does not require changes in road infrastructure	No
Introducing parking policy		1: Many parking policies use price as a disincentive for entering congested areas	No
Introducing high occupancy vehicle lanes		4: Enhances cooperation among people to find those who can ride together	No
Using road pricing to control vehicle use	2: Although it started in the 1970s in Singapore, this is still introduced in limited urban areas and is new for many cities	1: Drivers need to pay to enter congested city areas or drive along busy roads	Yes
Using a travel awareness initiative for wise use of automobiles	2: Influencing people's travel activities by campaigns and education is a new concept started in the 1990s	3: This does not require a change in road infrastructure 4: The campaigns and educational programmes involve various stakeholders, such as government, community groups, schools, etc.	Yes

Table 3.5-4 Evaluation of innovativeness based on the 'criteria of innovative policies for developing countries' context (cont'd)

Strategy 3: Reducing emissions from vehicles

SPO Title	Evaluation of Innovativeness		
	Basic idea (1) Policies that turn burdens into opportunities and weakness into strength (2) Policies that can introduce new ideas and mechanisms that can prove to be effective	Specific suggestions (1) Policies that utilise market mechanisms (2) Policies that will promote the enabling and catalytic roles of governments (3) Policies that improve the use of existing capacities for the betterment of the environment (infrastructure, institutional mechanisms) (4) Policies that harness the synergy of the various stakeholders and countries	Meeting both criteria?
Introducing vehicle emission standards and inspection/maintenance systems	1: Adoption of a high level of emission standards with improved maintenance and monitoring can help improve air quality in urban areas 2: Promoting vehicles which emit less through legislation (e.g. four-stroke vs. two-stroke motor cycles)	4: This can be applied with close cooperation among national and local governments, the automobile industry and end users	Yes
Introducing vehicle fuel standards	1: Adoption of improved fuel standards can help improve environmental performance of vehicles and reduce pollution	4: Cooperation among national and local governments, oil manufacturers, and distributors and end users	Yes
Greening fuel taxes	1: Fuels, the burning of which is the main source of pollution, can be used as a source of funding for environmental policies	1: This option introduces a tax incentive to prevent excessive fuel consumption and promote switching to cleaner fuels 3: Since taxation on fuel already exists in many countries, additional implementation mechanism is minimal	Yes
Promoting the spread of high efficiency vehicles	2: LEVs, especially clean diesels and hybrid cars, are new mechanisms that will be effective	1: For this option, economic instruments such as tax exemption for LEVs are used	Yes
Promoting alternative fuel vehicles	2: Alternative fuel vehicles are new ways to leapfrog the vehicle technologies dependent on petroleum fuels	1: Economic instruments such as tax exemption and subsidies are introduced. Introduction of innovative financing schemes are used for provision of needed infrastructures	Yes
Introducing an Intelligent Transport System (ITS)	2: ITS is based on new technologies (advanced information and telecommunications network)		No
Raising public awareness on environmentally friendly driving		3: This does not require a change in road infrastructure 4: Participation of various stakeholders, including drivers, local governments, etc., is necessary	No

2) Strategy 1: Reducing transport demand

Strategy 1, **reducing transport demand**, aims to reduce travel demand by preventing uncontrolled urban sprawl or introducing appropriate technologies (e.g. telecommunications, information technology, etc.). There are two kinds of changes necessary to reduce transport demand. One is to change land use patterns so that people do not have to make long trips for daily activities such as work and shopping. The objective of this change is to avoid urban sprawl. The other change is alteration in travel behaviour to reduce frequency of trips.

For the former change and objectives, two policy options were identified: ***Creating regional systems of cities*** and ***promoting compact cities and smart growth***. A ***regional system of cities*** moves some urban functions from large cities to self-sufficient sub-centres, to prevent uncontrolled sprawl and to reduce and divert the transport need in a large city. ***Compact cities and smart growth*** are land use planning focused on creating higher density and better accessibility, which reduce automobile dependency in urban areas. The ***compact cities and smart growth*** approach is applicable only until the density reaches a certain point and, if the city is overcrowded, the decentralised concentrated urban forms such as ***regional system of cities*** would be suitable.

For the latter change, alteration of travel behaviour to reduce frequency of trips, ***using Information Technology (IT)-based communications and services to reduce transportation need*** was identified. This policy option aims to reduce travel demand by providing remote accesses to workplaces, shopping centres, government offices, and so on, regardless of the land use patterns.

This study evaluated the innovativeness of the SPOs discussed in Section III-2-1. For strategy 1, all three SPOs were identified as innovative.

i) Creating regional systems of cities

The regional system of cities relocates some urban functions from large cities to self-sufficient sub-centres, to prevent uncontrolled sprawl and to reduce and divert the transport need. Examples of the functions to be moved to new developments include governmental functions, research, and so forth. This has potential for application where cities are growing over-congested, and there emerges a need to reduce the inflow of people. Air pollution and urban environment are the key environmental areas being targeted. This strategy can be enforced only with close cooperation among national and local government, infrastructure developers (transportation, housing, etc.) and, finally the local people. Creating regional systems of cities would be suitable in cities that are too large to introduce the compact city and smart growth approach, which is land use planning focused on creating higher density and better accessibility which reduce automobile dependency in urban areas.

ii) Promoting compact cities and smart growth

A “compact city” in this policy option refers to land planning focused on higher density and better accessibility which reduce automobile dependency.[78] “Smart growth” is a general term for land use practices that create more accessible land use patterns and reduce the amount of travel needed to reach goods and services (Litman 2003a). Experiences of compact city or smart growth include Curitiba (Brazil), Singapore, Hong Kong (PRC), Freiburg (Germany), and Portland (US). Critical instruments for this policy option include coordination with public transport infrastructure development, mixed land use, urban boundary, and coordination of different levels of government.

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[78] There is no single agreed definition of a compact city. Denzwik and Saaty were the first to make an effort to define the term and their definition consisted of components such as high-density settlements, less dependence of automobiles, clear boundary from surrounding area, mixed land use, diversity of life, clear identity, social fairness, self-sufficiency of daily life, and independency of governance (Kaji 2004).

Although there are still objections to the idea of high-density land planning, accumulated data on world cities, such as that by Kenworthy and Laube (1999), indicates a correlation of urban density with less transport energy use and less car use per capita. At the same time, it should be noted that the difference in travel per capita becomes relatively small in cities which have a high urban density of more than approximately 75 persons/ha, and most Asian large cities fall into this category. In cities with higher density than this level, the more relevant approach is the formation of sub-centres within the city or development of a regional system of cities

iii) Using IT-based communications and services to reduce transportation need

Information technology (IT) based communication and services to reduce travel needs is defined as services and communication which can provide alternative services so that people do not need to physically travel to destinations, especially in the categories such as commuting to work, business meetings, shopping, banking, payment for services, and public service visiting. Policy instruments to reduce travel demands in the above categories of activities by using IT communication and services include government promotion programmes, public planning, and public awareness programmes.

3) Strategy 2: Increasing the share of public transportation

Strategy 2, **increasing the share of public transportation**, seeks a more environmentally sound, higher proportion of usage of public transport as well as non-motorised transport.

The change this strategy requires is greater use of public transport and non-motorised transport. There are three objectives that need to be achieved: (1) improving public transport; that is, providing alternatives to automobiles; (2) improving non-motorised transport (NMT: walking and cycling); and (3) reducing ownership and use of automobiles.

To improve public transport, policy options to improve four types of modes were identified: ***promoting rail-based mass rapid transit (R-MRT) through innovative mechanisms to address high initial costs***; ***promoting Bus Rapid Transit (BRT)***; and ***using community vehicles***. Those options vary in carrying capacities, operational speed, infrastructure and financial requirement, flexibility to transport demand, and environmental effects. ***R-MRT*** has the highest capacity among them and the least environmental impact, but is the most costly and least flexible. Therefore, one of the most important issues in introducing R-MRTs in developing cities is the funding mechanism of the system. On the other hand, ***community vehicles***, a transport system initiated by private operators to satisfy the commuting needs of the public by such services as school buses and factory buses, can provide a flexible public transportation service where mass transport fails to cope with the increasing public transport demand. ***BRT*** and ***conventional buses*** are situated in between R-MRT and community vehicles in terms of the indicators mentioned above. ***BRT***, a rapid bus system operated on segregated bus lanes, has a capacity and operational speed very close to Light Rail Transit, one mode of R-MRT. Those modes also vary in terms of labour intensiveness. In choosing modes suitable to the city, the labour intensiveness of the economy should be considered.

NMTs, especially walking, are the oldest ways of transport but are threatened by the spread of motorisation. In order to improve NMT, one policy focusing on infrastructure and one on awareness raising were selected as the policy options. ***Promoting special lanes for pedestrians and cyclists*** aims to promote walking and cycling by providing segregated lanes to secure safe trips by those modes. ***Creating car-free zones*** are measures to limit the use of motor vehicles in designated zones. One category of this option is a car-free day, a campaign not only to discourage the use of private vehicles during a set period but also to raise awareness of the effect of transportation behaviour on the environment. This policy option also addresses the third objective, reducing ownership and use of automobiles.

To meet the objective of reducing ownership and use of automobiles, two policy options were selected regarding ownership of vehicles. A ***number plate bidding system*** is a system to limit the increase of private vehicles in cities by setting the total number of number plates that can be sold in a city and open auctions for them. ***Car sharing***, sometimes called short-term car rental, offers members access to a vehicle without ownership and thus eliminates the necessity to own private vehicles. The ***number plate bidding system*** has proven to be powerful in Singapore and Shanghai but faced opposition from industry in Shanghai. ***Car sharing*** is rather a "soft" approach but has spread among environmentally conscious citizens in Europe.

On the vehicle use side, policy options were identified to control traffic in congested urban areas or heavily used roads. ***Regulating entrance to the city centre*** limits access to the city centre by using the last digit of a number plate: cars with the designated digit are not allowed to enter the city centre on certain days of the week. A ***parking policy*** tries to control the traffic flow by controlling the total capacity and fees of parking spaces in congested areas. ***High occupancy vehicle lanes*** do not allow vehicles with only one (or two) passenger(s) to use them and thus reduces the total number of cars on the designated roads. ***Road pricing*** charges motorists for driving on a particular roadway or driving into particular areas, thus providing economic disincentives to drive on that roadway or in that area. In addition, a policy option using campaigns and education to change people's awareness, attitude, and travel behaviour (***using a travel awareness initiative for the wise use of automobiles***) was selected. ***Creating car-free zones***, as discussed in the NMT, also falls into this category of awareness-raising regarding less use of cars.

Based on an evaluation of the innovativeness of the SPOs, innovative policies for this strategy were identified. They are: promoting rail-based mass rapid transit (R-MRT) through innovative mechanisms to address high initial costs, promoting Bus Rapid Transit (BRT), using community vehicles, promoting special lanes for pedestrians and cyclists, creating car-free zones, introducing number plate bidding systems, promoting car sharing, using road pricing to control vehicle use, and using a travel awareness initiative for wise use of automobiles.

i) Promoting rail-based mass rapid transit (R-MRT) through innovative mechanisms to address high initial costs

R-MRT comprises a wide spectrum of urban public transport modes (including metros, suburban railways, and light rail transit) that either use fixed tracks or have exclusive and segregated use of potentially common-user roadways (World Bank 2002). R-MRT usually has a superior operating capacity and performance compared with un-segregated road-based public transport (such as buses, taxis, and paratransit). "Metro" is the most common international term for subways and heavy rail transit, though it is also commonly applied to elevated heavy rail systems. It is the most expensive form of mass rapid transport per kilometre, but has the highest theoretical capacity (Wright and Fjellstrom 2003). Underground metros are the most environmentally beneficial because they are considered less intrusive in the urban fabric. Suburban railways differ from Metros and LRT in that the passenger cars generally are heavier, the average trip lengths are usually longer, and the operations are carried out over tracks that are part of the railroad system in the area (Wright and Fjellstrom, 2003). An LRT system is a metropolitan electric railway system characterized by its ability to operate single cars or short trains along exclusive rights-of-way at ground level, on aerial structures, in subways, or occasionally in streets, and to board and discharge passengers at track or car floor level.

ii) Promoting Bus Rapid Transit (BRT)

Bus Rapid Transit (BRT) is a system that emphasizes priority for, and rapid movement of, buses by securing segregated busways (IEA, 2002). BRT is also known by other names, including 'High-Capacity Bus Systems', 'High-Quality Bus Systems', 'Metro-Bus' 'Express Bus Systems', 'Busway Systems', and 'Surface Metro' Systems (Wright, 2002). The extent of dedicated infrastructure and the level of sophistication of different systems vary considerably depending on the cases (IEA, 2002). Well-planned BRTs have high capacities to carry passengers and can provide comfortable, rapid, and low-cost public transport alternatives. BRTs started in Curitiba (Brazil) and are becoming widespread in the region including Bogota (Columbia) and Quito (Ecuador) and have proved to be a very cost-effective alternative. In North America, a number of cities have begun to develop BRT systems, including Ottawa (Canada), Pittsburgh, Los Angeles, and Honolulu (the United States). In Oceania, Brisbane and Adelaide (Australia) have BRT systems. In Europe, BRTs are becoming increasingly common in cities in the United Kingdom, including Leeds, London, Reading, and Ipswich. Cities in Asia are starting to introduce BRT, such as the systems in Nagoya (Japan), Taipei (China), Jakarta (Indonesia) and Seoul (Korea). Introduction of BRTs is being considered in Beijing (P.R. China), Bangkok (Thailand), Delhi, Hyderabad (India), and Dacca (Bangladesh) (IEA, 2002; Wright and Fjellstrom, 2002; ITDP, 2003a; Fjellstrom, 2003a, 2003b).

iii) Using community vehicles

The term "community vehicles", in this study, refers to the transport system initiated by private operators to satisfy the commuting needs of the public. It includes school buses, factory buses, or any other schemes offering a public/commercial transportation service to a group of commuters. For community vehicles to be a successful operation, government rules and regulations are very important, particularly in cases where such services are meant for the public in general, unlike school and factory buses. This option has been proven to be effective in meeting the needs of public transport in, for example, the Bangkok Metropolitan Region (BMR), Rome, Tokyo, etc.

iv) Promoting special lanes for pedestrians and cyclists

Walking and cycling are the two major modes of non-motorised transport (NMT). Usually they are regarded as personal transport, but cycling, including various formats such as cycle rickshaws, could be either personal or public, as demonstrated in South Asia (World Bank 2002). In higher-income countries, many people also walk or cycle for exercise and pleasure. Here, we exclude such activities from our consideration and concentrate on NMT solely in terms of necessary transport.

Although walking and cycling are systematically under-recognized, they remain viable options by which to meet the basic mobility needs of all groups in a sustainable way. Pedestrians, cyclists, and cycle rickshaw passengers, generate no air pollution, no greenhouse gases, and little noise pollution. Furthermore, they are more efficient users of scarce road space to combat congestion. Cyclists use less than a third of the road space used by private motor vehicles, and pedestrians use less than a sixth. Even rickshaws use considerably less road space per passenger than motorised taxis and single occupancy private motor vehicles (Hook, 2002).

Whereas many developing cities have adopted transport policies that unconsciously induce less utilization of bicycles (for example, Asian countries), an increasing number of city governments, especially in European countries, have worked actively to promote walking and cycling, pressured by both social and environmental problems induced by rapid motorisation. Conversely, in countries where the needs of bicyclists have been neglected, such as the USA, bicycle use has been falling.

v) Creating car-free zones

Creating car-free zones offers a sustainable commuting strategy without limiting mobility and introduces a more civilized infrastructure, attractive both to tourists and residents, without the visual, atmospheric, and noise pollution that endless cars, trucks, and tourist buses thrust on citizens (Boddy, 2003). One way to promote car-free zones is by regulating vehicle transport in cities. This has been initiated through the car-free day concept as well as by implementing measures such as pedestrian zone programmes. Car-free day is basically a campaign to discourage the use of vehicles and encourage people to make more use of public transportation. A pedestrian zone programme helps users understand the air pollution problems created by vehicle use in urban areas, secures the rights of pedestrians and cyclists, and highlights the need for more and better public transport. The car-free day has become a popular tool to promote walking as an environmentally sustainable transport system, and to promote local activities in the streets of urban areas. For this to be implemented successfully, the closure of the street to traffic should be well planned and various activities should be set up to attract people to come to walk on the street. This will change congested areas and streets to public spaces and make streets a meeting place. People will learn about alternative ways of using the streets and recognize the problems of car use, which consumes a lot of fossil energy resources and creates a great deal of air and noise pollution. Thus, car-free day does not aim at removing all cars from the streets, but rather persuades people to think about the effect of their travelling behaviour on the environment and to understand that cleaner and more effective forms of transportation can improve the quality of life. It is a very influential measure and can play a great role in shaping the transportation policies of a country.

vi) Introducing number plate bidding systems

Number plate bidding is a system to limit the increase of private vehicles in cities, especially in metropolises which have a high density of population and vehicles, and limited capacity for road construction and extension. In big cities such as Shanghai and Singapore, with the rapid growth of the economy and of people's living standards, due to the comfort and convenience of private cars more and more people prefer to drive cars by themselves instead of using public transport or bicycles for working and travelling. However, this will lead to a more serious situation of high traffic obstruction since the rate of road construction cannot meet the increased capacity demand caused by the growth of vehicle use, which in turn will produce more pollution from vehicles. The number plate bidding system is an innovative mechanism to solve this problem by using a market-based approach. In this system, the city government fixes the number of allowable vehicles in a certain period, and prospective owners must go through an open bidding process to obtain number plates (i.e. licenses) to own and drive their vehicles. The obtained number plate will be valid for a certain length of time (e.g. 10 years) and the revenue from number plates will be collected and reused in transportation infrastructure construction.

vii) Promoting car sharing

Car sharing is a scheme which offers members access to a vehicle without ownership (Ball et al., 2001, as cited in Enoch, 2002). Vehicles are collectively owned and maintained by car sharing organisations. The system can be thought of as organised short-term car rental (Shaheen et al., 1998); people who want to use those vehicles become members of an organisation, and make reservations when they need to drive. Users pay according to time and/or mileage, usually billed monthly. The major differences between car sharing and rent-a-car systems include: users can rent cars for a short time period (e.g. 30 minutes), and members do not have to visit the company counters for check out and check in of vehicles. The social benefits of car sharing include saving urban space, smoothing traffic flow, providing individual transport with low cost, and reducing environmental burden. It started in Switzerland in the late 1980s and now there are hundreds of operational organisations in Europe and 15 organisations in North America as of July 2003. In Asia, car sharing is not as prevalent as in Europe and North America, but is being introduced in Singapore and Japan.

viii) Using road pricing to control vehicle use

Road pricing means that motorists pay directly for driving on a particular roadway (Litman, 2004). Road pricing can be applied at various levels, such as a bridge or a tunnel, a roadway section, roadways in a corridor, all roads in an area (such as a central business district), roadways at regional centres or throughout a region. Road pricing schemes targeting roads in an area take different forms. Area pricing imposes a charge on the actual road use in cities. Congestion pricing refers to road pricing used as a demand management strategy to reduce traffic congestion (Litman, 2002). Cordon pricing is equivalent to an entrance fee into a city (Schwaab and Tielmann, 2001). Road pricing was first implemented in Singapore in 1975 as the Area Licensing System (ALS). Such schemes are being introduced in Seoul, cities in Norway (Bergen, Oslo and Trondheim), and London. Introduction of road pricing has been considered in some cities such as Hong Kong, Tokyo, and Stockholm.

ix) Using a travel awareness initiative for wise use of automobiles

Attempts to change travel behaviour through psychological strategies, instead of by regulatory measures or economic incentives, began to be introduced in the 1990s. This policy option focuses on these new programmes and defines travel awareness initiatives for wise use of automobiles as programmes which aim to change travel behaviour through strategies including provision of specific information, and by public transport, travel campaigns, and travel education. Past experience includes the TravelWise campaign in the United Kingdom (UK), the Headstart programme originated in Hampshire in the UK, the Individualised Marketing developed in Europe and applied in Australia, the Travel Blending ® Programme started in Australia and introduced in the UK, the United States, and Chile, and the Travel Feedback Programme in Japan which was developed based on the Travel Blending ® Programme. Various measures, including nationwide publicity utilising multiple media, involving local people in transport policy-making, marketing based on individual contact, and individual measurement and personalised information for travel activities, have been used in those initiatives. A measure common to all initiatives is collaboration by local stakeholders.

4) Strategy 3: Reducing emissions from vehicles

The purpose of strategy 3, **reducing emissions from vehicles**, is to achieve a lower environmental burden from each vehicle by improving vehicle technologies, traffic flow, and driving practice. The changes needed to achieve the strategy of reducing emissions from vehicles are identified based on the three components affecting the environmental effects of vehicles: low emission vehicle technology, smooth traffic flow and good driving practice.

For low emission vehicle technologies, there are two objectives. The first objective is reducing emissions from conventional fuel vehicles (i.e. gasoline and diesel). For this purpose, four policy options were selected. ***Introducing vehicle emission standards and inspection/maintenance systems***, and ***introducing vehicle fuel standards,*** focus on regulatory measures to assure the quality of vehicle emission control technologies and vehicle fuels. A ***greening fuel tax*** introduces economic instruments as disincentives for vehicle ownership and use, or incentives to switch to cleaner fuels, implying the raising of tax rates on more polluting fuels. It can also mobilise its revenue for more sustainable modes of transport. ***Promoting the spread of high efficiency vehicles*** aims to promote the proportion of vehicles with higher efficiency compared with conventional gasoline and diesel vehicles, and lower emissions. Those policy options are closely related to one another.

The second objective for low emission vehicle technologies is introducing alternative fuel vehicles, such as natural gas, liquefied petroleum gas (LPG), alcohol fuels, bio-diesel, and electricity. One policy option, ***promoting alternative fuel vehicles,*** was identified. Compared to conventional fuel vehicles, switching to alternative fuels imposes higher initial investment and maintenance costs, and the current prices of alternative fuels can be expensive but shows possibilities of being attractive in the future. Therefore, redirecting some resources towards those non-conventional fuels needs to be examined with a long-term perspective (Walsh and Kolke, 2002).

Regarding smooth traffic flow, the objective is reducing loss due to bottlenecks and congestion. To achieve the objective, one technology-oriented policy option, namely, ***introducing an Intelligent Transport System (ITS),*** was identified. ITS is a new transport system comprising an advanced information and telecommunications network for users, roads, and vehicles, and contributes to solving problems such as traffic accidents and congestion. ITS consists of nine development areas, such as advances in navigation systems, electronic toll collection systems, optimisation of traffic management (including area-wide signal control), and so forth (Ministry of Land, Infrastructure and Transport of Japan, 2004).

For the change involving good driving practice, emission reduction from personal driving styles needs to be achieved. ***Raising public awareness of environmentally friendly driving*** was identified as the policy option to influence people's driving style, such as driving in a way to reduce unnecessary idling.

Based on an evaluation of the innovativeness of SPOs, five policies were selected for this strategy. These are: introducing vehicle emission standards and inspection/maintenance systems, introducing vehicle fuel standards, greening fuel taxes, promoting the spread of high efficiency vehicles, and promoting alternative fuel vehicles.

i) Introducing vehicle emission standards and inspection/maintenance systems

The objective of emission standards as a strategic policy option is to reduce emissions from vehicles through cleaner auto-related technologies, thereby reducing pollution by the urban transportation sector. An emission standard is the maximum amount of air polluting discharge (such as carbon monoxide, sulphur dioxide, particulates), legally allowed from a single mobile or stationary source (ADB, 2003a). Although emission standards differ from country to country, standards are commonly set for hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NOx), and smoke & particulate matter (PM). This tool can be applied with close cooperation between governments, the automobile industry, and end users.

Inspection and maintenance (I/M) is a tool that aims, among other activities, to check the emissions control system in a vehicle. Vehicles can meet required emission standards only when their emission control devices and engines are functioning properly. The I/M requires periodic checks and appropriate repairs for vehicles not complying with the standard, thereby discouraging any tampering with emission control devices. Thus inspection/maintenance (I/M) coupled with vehicle emission standards would help in reducing emissions from vehicles.

ii) Introducing vehicle fuel standards

Vehicle fuel standards are set to limit the levels of components that cause air pollution such as lead, benzene and sulphur. In cities where the above-noted pollutants are a major threat to air quality, introduction of fuel standards is of utmost importance. This needs to be carried out with the close cooperation of national or local government, oil m***anufacturers and distributors, and end users. This option has been shown to be effective in combating air pollution in many Asian countries, for example, Thailand, Bangladesh, China and Singapore. Vehicle fuel standards can be very effective in combination with other Strategic Policy Options such as emission standards, fuel taxes, and alternative fuel vehicles.***

iii) Greening fuel taxes

Vehicle fuel taxes on gasoline and diesel are in place in many countries and generally considered to be a road user fee intended to fund roadway projects and services (Jones and Nix, 1995 and Brown, 2001; cited in Litman 2003b). However, given the fact that fuel consumption is causing environmental degradation, it can be justified to use fuel taxation in a way that contributes to environmental protection. This Strategic Policy Option defines greening fuel tax as: (1) using fuel tax as a disincentive for vehicle ownership and use, or incentive to switch to cleaner vehicles, implying the raising of tax rates on more polluting fuels; and/or (2) mobilising revenue from fuel tax for more sustainable modes of transport. World wide, especially in European countries, attempts have been made to introduce greening fuel taxes. Revenues from fuel taxes are used for the purpose of developing sustainable transport in countries such as Germany, the United States, Colombia, and the United Kingdom. For fuel shifting, many countries have used tax differentiation to discourage the use of leaded gasoline, and some European countries are introducing differentiated gasoline based on the level of environmental burden. In order to "green" fuel taxes, it is critical to consider the instruments, such as step-by-step approach, allocation of tax revenue for development of sustainable transport, setting tax rates favouring cleaner fuels, and awareness raising campaigns.

iv) Promoting the spread of high efficiency vehicles

High efficiency vehicles (HEVs) are vehicles that have higher efficiency compared with conventional gasoline and diesel vehicles, and lower emissions. In general, HEVs include:

- High efficiency gasoline and diesel vehicles, equipped with emission control devices such as three-way catalytic converters. The most efficient diesel car developed in Europe is the LUPO, which has a fuel efficiency of less than 3 litres per 100 kilometres. Small-engined cars also have 30% to 50% higher efficiency than normal gasoline cars.
- Hybrid vehicles. This type of vehicle has high energy efficiency and can significantly reduce pollutant emissions, including CO_2 emission. There are already several models becoming popular in Japan and the United States. The most recent model in Japan (Toyota's PRUIS) has fuel efficiency of 35 kilometres per litre, with between 50% and 70% CO_2 emission reduction.

HEVs are very important for energy conservation, air pollution control, and greenhouse gas (GHG) emission reduction. Some HEVs are already developed and widely used, while others are still in the development phase. Because of environmental pressure and high oil prices, development of a new generation of technology, such as hybrid cars, is being accelerated. Compared with normal vehicles, many HEVs are more expensive. Therefore, to promote HEVs, support by governments is necessary.

v) Promoting alternative fuel vehicles

Alternative Fuel Vehicles (AFVs) are vehicles that run on fuels other than petroleum products (i.e. gasoline and diesel) (CEC, 2000). In general, alternative fuels include:

- Compressed natural gas (CNG), ranking relatively high in convenience and availability
- Liquefied petroleum gas (LPG)
- Alcohol fuels such as methanol (methyl alcohol), denatured ethanol (ethyl alcohol) and other alcohol, in pure form (M100 and E100) or in mixtures of 85 percent or more by volume (mixed with up to 15 percent unleaded regular gasoline — M85 and E85)
- Bio-diesel
- Electricity (stored in batteries)
- Hydrogen (fuel-cell)
- Solar

Alternative fuels are generally cleaner than gasoline because they are chemically less complex than gasoline, and when oxidized or burned, they burn more cleanly with fewer emissions. The increased use of alternative fuels in internal combustion engines offers the potential to reduce both regulated and greenhouse gas emissions, reduce the transportation sector's reliance on petroleum, and provide a boost to the alternative fuel vehicle industry.

3.5.1.4. Scenario Analysis

(1) Introduction

1) Objectives

The applicability and expected effects of the strategies and SPOs differ, depending on the geographical and socio-economic situations of each city. To facilitate decision-making by cities, this research conducts scenario analyses to identify potentially applicable packages of the identified SPOs in selected cities and to assess the effects of those scenarios, focusing on emissions of air pollutants and greenhouse gas (CO_2).

2) Target cities

Two mega cities and one large city were selected as the target cities for the scenario analyses. Bangkok (Thailand) was chosen as one of the major cities in the Asia-Pacific region which for years has suffered from high environmental pollution due to transportation. Beijing (China) was chosen as a mega city going through rapid economic growth and vehicle population increase. Taiyuan (China) was selected as a large city with serious air pollution yet with a low vehicle population. The basic statistics for those cities are listed in Table 3.5-5. It should be noted that the figures are not standardised and are given merely for reference. Some data is for the metropolitan area (e.g. population in Bangkok) and some is just for the city (e.g. GDP for Bangkok).

Table 3.5-5 Basic indicators of the target cities

	Bangkok	Beijing [(f)]	Taiyuan [(f)]
Total area	7,760 km^2 [(a)]	16,800 km^2	6,989 km^2
Population	9.67 million (2002)[(b)]	11.34 million (2002)	3.27 million (2003) (Urban pop. 2.66 mil)
Total GDP	44.89 billion USD (1,757 billion Baht) (2000) [(c)]	41.67 billion USD (321.27 billion RMB) (2002)	5.62 billion USD (43.3 billion RMB) (2003)
GDP per capita	7183.58 USD (281,268 Baht) (2000) [(d)]	3674.53 USD (28,331 RMB) (2002)	2242.12 USD (17,287 RMB) (2003)
Vehicle stock	Excluding motorcycles: 3,046,391 (2002) Motorcycles: 2,352,762 (2002) [(e)]	Excluding motorcycles: 1,770,000 (2002)	Excluding motorcycles: 115,780 (2002) Motorcycles: 170,000 (2002)

[(a)] Calculated based on figure of (b).
[(b)] National Statistics Office (2003) as cited in Good Practice "Shift from Two- to Four-stroke Motorcycles in Bangkok"
[(c)] National Economic and Social Development Board (2001)
[(d)] Calculated based on figure of (c)
[(e)] Statistics Sub-Division, Technical and Planning Group, Land Transport Management Bureau, Department of Land Transport (2003)
[(f)] Scenario analysis for Beijing and Taiyuan

3) Reference cities

To compare the indicators of the target cities and identify their characteristics and the necessary strategic directions to be taken, three reference cities with distinctive features regarding the three strategies were identified: Curitiba, Singapore, and Tokyo. Curitiba is a city which introduced policy options towards Strategy 1 (Reducing Transport Demand) and Strategy 2 (Increasing Public Transport Use), by integrating land planning with the development of the bus rapid transit system.[79] Singapore also employs Strategy 1 and Strategy 2. Singapore integrates land planning and development of its public transport system (Metros and buses). However, in addition to those, it places strong emphasis on another side of Strategy 2 by limiting the ownership of vehicles (Vehicle Quota System) and traffic flow in congested areas (Electric Road Pricing). Tokyo has developed its policies towards Strategy 2 and Strategy 3 (Reducing Emissions from Vehicles). It has extensive railway networks covering the expanded mega city (Strategy 2). In terms of the direction towards Strategy 3, it has introduced very strict emission standards and fuel standards based on a stringent Japanese law. It has also started its own control on diesel trucks to reduce particulate matter from heavy vehicles.

4) Indicators towards strategies

This section tries to compare the indicators of the model cities and target cities using the data by Kenworthy and Laube (2001). The data year is 1995, which means that the data is almost 10 years old. However, this was the most comprehensive dataset covering all the model cities and target cities, excluding Taiyuan, as of the autumn of 2004. The boundary used by this dataset is the metropolitan region.[80]

i) Strategy I: Reducing transport Ddmand

Figure 3.5-7 shows the relationship between per capita GDP and the sum of passenger kilometres per capita including public transport, private passenger vehicles, and taxis. As discussed in the framework paper, the travel demand tends to increase as incomes grow. To combat the increase of travel demand, land use planning is an effective tool. From this figure, it can be inferred that Curitiba and Singapore have been able to limit the growth in travel demand by their land use planning, as compared to cities without land use measures (Bangkok and Tokyo). Bangkok shows very high travel demand compared to its per capita GDP, despite the highest population density among the five cities.[81] This indicates that although high density is often considered a favourable factor for reducing trip length, if land use policy is not well planned or the total population size becomes too large, the effect of density is not reflected. Beijing shows the lowest value as of 1995. However, with rapid economic growth, its travel demand could increase at a rapid rate if no appropriate measures are taken. It should be noted that since the sample of cities is very small, the correlation equation may not be very accurate.

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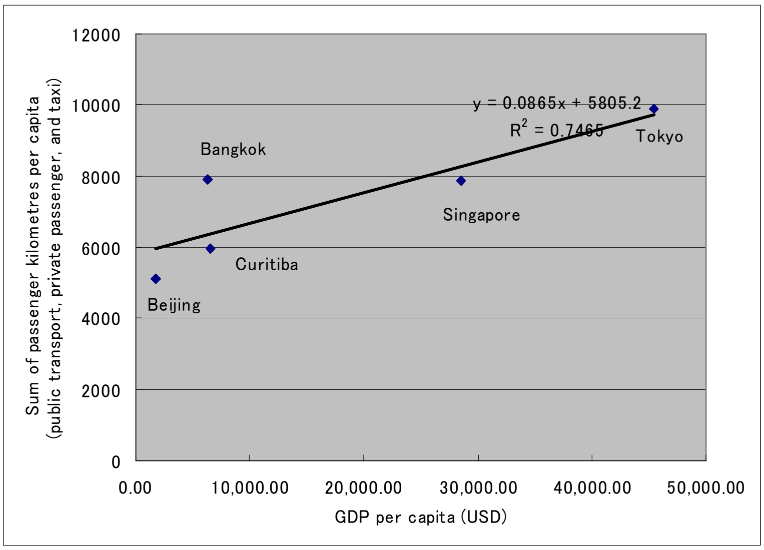
79 For the definition of strategies, refer to Doc 3 (Framework of Research on the Development of Environmentally Sustainable Transport Systems in Urban Areas).

80 The definition of “metropolitan region” in this dataset is the functional urban area of a town or region, defined as the catchment area for commuters (sometimes called labour market zone).

81 Urban density (persons/ha) in 1995 was: 138.69 in Bangkok; 123.11 in Beijing, 93.53 in Singapore, 87.68 in Tokyo, and 30.30 in Curitiba.



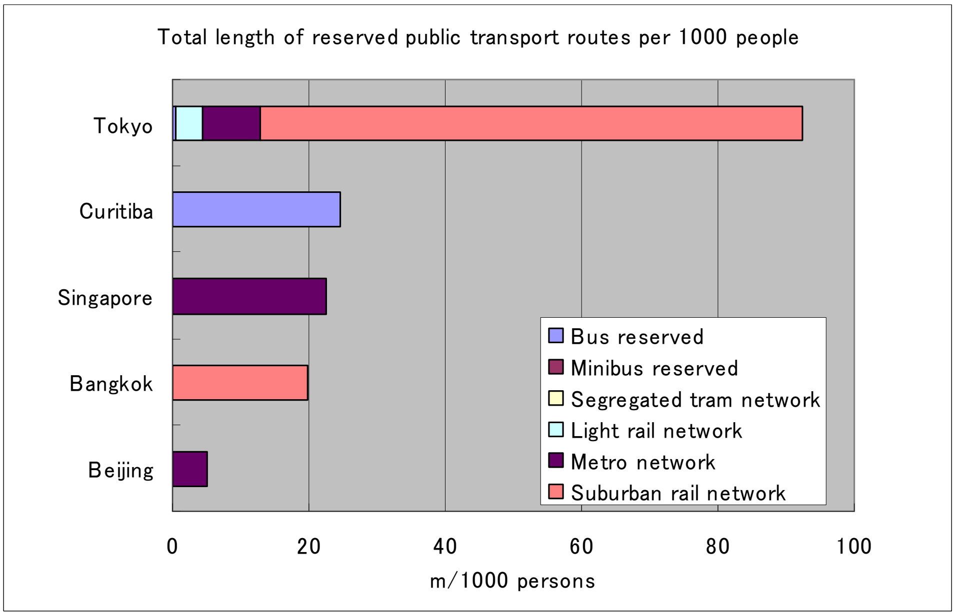
(Source: authors based on Kenworthy and Laube 2001)

Figure 3.5-7 Relationship between per capita GDP and travel demand in 1995

ii) Strategy 2: Increasing the share of public transportation

a. Public transport infrastructure

Figure 3.5-8 shows the length of reserved public transport routes per 1000 people. Tokyo has the longest reserved public transport length per 1000 people. Curitiba's feature is that its reserved public transport system consists of bus fleets only. The graph for Bangkok does not include the Metro network, since the data is from 1995, before the BTS (Skytrain) in Bangkok started operation. Beijing has the lowest length since it was still in the early stages of development. It is now extending its Metro network in preparation for the Olympic Games in 2008.

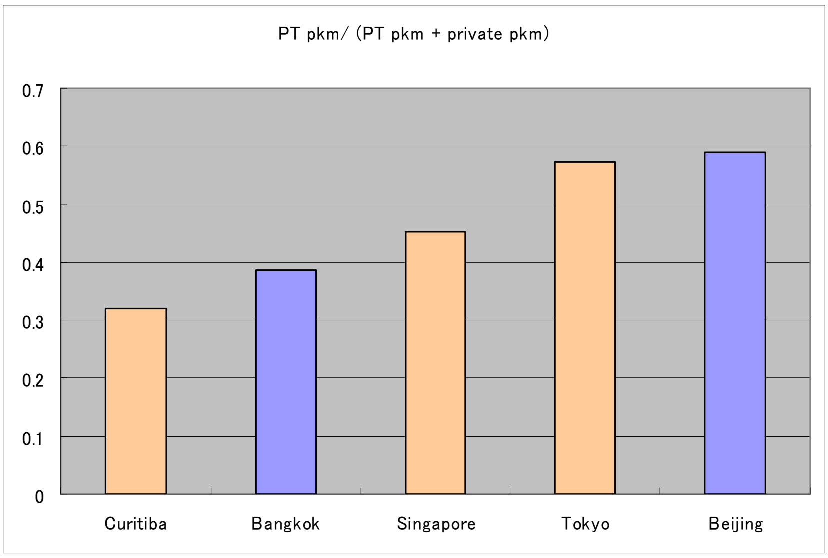


(Source: authors based on Kenworthy and Laube 2001)

Figure 3.5-8 Total length of reserved public transport routes per 1000 people in 1995

b. Public transport share

Figure 3.5-9 compares the share of public transport to the sum of public and private transport in passenger-kilometres across the cities. Curitiba shows the lowest, indicating that the effect of the bus rapid transit system is limited to the city centre whereas the data is taken from the metropolitan area. Interestingly, Beijing shows the highest value. This might be because of its relatively small transport demand as shown in Figure 3.5-7. Tokyo shows the highest share, probably due to the extensive public transport network.

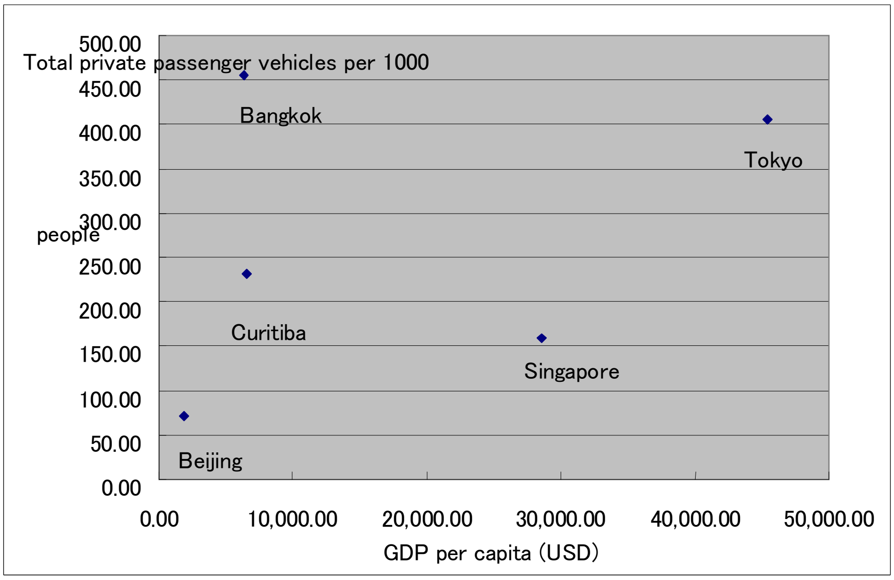


(Source: authors based on Kenworthy and Laube 2001)

Figure 3.5-9 Share of public transport passenger-kilometres compared to the sum of public and private transport passenger-kilometres in 1995

c. Vehicle ownership

Figure 3.5-10 plots vehicle ownership (including motorcycles) per 1000 people according to the per capita income. Although vehicle ownership tends to increase with income growth, this figure clearly shows that Singapore has been successful in limiting the growth of vehicle ownership. In contrast, Bangkok's vehicle ownership rate is very high compared to its income level, even higher than Tokyo. It should also be noted that the proportion of motorcycles is very high in Bangkok (205.4 units per 1000 people).

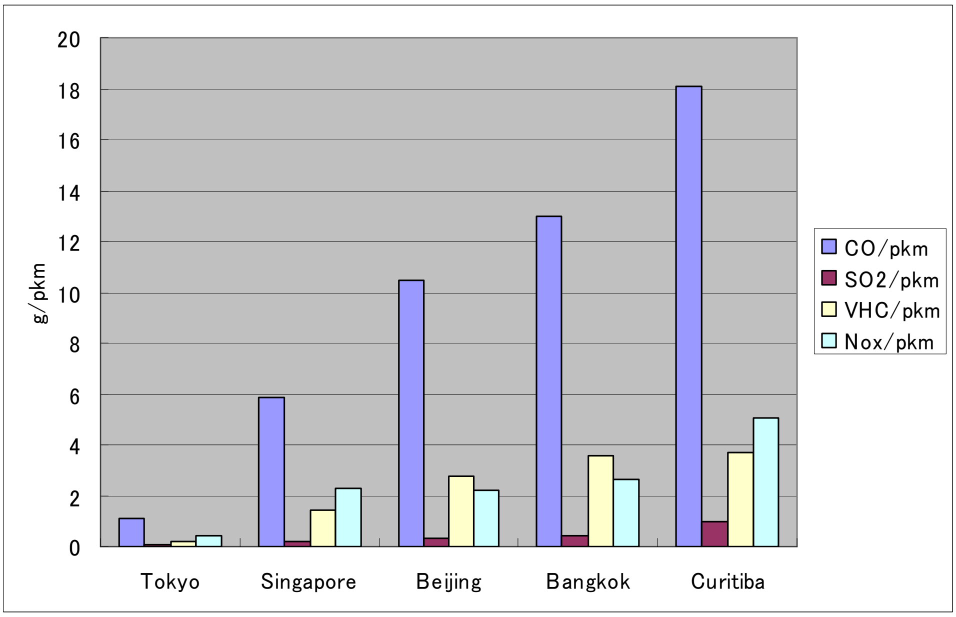


(Source: authors based on Kenworthy and Laube 2001)

Figure 3.5-10 Relationship between total private passenger vehicles per 1000 people and per capita in 1995

iii) Strategy 3: Reducing emissions from vehicles

Figure 3.5-11 shows the emission of four air pollutants (carbon monoxide, sulphur dioxide, volatile hydrocarbons or unburnt gasoline, and nitrogen oxides) per passenger-kilometre, including both public and private transport. It should be noted that Tokyo shows very low emissions per passenger-kilometre, perhaps due to strict emission and fuel standards and the high share of public transport. Curitiba shows the highest CO emissions. This might be because all the transport in Curitiba was automobile-based in 1995, including the bus rapid system, and there was no rail system in the city.



(Source: authors based on Kenworthy and Laube 2001)

Figure 3.5-11 Emission of air pollutants per passenger-kilometre in 1995

iv) Strategies for the target cities

Through comparative data analysis in the previous section, the characteristics of Bangkok and Beijing have been identified.

The data showed that Bangkok already induced very high transport demand at an early stage of its development. It also has a high rate of vehicle ownership relative to its GDP. In addition, the emission per passenger-kilometre is very high. It can be inferred that these factors contributed to Bangkok's notorious congestion and air pollution. Although since 1995 Bangkok has taken measures such as developing mass rapid transit facilities, phasing out lead in gasoline, and introducing EURO emission standards, the effects of air pollution are still serious. For example, it is reported that 1 million BMR residents have suffered from air pollution related illness (Bangkok scenario analysis report). Policies to mitigate the air pollution by addressing the above-mentioned factors need to be considered.

It was shown that in the year 1995 Beijing was still in the early stage of development in terms of urban transport infrastructure and vehicle ownership. It has been going through high economic development since then. The GDP of Beijing in 2002 (321.27 RMB) was approximately three times higher than in 1990, with annual growth rate as high as 9.72% (calculated by constant price). The economic growth has stimulated the increase in vehicle stock: the number of vehicles has been increasing at an average growth rate of 14% compared with that in 1980, and amounted to 1.77

million in 2002. The state of air pollution in Beijing is actually worse than Bangkok in terms of SO_2 and SPM, as shown in Figure. 3.5-11. Considering the high pace of growth, prompt policy measures should be taken to mitigate the environmental effects of transport.

To explore the possible scenarios for the above cities and for Taiyuan, this study identified several packages of the SPOs and estimated the effects of those scenarios in the target cities using the AIM/end-use model.[82] AIM/end-use is a technology selection framework for analysis of policies related to greenhouse gas emissions mitigation and local air pollution control. It simulates the flows of energy and materials in an economy, from supply of primary energy and materials, through conversion and supply of secondary energy and materials, to satisfaction of end-use services. AIM/end-use models these flows of energy and materials through detailed representation of technologies (Hibino et al., 2002).

(2) Case studies

1) Bangkok

i) Status of the Bangkok transport sector

Bangkok Metropolitan Region (BMR) is a densely populated (162 persons per hectare) area, which is a little above average for an Asian city. In length of road per person, it is about average for an Asian city. The number of parking spaces per 1000 jobs in the central business district in Bangkok is 338, which exceeds the average European city. Bangkok ranked first among Asian cities in total vehicle ownership (approx. 450 per 1000 people) while that of Tokyo was around 400 (Figure 3.5-10) in 1995. It has three times the level of the much wealthier Singapore. Bangkok is heavily motorised with 74% higher vehicle use than the average Asian city. Although public transport use in Bangkok is high on an international scale, it is too low for a city like this. The proportion of motorised work trips by public transport shows that Bangkok has rather low use of public transport (Kenworthy, 2003).

Transportation is a major source of pollution in Bangkok – both air and noise. The existence of a large number of vehicles and traffic congestion has had a severe impact on the city’s air quality. Among area, point and mobile sources, mobile sources are the major emitters of nitrogen oxides (NOx) (80%), carbon monoxide (CO) (75%), particulates (54%), and hydrocarbon (HC) (close to 100%) (UNEP, 2001). Among vehicular sources, according to the Land Transport Department records, light-duty vehicles are the major sources of CO (79%) and HC (64%), whereas heavy-duty vehicles and motorcycles significantly contribute to the emissions of NOx (61%) and particulate matter of less than 10 microns in diameter (PM_{10}) (48%), respectively (UNEP, 2001). In the early 1990s, motorcycles were considered to be the largest mobile source of hydrocarbon (HC) emissions (70% of total HC), and contributed to 30% of total CO, and 4% of particulate matter of less than 10 microns in diameter (PM_{10}) from mobile sources (SECOT Consulting, 2000; cited in Bhaopichitr and Warapetcharayut, 2001).

Over 1 million BMR residents have suffered from air pollution related illness (Thavisin, 2001; cited in Martel, 2003). In a survey of 643 respondents by Mahidol University in 2002, nearly three in four Bangkok residents consider air pollution to be the main environmental problem they face every day. Ninety percent of them identified transportation as the main source of air pollution (Wangwongwatana, 2002; cited in Martel, 2003). Investigations of the effects of air

82 For simulations for Chinese cities, the IPAC-AIM/Technology model, a model developed based on the AIM/end-use model by the Energy Research Institute and National Institute for Environmental Studies.

pollution on those groups who are highly exposed to it, such as bus drivers, traffic policemen, and street sweepers, showed a higher rate of respiratory illnesses and abnormal lung functions. Economic valuation of benefits from reduction in air pollution shows that a 20 μg/m^3 reduction in annual average PM_{10} concentrations in Bangkok would result in an estimated saving of 65 billion to 175 billion Baht (based on 1995 prices and the US$ to Baht exchange rate of 1$ per 25 Baht). These savings outweigh the cost of mitigation measures used to reduce the particulate matter (Radian International, 1998; cited in UNEP, 2001).

Road surfaces occupy only 11% of the total area of Bangkok, which is substantially lower than international standards which range between 20% and 25% (Wangwongwatana, 1999; cited in Martel, 2003). Though road network expansion is being initiated, it is unable to keep pace with the demand for transportation.

ii) Modelling assumptions and data

The study is based on the following major assumptions. These assumptions are common to both BAU and the two scenarios.

1. Emission standards for on-road vehicles in Thailand are formulated by the Pollution Control Department (PCD) and adopted by the Ministry of Industry (MOI) and/or the Ministry of Science, Technology and Environment (MOSTE).
2. Freight transportation is ignored in this study (due to time constraints and lack of data availability).
3. Motor-tricycles have been excluded from the model on the assumption that they are mainly being used for freight transportation.
4. Changes in prices of energy commodities over the planning horizon have been neglected due to the complexity of economic trends.
5. Service losses such as vehicle idling in transportation have been ignored, although vehicle idling due to traffic congestion could be fairly substantial in Bangkok city considering that the average speed of vehicles in Asia is 10-20 km/hr compared to 50-60 km/hr in the US and 30-40 km/hr in Europe (Minato, 2001).
6. Changes of vehicle characteristics, such as fixed cost and performance improvements (e.g. efficiency), over the planning horizon have not been considered.
7. It is assumed that the total passenger car demand is evenly distributed over a calendar year.

Figure 3.5-12 shows the end-use service demand classification adopted in the present study. It should be noted that only one technology has been considered under water transport. Present and future service demand data along with numbers of registered vehicles in the base year for the Bangkok transport sector were mainly obtained from the study carried out by Tanatvanit et al. (2003). This data has been summarized in Table EST 3.5-4. Table 3.5-5 shows passenger water and rail transport demand data which has been assumed based on the total passenger transport demand in BMR.

Technology characteristics such as cost, energy consumption and service output are based on Kainuma et al. (2003). The other data pertaining to the Skytrain and subway was from the BTS (2004) and MRTA (2004). As part of this work, discussions were held with policy officials of various government and non-government organisations, both in person and via other forms of communication, in order to exploit appropriate policy measures for environmentally friendly and efficient transportation in Bangkok.

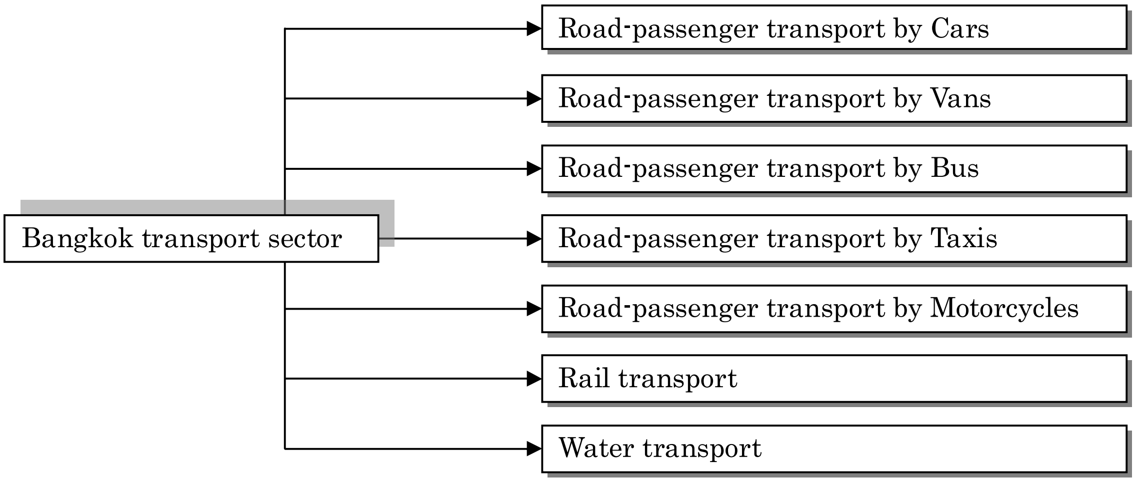


Figure 3.5-12 Classification of service demand for passenger transport in Bangkok

Table 3.5-6 Passenger transport data used for the study

Vehicle type	Number of registered vehicles in 2000	Estimated travel demand in BMR/(million p-km)		
		2000	2010	2020
Passenger car	1,240,985	19,402	28,528	30,980
Microbus and pickup	295,527	6,190	9,542	11,137
Van and pickup	737,476	12,750	28,100	33,784
Urban taxi	64,321	3,961	6,065	7,085
Fixed route taxi	8,187	158	140	110
Motor-tricycle taxi (tuk-tuk)	7,403	244	241	235
Motorcycle	1,964,850	11,057	10,947	11,262
Fixed route bus	15,379	972	999	1,049
Private bus	3,788	125	74	33

Source: Tanatvanit et al. (2003)

Table 3.5-7 Water and rail transport data

Vehicle type	Passenger Transport Demand in BMR/(million p-km)		
	2000	2010	2020
Water transport (Boat)	629	1,620	5,096
Rail transport	704	9,276	12,485

iii) Scenarios and SPOs applied

In order to understand the future energy and environmental implications of urban transportation in Bangkok, the study considers a business-as-usual case and two scenarios. The scenarios in the current study have been selected based on the policy options derived from SPO studies for Bangkok. Five strategic policy options have been considered for an environmentally sustainable transport system in Bangkok, namely: Vehicle emission standards and inspection/maintenance, Improved fuel standards, Regional system of cities, Community vehicles, and Car-free zones.

Since the first two strategies listed promote the use of more efficient/cleaner vehicles, the present study has made an attempt to find the implications of cleaner vehicles. Of the other three strategies, only the car-free day programme could be directly implemented in the AIM/end-use model. Therefore, the implication of the car-free day programme is also considered in this study.

In this particular study, the main interest is to assess the future energy and environmental implications of the Bangkok transport sector, such as final energy consumption patterns by vehicle type, final energy consumption patterns by fuel type, and environmental emissions under the business-as-usual case and under the selected scenarios. The environmental emissions in this study include CO_2, NOx, SO_2, and particulate emission.

Business-As-Usual case (BAU): In the case of the business-as-usual case (BAU), no major changes of policies or economic determinants from the existing trend are assumed in meeting the transport energy demand. Therefore, end-use energy service demands over the planning horizon are assumed to be met by existing technologies in the base year and through the policies already in place such as MRT and promoting alternative fuel vehicles. Efficient vehicles such as hybrid vehicles, electricity-driven vehicles, and fuel cell vehicles, have not been considered in the BAU case. The usage shares of each vehicle type have been estimated based on how much a percentage of a particular vehicle type provides a specific service from the total service demand of the same service type.

Scenario I: With rapidly increasing transport service demands, there have been several initiatives taken by the transport ministry of Thailand to address the traffic congestion in the city and make Bangkok environmentally clean. However, along with traffic measures such as flyovers, underpasses, and expressways to reduce vehicle idling and traffic congestion, some stricter strategic policies would also enforce mitigation of air pollution. Vehicle emission standards, vehicle fuel standards, and greening fuel taxes are some such policy options. Stricter emission and fuel standards, and fuel taxes raised for gasoline/diesel, could induce a switch to efficient technologies. Therefore, in the first scenario (hereafter referred to as *Scenario I*), efficient transport technologies have been considered. Under efficient technologies, hybrid vehicles, high efficient vehicles, electricity-driven vehicles, and fuel cell vehicles have been taken into account.

Scenario II: The rapidly increasing economic growth of many Asian cities has caused an increase of motorisation, in particular car ownership. Bangkok has a high motorisation rate, high private vehicle use, and low public transport use for a city of this scale (Kenworthy, 2003). A few sustainable transport modes such as regional system of cities, community vehicles, walking streets or lanes for bicycles, and pedestrian zones, have been suggested and implemented over the years. Car-free day programmes have been implemented in Bangkok as a sustainable transport strategy, and the second scenario considers the implications of car-free days. The car-free day programme would affect the transport service demands of passenger cars. It is assumed that the passenger transportation demands of cars will be decreased annually due to the implementation of car-free programmes. The energy and environmental implications of multiple car-free day programmes within a calendar year are also discussed in this section.

Table 3.5-6 summarizes the three cases selected in this study.

Table 3.5-8 Major assumptions of BAU, Scenario I, and Scenario II

	BAU	Scenario I	Scenario II
GDP	2000: 44.89 billion USD	2000: 44.89 billion USD	2000: 44.89 billion USD
Population	6.355 million (2000)	6.355 million (2000)	6.355 million (2000)
GDP per capita	2000: 7183.58 USD	2000: 7183.58 USD	2000: 7183.58 USD
Vehicle types	Gasoline, diesel, LPG, natural gas driven vehicles	Gasoline, diesel, LPG, natural gas driven vehicles, electricity-driven, methane-driven, fuel cell-driven vehicles	Gasoline, diesel, LPG, natural gas driven vehicles
Clean fuel	No clean fuel is considered	2005: electricity-driven, methane-driven, fuel cell-driven vehicles	No clean fuel is considered
Total passenger demand	2000: 56,192 x 10^6 p-km 2020: 113,256 x 10^6 p-km	Same	Demand for passenger cars has been reduced. 2010: 28450 x 10^6 p-km; 2020: 30895 x 10^6 p-km
High efficiency car	High efficiency cars are not considered	2005: Hybrid car 2005: Fuel cell car 2005: Electricity-driven car, bus, van, taxi	High efficiency cars are not considered

iv) Results and analysis

a. Energy consumption

Figure 3.5-13 shows final energy consumption under BAU, Scenario I and II. It is estimated that Scenario I (introduction of efficient technology) will reduce energy consumption by 1.18 Mtoe from BAU in 2005 and 2.36 Mtoe in 2010. After 2010, the saving due to the introduction of efficient technology is expected to be reasonably consistent, kept to around 2.3 Mtoe. The difference Scenario II makes is small compared to Scenario I, 3.6 Ktoe in 2005, 8.9 Ktoe in 2010, 9.4 Ktoe in 2015, and 9.9 Ktoe in 2020.

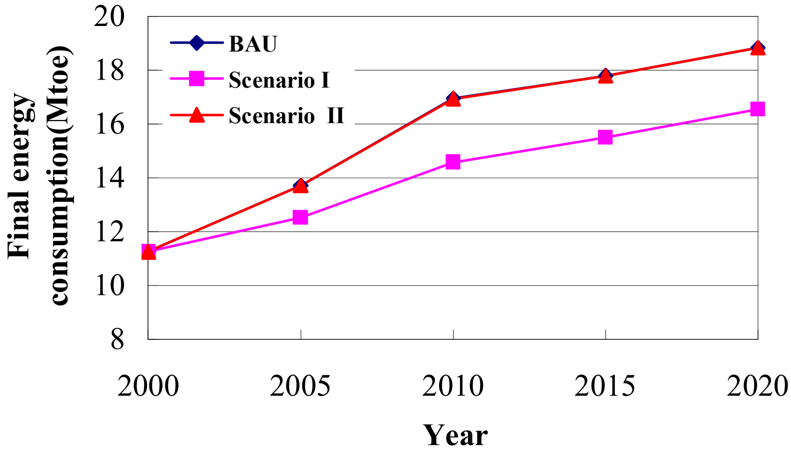


Figure 3.5-13 Comparison of energy consumption of the two scenarios with the BAU case

b. CO_2 emissions

Figure EST-14 shows the total CO_2 emissions under the three cases. The introduction of efficient technologies seems to be more effective in mitigation of CO_2 emission during the entire planning period. Introduction of more efficient vehicles would reduce CO_2 emissions by about 6.07 thousand tons, while the figure could be as high as about 6.3 thousand tons in 2020. However, introduction of car-free day programmes would significantly contribute to mitigation of CO_2 emissions towards the end of the planning period.

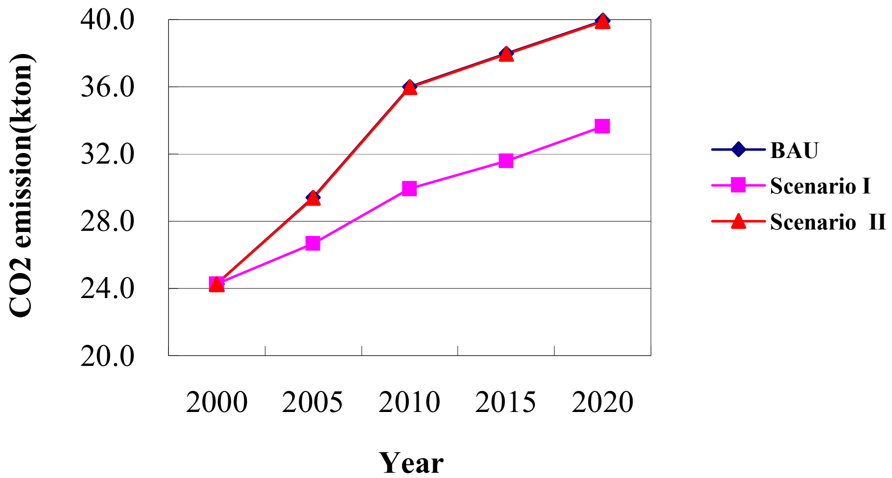


Figure 3.5-14 Comparison of CO_2 emissions of the two scenarios with the BAU case

c. NOx emissions

Figure 3.5-15 shows the variation of NOx emissions under the two scenarios along with the BAU case. No significant change in NOx emissions could be expected from either efficient vehicles or a car-free day programme. Under Scenario I, about 35 tonnes of total NOx emissions could be mitigated in 2020.

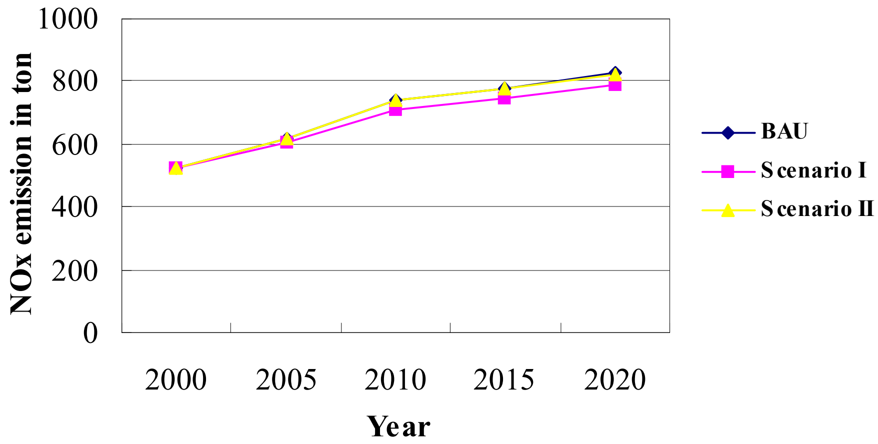


Figure 3.5-15 Comparison of NOx emissions for the two scenarios with the BAU case

d. SO_2 emissions

SO_2 emissions for Scenario I and Scenario II are shown in Figure 3.5-16 SO2 emissions would be reduced slightly starting from 2005 under Scenario I compared to the BAU case. However, total SO_2 emissions under both BAU and Scenario II are expected to be almost the same throughout the planning horizon.

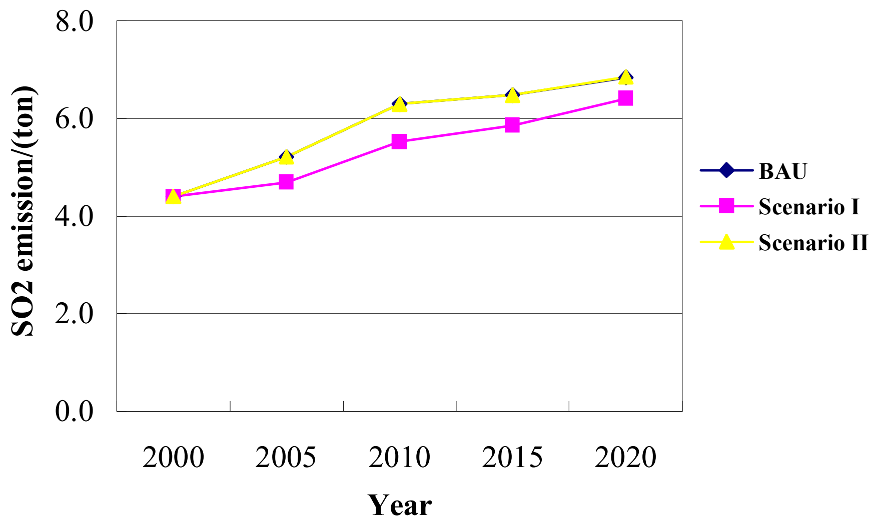


Figure 3.5-16 Comparison SO2 emissions for the two scenarios with the BAU case

e. PM emission

Particulate emissions are shown in Figure 3.5-17. It follows the same pattern as in the case of SO_2 emissions described above. The total particulate emission in 2010 under Scenario I is 7.51 tons compared to about 8.47 tons in the case of BAU. In 2020, the total particulate emission under Scenario I would increase to 8.76 tons compared to 9.24 tons in the case of BAU. However, the particulate emission of Scenario II is the same throughout the planning period and a car-free day programme does not influence particulate emissions reduction.

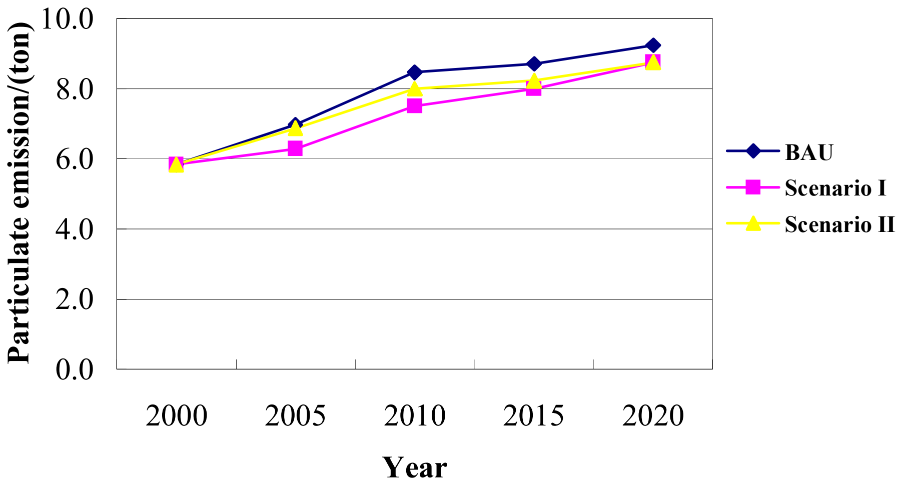


Figure 3.5-17 Comparison of particulate emissions of the two scenarios with the BAU case

v) Comments from policy-makers

During the entire study, a close interaction with policy-makers was maintained. In the case of the scenario analysis, an attempt was made to obtain feedback from relevant policy-makers through a questionnaire survey. The responses can be summarised as below:

a) According to *the Office of Transport and Traffic Policy and Planning (OTTP)*, the selected scenarios for the Bangkok metropolitan region are relevant, and the methodology of assessment is clear. OTTP also agrees with the suggested energy consumptions and environmental emissions. In brief, OTTP recognizes that the study covers an important area of transportation issues in Bangkok and that it indicates potential countermeasures for a sustainable transportation system in that city.

   They suggested the use of other energy-environmental models to incorporate other SPOs and/or issues. They also commented on the importance of freight transportation in Bangkok by trucks, which was not considered in this study.

b) The Environmental Quality Management and Control Division of Bangkok Metropolitan Administration (BMA) also responded to the questionnaire. They suggested carrying out similar studies on medium-size cities such as Chiang Mai, Nakhen Ratchasima, and Hat Yai. BMA also raised the importance of other relevant Strategic Policy Options for Bangkok, as can be found in the six-year BMR mass transportation plan.

Table 3.5-9 Strategy-SPO-scenario analyses framework

Strategy	SPO	Critical Instruments	Assumptions	Results	Evaluation		Recommendations
Strategy 3: Reducing emissions from vehicles	Promoting the spread of high efficiency vehicles	Hybrid car, fuel cell car, electricity-driven car, bus, van, taxi	2005: Hybrid car 2005: Fuel cell car 2005: Electricity-driven car, bus, van, taxi (usage shares given in Appendix D)	Reduction of CO_2: 2010: 6.07 ktons 2020: 2.3 ktons	sustainability	good	Increase the penetration level of efficient vehicles (usage share) through promotions such as subsidies
					equity	good	
					efficiency	good	
					effectiveness	medium	
					relevance	good	
Strategy 2: Increasing the share of public transportation	Creating car-free zones	Car-free day programmes	Demand for passenger cars has been reduced. 2010: 28450 x 10^6 p-km; 2020: 30895 x 10^6 p-km	Reduction of CO_2: 2010: 24.58 tons 2020: 25.42 tons	sustainability	medium	Increase frequency of car-free day programmes each year
					equity	good	
					efficiency	poor	
					effectiveness	medium	
					relevance	medium	

vi) Conclusion and recommendations

The study has examined the energy use and environmental implications in the transport sector of Bangkok, Thailand, during 2000-2020. The present study projects that passenger transportation by vans will become the dominant form of final energy consumption from 2010 onwards, while passenger transportation by bus will be significant up to 2010. Consumption of diesel indicates the highest share of the energy mix during each year of the planning horizon. The energy mix in the year 2020 would be 55% diesel, 23% gasoline, 19% LPG and about 3% CNG.

It can also be observed that the two scenarios considered in the present study are fairly attractive for a sustainable transport system in the city. Under Scenario I, in 2005 it can be expected that the reduction of final energy consumption will be about 1,182.8 Ktoe while that in 2010 and 2020 will be 2,363.2 Ktoe and 2,277.1 Ktoe respectively. A reduction of about 6,071 tons of CO_2 can be expected in 2010, while the figure will reach 6,295 tons in 2020.

In Scenario II, due to the rapidly increasing transportation demand beyond 2010, car-free days may not be effective compared to the period before 2010. In order to overcome this ineffectiveness, the frequency of car-free days should be increased from 2010 onwards.

Table 3.5-9 summarizes the strategy-SPO-scenario analyses framework of the present study. Two scenarios have been assessed based on five evaluation criteria. The relevance of the two scenarios is based mainly on the responses from policy-makers. It was found from this study that use of efficient vehicles could mitigate both final energy consumption in transportation and environmental emissions. Therefore, it is recommended to further promote efficient vehicles through subsidies, reduction of taxes, etc. However, the potential for mitigation of energy and emissions by non-motorised transport (mainly through car-free day programmes) may not be effective towards 2020. A package of options could be considered so as to establish their effectiveness.

(2) Beijing

i) Status of the Beijing transport sector

Beijing is the capital city of the People's Republic of China, with a 5000-year history, and it is the political and cultural centre of China. It is located at the far northwest of the North China Plain, with the Po Hai (Gulf of Chihli) close to the southeast. The total area of Beijing is 16,800 km^2, with a permanent resident population of 11.336 million (2002). From 1990 to 2002, the annual population growth rate was about 0.8%. The gross domestic product (GDP) of Beijing is 321.27 billion RMB (2002), about 3.04 times that in 1990, and annual growth rate was as high as 9.72% calculated by constant price.

High economic growth has stimulated the growth of vehicle stock. Vehicle stock (not including motorcycles) in 2002 amounted to 1.77 million, with an average growth rate of 14% compared with that in 1980. Recent information shows that the vehicle stock was over 2 million in August 2003.

Private car numbers are growing dramatically. In 1980, only 22 cars were registered for private purposes, but this number had grown to 458,000 by the end of 2002. Average annual growth rate is as high as 57.14%, much higher than that of the vehicle stock in general during the same period. Car ownership, 11 cars per 100 households, shows that Beijing has become a motorised society. This kind of astonishing growth rate brings heavy pressure on the limited road network whose growth rate is much lower, on oil supply, and on environmental emissions. China became a net oil-importing country in 1994, and 30% of oil consumed now is imported from abroad. Furthermore, urban transport has become one of three major emitters of pollutants such as CO, NOx and HC.

Having become aware of serious deterioration of environmental quality, in particular regarding air pollution, a series of policies and command and control measures have been carried out by Beijing municipal government since 1998 to reduce the emissions from the urban transport sector, including issuing new tail-pipe emission standards, introducing alternative fuel vehicles (AFVs), scrapping badly polluting vehicles, enhancing the inspection & maintenance system (I&M), and accelerating the development of MRTs. The action has been quite effective, although limited because the introduction of AFVs to the private sector is difficult and the huge initial cost of MRTs requires an innovative financial and management mechanism.

ii) Modelling assumption and data

In this study, the IPAC-AIM/technology model was used for the simulation. The IPAC-AIM/technology model is of the IPAC model family, which was developed by the Energy Research Institute, and was based on the AIM/end-use model by collaboration between the Energy Research Institute and the National Institute for Environment Studies of Japan. It is extended from an end-use energy technology model to an end-use technology, energy supply, and non-CO_2 emission technology model. It projects and assesses future energy consumption and CO_2 emission scenarios, and the abatement measures of future pollutant emission, using a bottom-up approach based on detailed information on technology and social structure change. This model comprises three modules: an energy service module, an energy efficiency module, and a technology selection module. Also included is a module that estimates the optimal solutions for each sector by combining these three modules.

Major assumptions for the modelling study are as follows:

a Transport mode parameter

In the model analysis, transport was divided into several modes, such as public transport, private transport, and freight transport, in order to provide details based on technology classification. In each model, sub-modes (e.g. subways and buses for public transport) were introduced to make further classification, and then technologies (e.g. gasoline bus, CNG bus, etc.) were provided. Energy and emission are calculated based on the use of each technology in a targeted year.

b Traffic volume

Traffic volume was estimated based on the development plan of Beijing and other related studies, GDP growth, vehicle ownership, and related policies. For example, in the case of the business-as-usual scenario, road passenger traffic volume was estimated to increase from 74.9 billion passenger-km in 2000 to 166.5 billion passenger-km in 2020, while railway passenger traffic volume changed from 6.27 billion passenger-km in 2020 to 14.0 billion passenger-kms in 2020.

c Technology parameter

To calculate energy use in the transport sector, fuel efficiency for each technology was identified. For gasoline buses, fuel efficiency was 0.0618 Mcal/1000 passenger-km, and that for trolley buses was 0.0456 Mcal/1000 passenger-km.

Base year data is taken from the Beijing Year Book 2003, and calculated by the authors. The future data is given based on the authors' judgment, arrived at by examining government planning and related researches.

iii) Scenarios and SPOs applied

Two scenarios are identified for Beijing, focusing on different interventions in transport technologies for lower emissions. The baseline case, incorporating existing technologies and policies, is also considered. In order to analyse the effects of Strategic Policy Options (SPOs) in this project, adoption of SPOs in the scenarios is assumed. In the definition of each scenario, we have described the relationship between SPOs and scenarios.

Government promotion (BAU): Present transportation policies will continue; present vehicles with lower energy use will become gradually more popular. This is based on a review of the policies adopted and planned by the local government.

Technology Progress (TG): Additional environment-friendly policies such as emission standards and public transport promotion policies will be introduced, and present vehicles with lower energy use, such as high fuel economy gasoline vehicle and new diesel vehicles, will become rapidly more popular.

Clean future (CF): Additional policies and countermeasures will be introduced to increase the environmental performance of transportation, such as the introduction of advanced cars (e.g. hybrid cars, fuel-cell cars), policies to encourage mini cars, integrated design of transportation system and city function area, top priority given to public transport, use of bio-gasoline, and public involvement.

Major assumptions for the three scenarios are shown in Table 3.5-9. In the table, base year data comes from the Beijing Year Book 2003, and is calculated by the authors.

Table 3.5-10 Major assumptions for the three scenarios

	SPO applied	BAU	TG	CF
GDP, billion Yuan		2000: 248 2020 1500	Same	Same
POP		2000: 12.78 million 2020: 18 million	Same	Same
GDP per capita		2002: 27746 CNY 2020: 85500	Same	Same
Vehicle stock		2000: 1.37 million 2020: 5.9 million	2000: 1.37 million 2020: 5.6 million	2000: 1.37 million 2020: 5.6 million
Total passenger traffic volume (billion passenger-km)		2000: 23.4 2020: 36.7	Same	Same
Total freight traffic volume (billion ton-km)		2000: 8.73 2020: 13.36	2000: 8.73 2020: 13.36	2000: 8.73 2020: 13.36
Share of public transport in total passenger		2000: 31.7% 2020: 32%	2000: 31.7% 2020: 44%	2000: 31.7% 2020: 44%
MRT, km	Rail-based mass rapid transit	2000: 56 2008: 300 2020: 1000	Same	Same
Number of buses		2000: 13000 2020: 23000	2000: 13000 2020: 23000	2000: 13000 2020: 24000
Clean fuel bus	Promoting alternative fuel vehicles	2000: 3680 2020: 10000	2000: 3680 2020: 12000	2000: 3680 2020: 12000
Emission standards	Vehicle emission standards and inspection/maintenance	2007: EURO III	2005: EURO III 2010: EURO IV	2005: EURO III 2010: EURO IV
Parking fee			Increase	Increase
Public transport oriented policy			Bus lane Better interchange	Bus lane Better interchange
ITS			Finish by 2006	Finish by 2006
Clean fuel	Promoting alternative fuel vehicles			2007: M15%
High efficiency car	Promoting the spread of high efficiency vehicles			2004: Hybrid car 2005: New diesel car 2013: Fuel cell car
Mini car	Promoting the spread of high efficiency vehicles			Incentive policies
Integrated transport	Promoting special lanes for walking and biking		Public interchange	Public interchange Bicycle
Public involvement	Travel awareness initiative for wise use of automobiles			Public transport Energy saving driving
Transport demand reduction	IT-based communication and services to reduce transportation needs			Tele-conferencing, on-line shopping, local service

Data source: Beijing Year Book 2003, and calculated by authors

iv) Results and analysis

The results of running the model are given in Figures 3.5-18 to Figure 3.5-23.

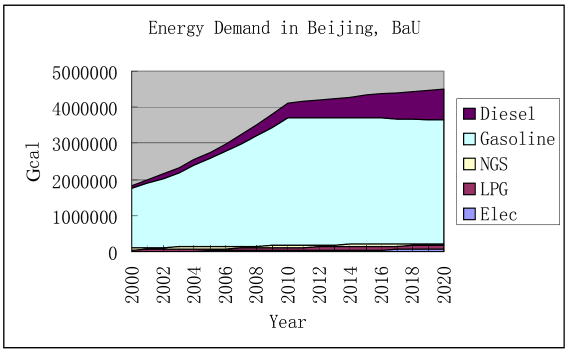


Figure 3.5-18 Energy demand for Urban Transport in Beijing, BAU scenario

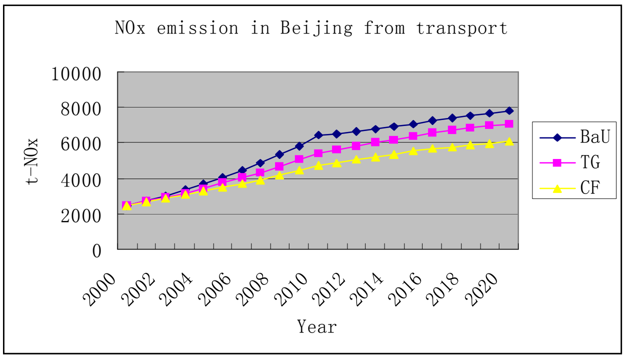


Figure3.5-19 NOx emissions from urban transport in Beijing

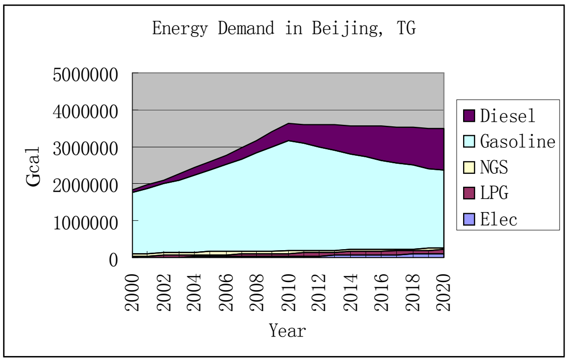


Figure 3.5-20 Energy demand for Urban Transport in Beijing , TG scenario

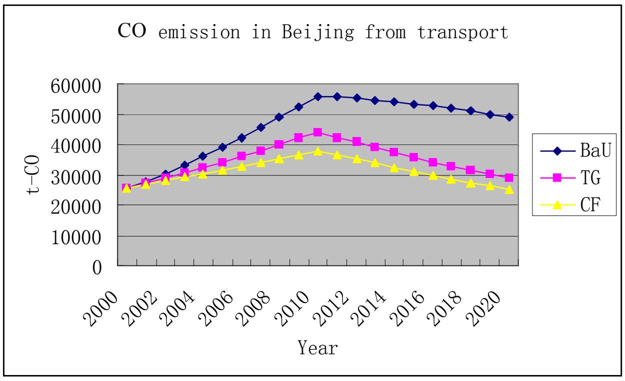


Figure 3.5-21 CO emissions from urban transport in Beijing

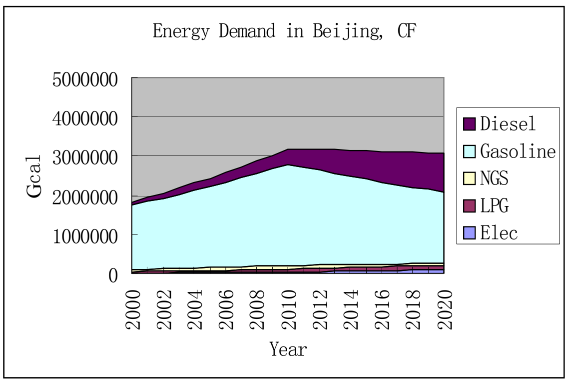


Figure 3.5-22 Energy demand for Urban Transport in Beijing, CF scenario

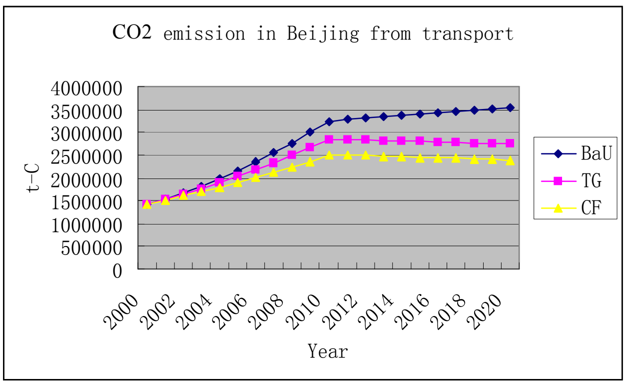


Figure 3.5-23 CO_2 emissions from urban transport in Beijing

From the results we can see that energy use for transport will increase rapidly before 2010. After 2010, the growth rate could be reduced and total energy use can remain stable. In the BAU case, energy use in 2010 is the effect of use of new transport technology and policy options. In the BAU case, the total energy use for transport in Beijing would be 4.11 Mtoe in 2010 and 4.46 Mtoe in 2020. Compared with the BAU case, there will be 0.45 Mtoe and 0.86 Mtoe saved in 2010 and 2020 in the technology progress scenario, and 0.92 Mtoe and 1.36 Mtoe in the clean future scenario. We can observe a large amount of energy saving. In the meantime, NOx, CO and CO_2 emissions would also be reduced. Compared with the BAU scenario, there would be 19%, 48% and 31% reductions in NOx, CO and CO_2 emissions in the clean future scenario. Among the technology and policy options, energy efficient vehicles such as hybrid cars and advanced diesel vehicles are major contributors to energy saving and emissions reduction in Beijing's urban transport, by creating nearly 44% of total energy saving and 48% of CO_2 emission reduction. Similarly, more use of public transport is another major contributor. Policies to promote highly efficient vehicles and public transport can play an important role.

v) Conclusions and recommendations

Based on the scenario study, the following policy recommendations were made:

Maintain present transportation control policy

Policy to encourage low-energy-use vehicles:

1) encouraging development of mini cars and abolishing the limit on running of mini cars
2) encouraging low-energy-use vehicles: reducing tax, and putting out energy use standards as soon as possible
3) introducing advanced vehicles, such as PRIUS, LUPO
4) establishing a long-term development plan for fuel-cell vehicles

Use of ethanol gasoline

Integrated design of transportation system

Integrated design for city function areas (this should be divided according to district, not street)

Traffic control policy

1) on the condition of improvement of public transport, increasing the running costs of cars (increase the parking fee to 10-20 Yuan/h, integrated with public transport)
2) encouraging telephone meetings
3) developing electronic payment methods
4) local purchasing
5) school-bus plan

Public involvement (switching off when waiting for more than 6 minutes, reduced vehicle use, increased walking and cycling)

Develop a clean transportation system through an international cooperation mechanism

3) Taiyuan

i) Status of the Taiyuan transport sector

Taiyuan is the capital city of Shanxi province, the major centre of coal production in China. In 2003, the population of Taiyuan was 3.27 million, of which 2.66 million lived in the urban area. GDP in 2003 of Taiyuan was 51.57 billion yuan, with a per capita income of 15,770 yuan. Taiyuan is now in period of rapid development, with an annual average growth rate of 10.5% from 2000 to 2003. However, the city was one of the most polluted cities in the world in 1997 in terms of air pollution (World Resource Report, 1999), and because of weak economic capacity and lack of clean energy sources it remains among the most polluted cities in China.

In 2002, the total number of vehicles in Taiyuan was 115,780, together with around 170,000 motorcycles. The road length in Taiyuan city is 1,264 km with a total area of 15 million km^2. Total freight traffic volume was 3,943 million ton-km, with freight traffic of 100 million tons; passenger traffic volume was 764 million passenger-km, with passenger traffic of 12.16 million persons. In Taiyuan there are 67 bus routes covering a length of 910.9 km. The total number of buses is 1,343, while the number of taxis is 8,300. So far, there are no railways in Taiyuan.

In Taiyuan, the vehicle fleet was still relative small, and not much thought was given to policies for urban transport. However, the local government made an effort to develop the public transport system by using more buses, and allocated a government budget to support it. Emission standards for vehicles, and non-leaded fuels, were also adopted in Taiyuan under national regulation. Because of serious air pollution problems, the local government is looking for more options for clean urban transport.

ii) Modelling assumptions and data

For transport mode parameters and technology parameters, the same modelling assumptions as used for Beijing were applied. For traffic volume data as well as other socio-economic data for the base year, the Shanxi Year Book 2003 was consulted and the future data is given based on the authors' judgment, arrived at by examining government planning and related researches. Estimated road passenger traffic volumes for the business-as-usual case were 12.6 billion passenger-km in 2003 and 272.2 billion passenger-km in 2020.

iii) Scenarios and SPOs applied

Similar to the scenario study for Beijing, three cases have been designed for the Taiyuan urban transport scenario analysis. These are described below.

Government promotion (BAU): Present transportation policies will continue; present vehicles with lower energy use will become gradually more popular.

Technology Progress (TG): Additional environment-friendly policies will be introduced, and present vehicles with lower energy use will become rapidly more popular.

Policy scenario (PS): Additional policies and countermeasures will be introduced to increase the environmental performance of transportation, such as the introduction of a railway-based mass transport system, alternative fuel vehicles including CNG buses, E10 gasoline, advanced cars (e.g. hybrid cars, fuel-cell cars), policies to encourage mini cars, integrated design of transportation system and city function area, top priority given to public transport, and public involvement.

Major assumptions for the three scenarios are shown in Table 3.5-10. In the table, base year data comes from the Shanxi Year Book 2003, and is calculated by the authors. The future data is given based on the authors' judgment, arrived at by examining government planning and related researches.

Table 3.5-11 Major assumptions for the three scenarios

	SPO adopted	BAU	TG	PS
GDP (2003 price) billion yuan		2003: 43.3 2020: 192	Same	Same
POP		2020：3.80 million, 3.4 million in urban	Same	Same
GDP per capita, yuan		2003: 17287 2020: 56499	Same	Same
Vehicle stock		2003: 115780 2020: 520000	Same	Same
Total passenger traffic volume, billion passenger-km		2003: 12.6 2020: 27.23	Same	2003: 12.6 2020: 26.8
Total freight traffic volume, billion ton-km		2003: 1.9 2020: 6.4	2003: 1.9 2020: 6.4	2003: 1.9 2020: 6.4
Share of public transport use in total passenger travel		2003: 27.8% 2020: 34%	2003: 27.8% 2020: 34%	2003: 27.8% 2020: 43%
MRT, km	Rail-based mass rapid transit	2003: 0 2020: 0	2003: 0 2020: 0	2003: 0 2020: 180
Number of buses		2003: 1267 2020: 3200	Same	2003: 1267 2020: 2700
Clean fuel bus	Promoting alternative fuel vehicles	2003: 0 2020: 0	2003: 0 2020: 120	2003: 0 2020: 800
Emission standards	Vehicle emission standard and inspection/maintenance	2005: EURO II 2008: EURO III	2005: EURO II 2008: EURO III	2007: EURO III 2010: EURO IV
Parking fee	Parking policy		Increase	Increase
Public transport oriented policy	High occupancy vehicle lanes		Bus lane Better interchange	Bus lane Better interchange
ITS			Finish by 2008	Finish by 2008
Clean fuel	Promoting alternative fuel vehicles			2010: M15%
High efficiency car	Promoting the spread of high efficiency vehicles			Introduced year: 2006: Hybrid car, 2020: 15% of total cars 2008: New diesel car 2000: 12% of total cars 2013: Fuel cell car 2000: 1% of total cars
Mini car	Promoting the spread of high efficiency vehicles			Incentive policies
Integrated transport	Promoting special lanes for walking and biking		Public interchange	Public interchange Bicycle
Public involvement	Travel awareness initiative for wise use of automobiles			Public transport Energy saving driving
Transport demand reduction	IT-based communication and services to reduce transportation need			Tele-conferencing, on-line shopping, local service, by 2020 1.6% decrease in travel demand

iv) Results and analysis

Based on the assumptions and data for Taiyuan, the results were as given in Figure 3.5-24 to Figure 3.5-29.

There will be a significant increase in energy demand in 2020 for all scenarios, increased from 250 thousand toe in 2003 to 558 thousand toe and 729 thousand toe in 2020. The usage share of diesel oil will increase in all scenarios because of more use of diesel vehicles due to their high energy efficiency. Even though many policy options were considered in the policy scenarios, there is still a 1.3-fold increase in the policy scenario for 2020. That means stronger policies are necessary.

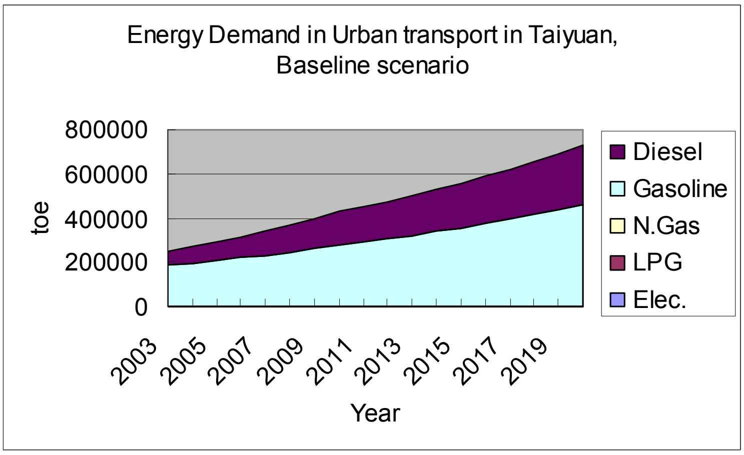


Figure 3.5-24 Energy demand for urban transport in Taiyuan, Baseline scenario

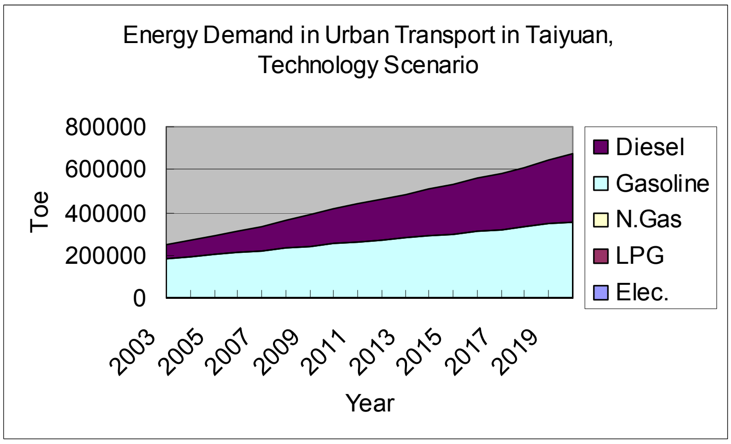


Figure 3.5-25 Energy demand for urban transport in Taiyuan, Technology Progress scenario

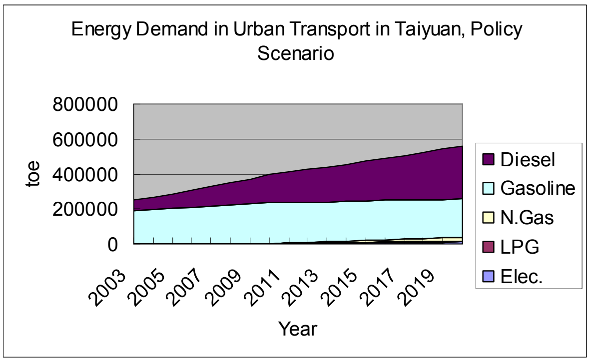


Figure 3.5-26 Energy demand for urban transport in Taiyuan, Policy scenario

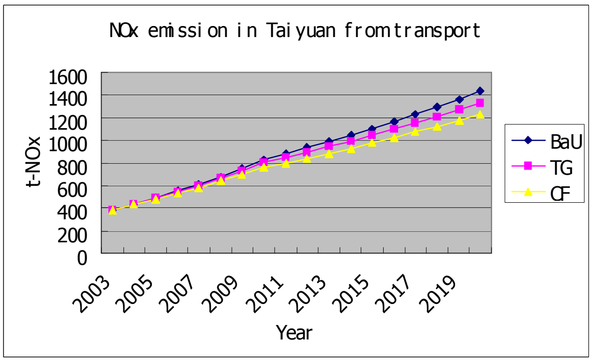


Figure 3.5-27 NOx emissions from transport in Taiyuan

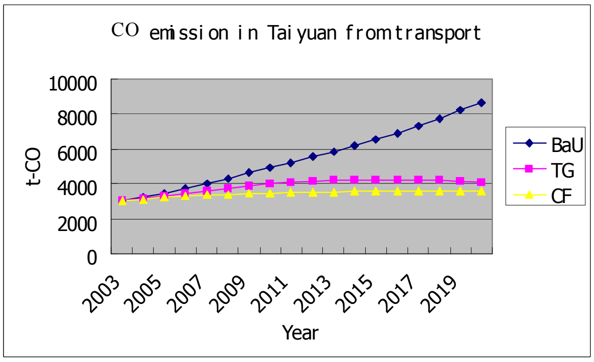


Figure 3.5-28 CO emissions from transport in Taiyuan

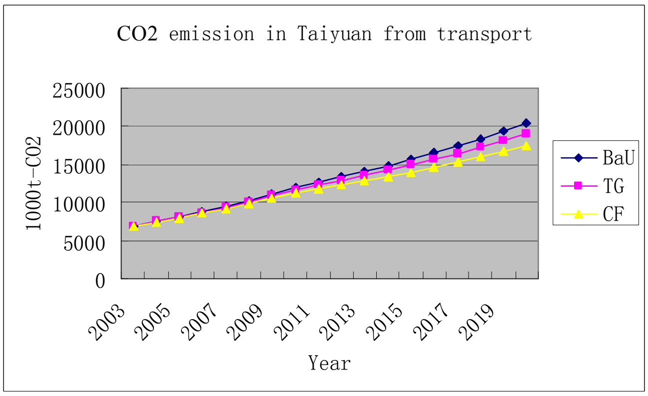


Figure 3.5-29 CO_2 emissions from transport in Taiyuan

vi) Conclusions and recommendations

In the study of urban transport scenarios, a range of policy options were analysed. The following are policy suggestions for urban transport development in Taiyuan:

- A group of policy options is necessary for urban transport development in Taiyuan. No single policy could contribute to mitigating energy demand and emissions in urban transport.
- Further promote the public transport system in Taiyuan, by using more public transport oriented policy options such as more buses, bus lanes, a railway mass transit system, etc.
- A subway or city light railway system should be developed in Taiyuan for further energy saving and emission reduction.
- As a short-term policy option, alternative vehicles, especially for buses such as CNG buses and LPG buses, should be introduced. This could be relatively low cost and has been well applied in some other cities, such as Beijing.
- Ethanol gasoline is a good option for Taiyuan, which could mitigate emissions and benefit the local economy, reducing gasoline and diesel dependence.
- Encourage the development of mini cars and abolish the limit on running of mini cars.
- Encourage low-energy-use vehicles: reduce tax, and issue energy use standards as soon as possible.
- Introduce advanced vehicles, such as PRIUS and LUPO.
- Establish a long-term development plan for fuel-cell vehicles.
- Integrated design for city function areas (this should be divided according to district, not street)
- Use a traffic control policy, including:
    1) On the condition of improvement of public transport, increase the running costs of cars (increase the parking fee to 10-20 Yuan/h, integrated with public transport)
    2) Encourage telephone meetings
    3) Develop electronic payment facilities
    4) Local purchasing
    5) School-bus plan
- Public involvement (switching off when waiting for more than 6 minutes, reduced vehicle use, increased walking and cycling).
- Develop a clean transportation system through an international cooperation mechanism.

3.5.1.5. Conclusions

The following conclusions were reached by this study

(1) It is likely that with growing economies and population in the Asia-Pacific region, motorisation will accelerate and traffic volume will increase dramatically. To address and mitigate this trend, policies to reduce the negative environmental effects from the transport sector are urgently needed.

(1) By tracking the causal chains among socio-economic factors, transport, and environmental problems, factors of transport that cause environmental problems were identified as: increase in travel demand (the issue of quantity); increase in vehicle ownership and use, and lack of alternatives (the issue of balance); and high environmental impact due to vehicle use (the issue of quality).

(2) To address these factors, three strategies, each focusing on quantity, balance, and quality were selected. Those strategies are: reducing transport demand, increasing public transport usage, and reducing emissions from vehicles.

(3) For the strategy of reducing transport demand, "innovative" SPOs for developing countries in the Asia-Pacific were identified. Those include creating regional systems of cities, promoting compact cities and smart growth, and using IT-based communication and services to reduce transportation needs.

(4) Innovative SPOs for the strategy of increasing public transport usage include: promoting rail-based mass rapid transit (R-MRT) through innovative mechanisms to address high initial costs, promoting bus rapid transit (BRT), using community vehicles, promoting special lanes for walking and cycling, creating car-free zones, introducing number plate bidding systems, promoting car sharing, and using road pricing to control vehicle use.

(5) Five SPOs were selected as innovative for the strategy of reducing emissions from vehicles. Those SPOs are: introducing vehicle emission standards and inspection/maintenance systems, introducing vehicle fuel standards, greening fuel tax, promoting the spread of high efficiency vehicles, and promoting alternative fuel vehicles.

(6) Through comparative data analysis in the previous section, the characteristics of Bangkok and Beijing have been identified. Bangkok already has high transport demand, a high rate of vehicle ownership, and high emissions per passenger-kilometre. The effects of air pollution are still serious, although the city has taken measures such as developing mass rapid transit, phasing out lead in gasoline, and introducing EURO emission standards. Beijing was still in the early stage of development in terms of urban transport infrastructure and vehicle ownership. However, considering the high pace of growth, prompt policy measures should be introduced to mitigate the environmental effects of transport.

(7) According to a scenario study of the energy use and environmental implications in the transport sector of Bangkok during 2000-2020, it was projected that, in the BAU case, energy consumption, emission of air pollutants, and CO_2, will increase from 2000 to 2020. For example, CO_2 is expected to increase from approx. 24 thousand tons in 2000 to 40 thousand tons, and PM emission would increase from approx. 6 tons to 9.24. In the scenario in which efficient transport technologies (focusing on the strategy of reducing emissions from vehicles) are introduced, it is expected that CO_2 emission would be reduced by 6.3 thousand tons and PM emission by 0.48 ton in 2020 compared with the BAU case. In the scenario focusing on introduction of car-free days, the mitigation would not be as effective as in the previous scenario. In order to overcome this ineffectiveness, the frequency of car-free days should be

increased from 2010 onwards. Also, a more systematic policy mix to increase public transportation usage would be needed.

(8) A scenario study for Beijing showed that energy use for transport would increase rapidly before 2010. After 2010, the growth rate could be reduced and total energy use can remain stable. In the BAU case, energy use in 2010 is the effect of the use of new transport technology and policy options, and the total energy use for transport in Beijing would be 4.11 Mtoe in 2010 and 4.46 Mtoe in 2020. Compared with the BAU case, there will be 0.45 Mtoe and 0.86 Mtoe saved respectively in 2010 and 2020 in the technology progress scenario (containing SPOs such as public transport promotion policies and emission standards), 0.92 Mtoe and 1.36 Mtoe in the clean future scenario (containing further additional SPOs including introduction of highly efficient vehicles and alternative fuel vehicles, and IT technology to reduce transport demand). In the meantime, NOx, CO and CO_2 emissions would also be reduced. Compared with the BAU scenario, there would be 19%, 48% and 31% reductions in NOx, CO and CO_2 emissions in the clean future scenario. Among the technology and policy options, energy efficient vehicles such as the hybrid car and advanced diesel vehicle, and policies to promote public transport, can play an important role.

(9) A scenario study in Taiyuan showed that there will be a significant increase in energy demand in 2020 for all three cases considered. For the business-as-usual scenario, energy demand is estimated to increase from 357 thousand toe in 2003 to 797 thousand toe and 1,040 thousand toe in 2020. The proportion of diesel oil usage will increase in all scenarios because of more use of diesel vehicles due to their high energy efficiency. Even though additional policy options, such as rail-based mass rapid transit, alternative fuel vehicles, and integrated design of transportation system, were considered in the policy scenarios, there is still a 1.3-fold increase in energy demand in 2020. That means that strong policy intervention is necessary in Taiyuan.

3.5.1.6. References

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