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Energy Efficiency in Urban Transport*

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Abstracts

Transport is the largest and fastest-growing energy user, with a forecast annual growth rate of 2.1% worldwide and 4.3% for East Asia and the Pacific over the period 2002 - 2030. The growing energy use by the transport sector generates a third or more of total greenhouse gas emissions in urban centers. The Asian Development Bank (ADB) is addressing the challenges posed by increasing energy use through (i) its energy, transport, and environmental projects and related capacity-building activities to support economic growth while safeguarding the environment; and (ii) the Clean Air Initiative for Asian Cities which promotes knowledge sharing on relevant challenges and solutions. Additionally, ADB, with supplementary funding from the United Kingdom Department for International Development and within the context of the 2005 Group of Eight (G8) Gleneagles' Action Plan on Climate Change, has also undertaken analytical work to contribute to the development of an overall investment framework to guide investments and address energy efficiency and climate change in the transport sector in Asia. This paperfocuses on transport planning and policy instruments to reduce energy consumption, associated global emissions, and tailpipe emissions from transport－a major contributor to the deteriorating air quality in Asian cities. The paper identifies four key areas on how ADB can assist its developing member countries in promoting energy efficiency and sustainability in transport, namely: (i) knowledge products, improved tools, and related capacity building; (ii) support for developing appropriate frameworks at the national and city levels; (iii) strengthened partnerships and common approaches among bilateral and multilateral agencies on a national basis; and (iv) targeted investment to promote leading practices.

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Keywords : Asian Development Bank, Energy Efficiency, Transport

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Ⅰ. Introduction

The transport sector is the largest and fastest-growing energy user, with a forecast annual increase of 2.1% worldwide and 4.3% for East Asia and the Pacific in 2002 - 2030 (International Energy Agency [IEA], 2004). Local emissions and their associated harmful health impacts are expected to increase at a similar rate during this period. The sector is also a major source of greenhouse gas (GHG) emissions. Transport activities, especially passenger traffic, are concentrated in cities; making them the most heavily polluted and congested areas. Therefore, urban areas stand to benefit most from improvements in energy efficiency.

The Asian Development Bank (ADB) is addressing the challenges posed by rising energy use through (i) energy, transport, and environmental project loans and related capacity-building activities to support economic growth while safeguarding the environment; and (ii) the Clean Air Initiative for Asian Cities, which promotes knowledge sharing on relevant challenges and solutions.

ADB initiated[1)] to contribute to the development of an overall investment framework on climate change under the Group of Eight (G8) Gleneagles' Action Plan on Climate Change, Clean Energy, and Sustainable Development, which was approved in July 2005. At the same time, ADB is increasingly being called upon to become involved in urban transport investments, such as bus rapid transit (BRT), mass rapid transit (MRT), urban roads, and wider urban infrastructure development with transport components in

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1) Asian Development Bank (ADB). 2005. *Climate Change Mitigation in the Transport Sector.* Manila: ADB.

various countries across Asia and the Pacific region (the region).

This paper will present the technical analysis of transport planning and policy instruments to reduce energy consumption, associated global emissions, and tailpipe emissions from transport —a major contributor to the deteriorating air quality in Asian cities. Transport planning and policy instruments include (i) transport management and traffic restraint measures, (ii) public transport, (iii) road use pricing, and (iv) other fiscal and administrative measures.

Ⅱ. Urban Transport Issues

A. Urban Transport

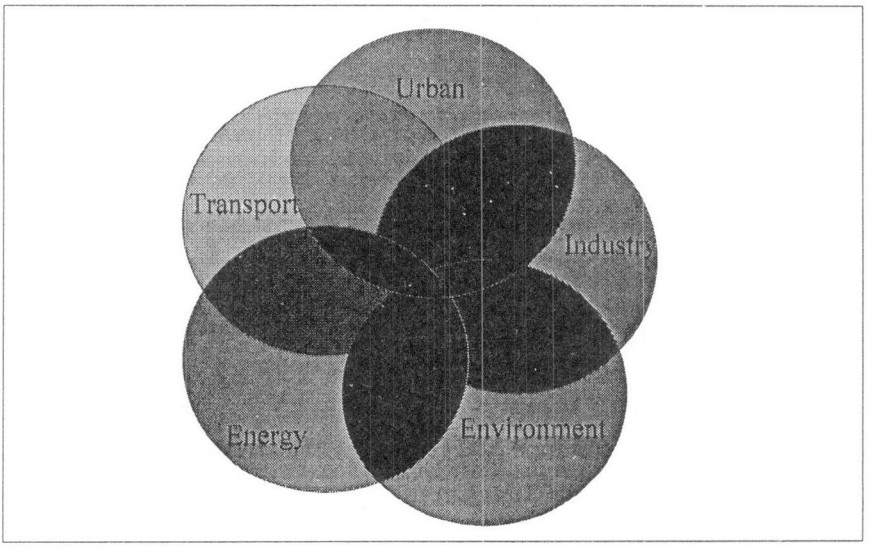
Rapid urbanization, rising incomes, and an explosive increase in the use and number of vehicles have worsened traffic congestion in developing member countries' (DMC) urban areas. As traffic increases, so do the consumption of oil-based fuels and the generation of greenhouse gases (GHGs). Among the results are more pollution, environmental degradation, and a declining quality of life in the cities. Unfortunately, ways to address these problems, or to stabilize urban sprawl, or curb the growth of private vehicle fleets, appear to be out of reach at the moment.

Urban transport is not usually undertaken for its own sake, as it is a derived demand characterized by: (i) the movement of a large volume of people, freight, and vehicles in complex patterns; (ii) interlinks with other sectors, where transport is merely the means for participation in activities (Figure 1); (iii) the involvement of a diverse range of activities and participants;[2] and (iv) the presence

2) Roads must be constructed and maintained, and the associated traffic,

of negative externalities, such as congestion, local tailpipe emissions (carbon monoxide [CO], oxides of nitrogen [NO_x], sulfur oxide [SO], hydrocarbon [HC], and particulate matter [PM]), global emissions (such as GHG carbon dioxide [CO_2], in the case of transport-related impacts), and noise pollution.

[Figure 1] Transport Interlinks with Other Sectors



Source: Asian Development Bank (ADB), 2006

Transport improvements aim to realize the following desirable outcomes: (i) increased efficiency and productivity; (ii) better services, mobility, and access; (iii) reduced energy use, emissions, and noise pollution; and (iv) improved road safety. In turn, such positive results will contribute to broader desirable community outcomes (Table 1). Sustainability within the transport sector has several dimensions—economic, socioeconomic, environmental,

managed. Fixed-track public transport, such as railways and bus rapid transit (BRT), are usually provided by vertically integrated agencies, which construct and maintain the tracks, and associated vehicle control systems that purchase vehicles, and which may operate the system as a whole. The ownership and use of private, corporate, and public transport vehicles in the road system is widely dispersed.

financial, energy, and social.[3)]

【Table 1】 Transport Objectives and Outcomes

Transport Objectives	Transport Outcomes	Community Outcomes – Quality of Life
Efficient road network (improved flow and traffic movement) Efficient movement of freight (delivery of goods on time and to the right place)	Improved transport efficiency and productivity	Industrial competitiveness and growth
Quality integrated mass transit (better services, mobility, and access)	More affordable services and better mobility and access	Livable communities
Better management of travel demand (influencing travel choice) Clean personal transport (reduce energy use, emissions, and noise)	Reduced energy use, emissions, and noise	Environmentally sustainable
Safer roads, vehicles, and road users (improved road safety and security)	Improved road safety and security	Safer communities

Source: ADB. 2006.

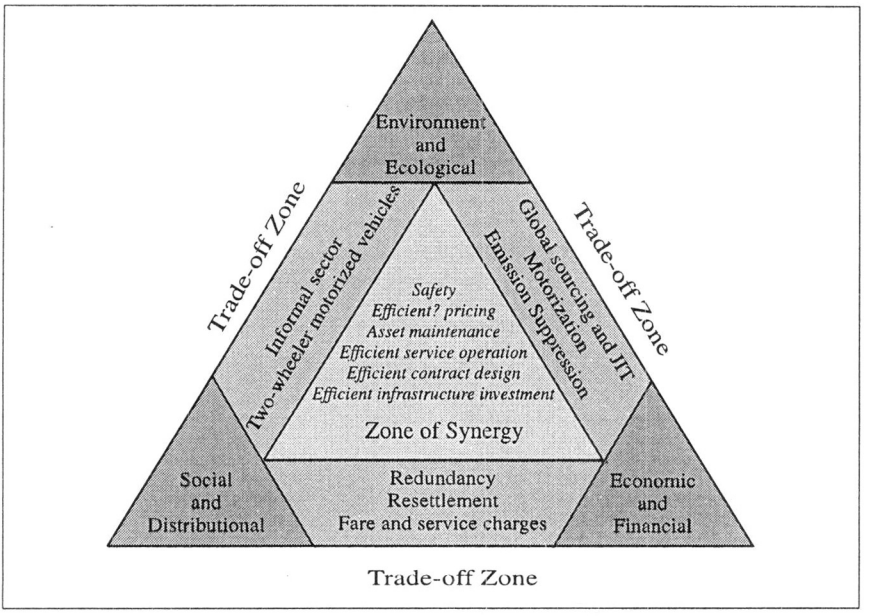
As described in the World Bank report (1996), there are difficult trade-offs between the goals and synergies (Figure 2). Trade-offs may occur in any of the three dimensions, while synergies or "win - win/no-regrets"strategies occur in the center of the triangle. There may be significant synergies between strategies in reducing energy consumption, as they also directly decrease GHG and will usually reduce the harmful local or tailpipe emissions.

ADB is committed to raise the standard of living in its developing member countries (DMCs) in the Asia and Pacific region through policies that promote poverty reduction and economic growth. Corollary to growth are complex interactions

3) Supporting concepts are (i) financial sustainability – programs need to be maintained by adequate capital and ongoing revenues and budgets; (ii) institutional sustainability, which requires the engagement of existing institutions for it to be scaled up to a level where programs can make a significant impact; (iii) the location-specific characteristic of sustainability; and (iv) the importance of safety and security.

affecting its pattern and urbanization—increased energy use (Wright and Fulton, 2005), motorization, the resultant emissions, and congestion.

[Figure 2] Dimensions of Sustainability



JIT = just-in-time logistics.
Source: World Bank. 1996.

B. Urbanization

The world's population is projected to grow from 6.5 billion today to almost 8 billion by 2025. Around half of the increase is expected to occur in Asia. As urbanization swiftly spreads throughout the region, the megacities (over 10 million people) are getting larger and rapidly suburbanizing. The number of megacities in Asia is expected to reach 13 by 2025, from 9 today. The small-and medium-sized cities are also expanding quickly. By 2025, over 300 cities are expected to have a population of one million or more (United Nations, 2004).

The development has been largely unplanned, and the provision

of urban services has lagged due to limited city budgets and inadequate technical capability. The expansion of road corridors has created "superblocks"—large parcels of land which are developed inefficiently. "Superblocks" rely almost entirely on major roads (e.g., expressways and highways) for access, thus mingling both local and long distance traffic movement and exacerbating traffic congestion.

The poor, who tend to live on the fringes of cities—far from their places of employment—are usually burdened with the highest transport costs, which deny them he benefits of economic growth.[4] Many lower income earners, including bus and taxi drivers, and vendors, are exposed to pollutants everyday. Constant exposure to vehicle emissions increases the severity of the potential roadside impacts on the poor.

Transport and other major infrastructure, such as water supply, have a fundamental role in the function of cities. Because of the complexities of transport and its negative externalities, inappropriate policies on transport may impose heavy costs on cities and their citizens in the form of long and costly travel, exposure to pollution, and associated harmful health impacts.

Since there are many variables which households and firms seek to optimize with complex interactions, excessive transportation use may not be curbed significantly by land-use controls. Furthermore, it is unclear which policies and time frame will be effective in a city. Conventional wisdom argues that low-density, dispersed cities

4) ADB (2006b), German Technical Agency for Cooperation or GTZ(2002), and World Bank (2002) have well documented these issues. Newman and Kenworthy (1991) have also observed that low-density cities in the United States of America (USA) and Australia consume more fuel per capita than higher density cities. However, housing typically costs more in high-density areas in cities less residential floor space per person is used (Ingram, 1997). For initial affordability and lifestyle, many households trade-off lower housing unit costs with higher space consumption and increased transport cost and fuel use at the urban fringe.

require longer travel times and breed a greater reliance on private vehicles, which results in more traffic congestion and fuel use. Meanwhile, another school of thought says that the suburbanization of population and employment would actually ease congestion. These arguments were investigated by Sarzynski, et al (2005) using data for the United States of America (USA). Neither proposition could be proved or disproved, although locating employment and residential centers in reasonable proximity appeared to marginally reduce congestion.

In developing cities where local technical capacity is weak, planning instruments are rudimentary and responsibilities, fragmented. The location or direction of urban development influences transport investment, particularly in roads. Even in developed cities, the available urban planning instruments are limited in their ability to manage urban growth as envisioned by the planners, assuming that the planners know what is best for their citizens. National economic policies on investment, local interests, the influence of accessibility that transport provides, and other factors are more likely to influence the rate of development and its spatial distribution. Recognizing what can be controlled and, consequently, preparing implementable "framework"plans that will improve the coordination and timing of supporting investments appear to be the better path to superior urban development.

C. Motorization

From 1992 to 2001, the region's per capita income rose more than 70%, towing with it motorization (rate of vehicle ownership). As a result, most cities in the region are struggling to cope with rapidly increasing motorization. The vehicle fleet roughly doubled

from 2000 to 2005 in most cities, so that congestion is rapidly worsening, as are related problems such as insufficient parking space, the declining speed (due to congestion) and service quality of the buses, worsening air and noise pollution, rising fuel consumption, and deteriorating living conditions.[5]

Compared to developed countries, per capita motorization of Asia is generally lower (Figure 3), but the popularity of motorcycles in Asia has kept the gap relatively narrow. Asian vehicle ownership is one or more vehicles per household, as in Malaysia and Thailand, due to the large number of motorcycles and three-wheelers owned. Motorcycles, which have small engines (around 100cc) and are much cheaper than cars, comprise a high proportion of the vehicle fleets in Asia.

Economic growth has also boosted freight transport demand. In developing cities, trucks make up around 30% of vehicles using roads. Unfortunately, in developing Asian countries, truck fleets tend to be old and thus a major source of fine particulate matter that is a health hazard.

The general trend is toward private motorized transport for ease of mobility. Decision makers frequently equate development with growth in vehicle ownership, thereby perpetuating the trend and reinforcing the bias for motor vehicles in policies and planning processes.

Once a household becomes "motorized", getting its members used to public transport and nonmotorized modes is extremely

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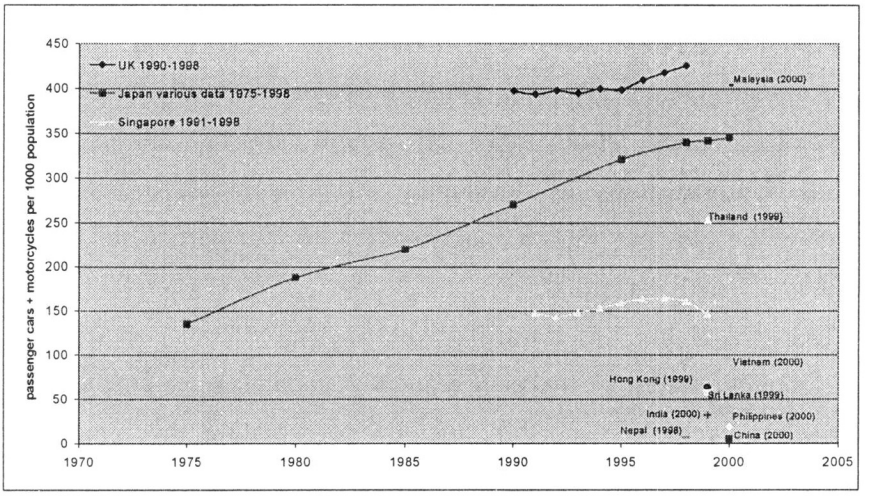
5) The annual growth rates of registered vehicle fleets varied among countries (e.g., India posted 17.6%; the People's Republic of China [PRC], more than 11%; and Thailand, 10%). Vehicle registration statistics in some countries fail to accurately account for retired vehicles, so that the actual number of in-use vehicles may be overstated. In Thailand, the in-use fleet was estimated to be half of the registered fleet in 2003. These errors also affect estimated annual growth rates; Thailand's in-use fleet expanded at an average of 5.5% per annum from 1994 to 2003.

difficult (ADB, 2006band World Bank, 2006). Ironically, instead of shortening travel time, increasing the number of vehicles on the street makes it longer. Yet, despite the high vehicle growth in Asian cities, many households still do not own a car or even a motorcycle. For example, in Bangkok, Thailand, around 44.5% of all households had no vehicle in 1995 (MVA Consultants,1996). Thus, there appears to be an opportunity in many cities to provide more sustainable modes of transportation before motorization is completely entrenched.

[Figure 3] Motorization per Capita in Selected Asian and Developed Countries



UK = United Kingdom.

Notes:

1. Motorization = registered private cars + motorcycles
2. Vehicle registrations in some developing countries (e.g., Lao People's Democratic Republic and Thailand) are known to overstate actual in-use fleet. In Thailand, the in-use fleet was half of the registered fleet in 2003.

Source: ADB, 2002.

D. Public Transport

Asian cities have varied public transport modes and services, such as new urban rail or mass transit systems; small and large

buses; van transport operating on fixed routes, point-to-point, or nonfixed routes; taxis; small motorized two- and three-wheel vehicles, including motorcycle taxis; and nonmotorized vehicles. The different transport modes cater to specific market niches, providing a wide range of service levels and quality, and charging varied fares. However, the proportion of motorized trips made on public transport is steadily declining globally[6](Table 2).

[Table 2] Trends in the Mode Share of Public Transport in Developing Cities

City	Earlier year	Public transport as a percentage of motorized trips	Later Year	Public transport as a percentage of motorized trips
Bangkok	1970	53	1990	39
Buenos Aires	1993	49	1999	33
Kuala Lumpur	1985	34	1997	19
Mexico	1984	80	1994	72
Moscow	1990	87	1997	83
Sao Paulo	1977	46	1997	33
Seoul	1970	67	1992	61
Tokyo	1970	65	1990	48
Shanghai	1986	24	1995	15
Warsaw	1987	80	1998	53

Source: World Business Council for Sustainable Development. 2004.

Public transport services in many developing cities are of poor quality: crowded, dirty, slow, infrequent, and unsafe. Access—embarking and disembarking—is often difficult, and sidewalks are cluttered and dirty.

In many Asian cities, the public transport sector is dominated by a single or several state-owned bus operators who, in some

6) In Asia, the Vietnamese cities of Hanoi and Ho Chi Minh are exceptions, as bus transport companies failed to operate in the early 1990s and public transport's share of all trips fell to low levels. The Government is steadily reinvesting in public transport so that the mode share is now around 5%.

cases, subcontract operations to private companies. Usually, both the state-owned and private operators are heavily constrained by the regulatory system within which they operate, which tend to inhibit innovation. As a result, the financial position of public transport operators is weak and does not allow for proper maintenance and depreciation to ensure the regular and timely replacement of the units, never mind if passengers are willing to pay more for greater convenience and safety.

New BRT systems are being implemented in several Asian cities based on the concepts demonstrated in South America (e.g., Bogota, Guangzhou, and Curitiba). The PRC has been the most active, developing BRT systems in major cities such as Beijing and Kunming. A new single line "closed"[7] BRT system was introduced in Jakarta, Indonesia in 2004 and a similar system will soon be operational in Bangkok. In both Jakarta and Bangkok, the design and effectiveness of the BRT system were constrained by funding and the difficulty in attracting sufficient political support. In many cities, BRT has encountered resistance since it is not perceived to be as upscale or sophisticated as rail systems. However, modern high-quality, exclusive BRT lines with a segregated right of way, modern stations, and clean, comfortable vehicles may win better acceptance with the traveling public. With a more positive image, BRT may be able to attract more investment and further technological fleet upgrading (IEA, 2002).

Over 40% of all person-trips in major cities in Asia are made on nonmotorized transport (NMT) such as walking, bicycles, and three-wheel pedal-powered vehicles. However, governments usually tend to eliminate or hinder NMT operations, which are seen as hampering traffic flow or projecting an undesirable "image".Yet, NMT is of major economic importance to the poor as a mode of

7) "Closed" means that BRT buses run exclusively on the segregated track.

transport and source of income, with a distinct environmental advantage because it does not contribute to air pollution. NMT is also important for a city's economic activity (World Bank, 2002). NMTs are usually overlooked in conventional transport planning and infrastructure programs, thus left to operate in chaotic streets, exposing the users to pollution and safety risks.

Persuading car and motorcycle riders to switch to public transport is not easy in view of the status and convenience conferred by private vehicle ownership. On the other hand, high-quality, fast, and accessible public transport services—rail or bus—have successfully attracted the users of buses and paratransit.

Policies on improving air quality work directly (requiring engine upgrades, the use of alternative fuels, etc.) and indirectly (promoting the use of public transport). However, these policies need to be implemented in an environment where the operations are efficient and financially sustainable.

The vehicle and road user mix, pedestrians, and NMT vehicles vary from city to city, often with conflicting needs. Planners rarely prioritize the needs of NMT vehicles and pedestrians. Catering to the needs of NMT at the design stage of urban transport projects (roads, traffic management, and BRT or MRT) is far easier and cheaper than to retrofit partial solutions later. The major barrier to effective public transport systems is the enabling environment and mindset of politicians and transport agencies.

E. Congestion

While a certain amount of traffic activity is unavoidable in a prosperous city, traffic congestion makes city living unbearable. Due to the rapid growth and motorization of cities and inadequate supply of road space, congestion in Asian cities tends to be worse

than in developed cities of equivalent size. Congestion is exacerbated by underdeveloped road hierarchies, forcing both long- and short-distance trips to mix.

The prospects of reducing traffic congestion in developed cities and Asian cities are limited (Stopher, 2004). Nevertheless, urban road and traffic investments, appropriate transport policies, and better management practices are necessary, especially in developing Asian cities.

Congestion affects industrial productivity through (i) higher labor and vehicle operating costs, and freight damage; (ii) the higher cost of obtaining inputs and serving markets; (iii) reduced reliability in the delivery of inputs and distribution of finished goods; and (iv) reduced access and scaled economies, which increase production costs.

Cities rely on well-planned roads when undertaking urban development and distributing traffic, but road building alone cannot keep pace with the explosive demand for travel. As cities become developed, the environmental and social impacts of urban road construction become increasingly and often prohibitively difficult.

Sustaining the implementation of traffic management schemes poses a challenge to transport agencies. Even when the schemes are initially successful, they require effective management and the associated technical capacity to sustain the scheme. In many cases, the resources are insufficient.

Most Asian cities (except Singapore) do not have an explicit road-user charging system. Just the same, road users pay substantial charges in the form of fuel excise charges, high sales taxes on new vehicles, and motor vehicle registration fees. However, when noncash costs—depreciation, externalities (environmental and pollution-related health costs, congestion costs, etc.)—

and the cost of capital required for the supply of transport assets are included, it is possible that road users are not paying the full cost they impose on the community.

F. Energy Consumption and Global Emissions

The energy demand of the transport sector is increasing, particularly for fossil fuels, the combustion of which releases GHGs as a by-product. Transport activity generates a third or more of total GHG emissions in urban centers (World Bank,2006). GHGs, which are linked to global warming (ADB 2006), are emitted in the form of CO_2, methane (CH_4), and nitrous oxide (N_2O) and gases responsible for the formation of ozone (O_3), such as NO_x and volatile organic compounds (VOCs).

IEA forecasts that, between 2002 and 2030 (Table 3), the total transport-related oil demand worldwide will grow from 1,827 million tons of oil equivalent (Mtoe) to 3,273 Mtoe at an average annual growth of 2.1%, with the rate falling slightly over time. In Asia,[8] the total transport-related oil demand is expected to expand much faster, at 4.3% per annum during the same period. CO_2 emissions (as a measure of GHG) in the region are projected to grow at a similar rate.

Despite the region's high growth rate, the per capita demand for transport oil will still be less than in the member countries of the Organisation for Economic Co-operation and Development (OECD), as incomes will remain lower in terms of purchasing power parity

8) Asia is defined as East Asia plus the People's Republic of China, with definitions of each region according to International Energy Agency or IEA (2004). Figures for South Asia and India were also examined, but it was not clear whether India data were already included in the totals for South Asia. However, the inclusion of South Asia or South Asia plus India into "Asia" would not make any significant difference in the reported growth rates for Asia.

【Table 3】 IEA 2004 Reference Case Forecasts for Selected Areas in Asia and the World

Region	2002	2010	2020	2030	Growth Rate Per Annum 2002 - 2010 (%)	2010 - 2020 (%)	2020 - 2030 (%)	2002 - 2030 (%)
World Total								
Total primary energy supply (Mtoe)	10,345	12,914	14,404	16,487	2.81	1.10	1.36	1.68
End consumption - Transport (Mtoe)	1,827	2,230	2,755	3,273	2.52	2.14	1.74	2.10
Total CO_2 emissions (Mt)	23,579	27,817	33,226	36,214	2.09	1.79	0.86	1.54
CO_2 emissions - Transport (Mt)	4,914	5,977	7,375	8,739	2.48	2.12	1.71	2.08
PRC Total								
Total primary energy supply (Mtoe)	1,242	1,622	2,072	2,539	3.39	2.48	2.05	2.59
End consumption - Transport (Mtoe)	87	136	212	306	5.74	4.54	3.74	4.59
Total CO_2 emissions (Mt)	3,307	4,386	5,708	7,144	3.59	2.67	2.27	2.79
CO_2 emissions - Transport (Mt)	244	383	592	852	5.80	4.45	3.71	4.57
East Asia Total								
Total primary energy supply (Mtoe)	533	712	955	1,188	3.69	2.98	2.21	2.90
End consumption - Transport (Mtoe)	91	137	205	269	5.25	4.11	2.75	3.95
Total CO_2 emissions (Mt)	1,055	1,459	2,092	2,701	4.14	3.67	2.59	3.41
CO_2 emissions - Transport (Mt)	236	354	530	693	5.20	4.12	2.72	3.92
East Asia + PRC Total								
Total primary energy supply (Mtoe)	1,775	2,334	3,027	3,727	3.48	2.63	2.10	2.68
End consumption - Transport (Mtoe)	178	273	417	575	5.49	4.33	3.27	4.28
Total CO_2 emissions (Mt)	4,362	5,845	7,800	9,845	3.73	2.93	2.36	2.95
CO_2 emissions - Transport (Mt)	480	737	1,122	1,545	5.51	4.29	3.25	4.26

% = percent, CO_2 = carbon dioxide, IEA = International Energy Agency, Mt = million tons, Mtoe = million tons of oil equivalent, PRC = People's Republic of China.
Source: Analysis of data presented in Appendix I, IEA. 2004.

(IEA, 2004). IEA further states that, "by 2030, incomes in developing countries will approach those of OECD countries in 1971, yet transport oil demand will be less than half of what it was in the OECD countries 3 decades ago. This is because vehicles will be less fuel-intensive than in the past. Oil demand

for transport will remain higher in North America than in Europe, relative to incomes, because of lower fuel taxes, long driving distances, and cultural factors."

Although the newer engines are cleaner and more fuel-efficient, both the in-use and new vehicles will continue to contribute substantially to GHG emissions and energy use. CO_2 is a by-product of gasoline and diesel fuel combustion, while CH_4 is released by vehicles and distribution networks that run on compressed natural gas (World Bank, 2006).

Vehicle speeds have a major impact on the rate of fuel consumption and, in turn, on the quantity of emissions. At low speeds, more fuel is consumed and, therefore, more GHGs are released. The exception is NO_x, which normally decreases as a vehicle slows down.

The current spike in world fuel prices has not dampened the overall demand for automotive fuel because the demand is fairly inelastic.[9] Fuel taxation alone would not likely discourage travel. However, fuel use could drop as a result of substitution; for example, switching to smaller, fuel-efficient vehicles or opting for closer travel destinations.

G. Local Emissions

Poor urban air quality is a serious environmental hazard to which transport is usually the main contributor. The air quality of a given locality is determined by the amount of emissions that motor vehicles produce, the average traffic speed, and other factors, such as topography and the prevailing meteorological conditions. Cars are major sources of carbon monoxide (CO), hydrocarbons (HC), and NO_x two-stroke motorcycles are the

9) ADB (2006) reports a -0.2 fuel price elasticity in the short term and -0.6 in the long term.

principal source of HC and contribute significantly to particulate matter (PM) and CO emissions; and diesel trucks (heavy- and light-duty) are responsible for high emissions of PM, NO_x, HC, and CO. Fine PM,[10] which can penetrate deep into the lungs, is known as particulate matter smaller than 10 microns (PM_{10}) and poses a severe threat on human health.

Pollutants in the ambient air of almost all large Asian cities exceed acceptable standards and are linked to major health problems. Particulate matter (PM) is a growing problem in many urban areas in developing countries. Collectively, particulate pollution is often referred to as total suspended particulates. Fine particulates that are less than 10 and 2.5 microns—referred to as PM_{10} and $PM_{2.5}$—have the strongest adverse impact on human health because they can penetrate deep into the lungs. PM emissions are a key health concern, with estimated economic damage costs much higher than for other pollutants. The major sources of particulate pollution in urban areas are likely to be industry and commerce, the resuspension of road and construction dust, and vehicles. In nonurban areas, practices such as agricultural burning contribute significantly to overall particulate pollution, and their impacts are also felt in urban areas.

Health impacts vary depending on the type of pollutant, length of exposure, and extent of interaction with other pollutants. Carbon monoxide (CO) is an odorless, invisible gas resulting from the incomplete combustion of carbon in fuel. The inhalation of CO can disrupt the supply of essential oxygen to the body's tissues, thus posing a major health risk, especially for those who suffer from cardiovascular disease. At high levels of inhalation, CO can be fatal. Automobiles are the largest source of CO emissions.[11]

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10) Below 10 microns in diameter or finer. It is now common to measure particulate matter smaller than 2.5 microns ($PM_{2.5}$).

11) Lesser sources include industrial processes, nontransportation fuel

Nitrogen oxides (NO_x), including nitrogen dioxide (NO_2), are mainly produced by fossil fuel (petroleum and its derivatives) combustion. They play a major role in the formation of ozone, particulate matter, and acid rain. Short-term exposure to low levels of NO_2 (even less than 3 hours) may impair lung function in individuals with preexisting respiratory illnesses and increase the incidence of respiratory illnesses in children. Long-term exposure to NO_2 may increase susceptibility to respiratory infections and cause permanent alterations in the lung. Diesel-powered vehicles are major contributors to NO_x emissions.

Hydrocarbons (HC) and other volatile organic compounds (VOCs) are compounds with low molecular weight that have unpleasant effects such as eye irritation, coughing, sneezing, and drowsiness. On the other hand, compounds with heavy molecular weight may have carcinogenic or mutagenic effects. Some hydrocarbons have a close affinity to diesel particulates and may contribute to lung disease.

Ozone (O_3) is a highly reactive gas, formed by VOCs and NO_x in the presence of heat and sunlight. Ozone can cause a range of acute health problems, including eye, nose, and throat irritation; chest discomfort; coughing; and headaches. Children are most at risk because they are active outdoors when ozone levels are high. Ozone also affects vegetation and ecosystems, decreasing yields of commercial crops and plantations, and lowering the aesthetic value of national parks.

While health impacts are no doubt the most compelling reason to take action, equally critical are the nonhealth costs of pollution, which stem from congestion and the loss of productivity, damage to ecosystems, and physical infrastructure.[12] Lead in ambient air

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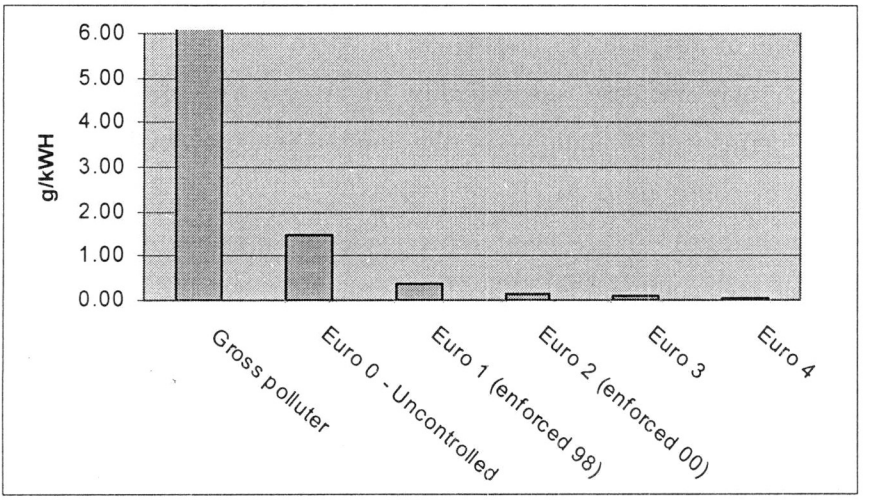
combustion, and fires.

12) Transboundary and global impacts include acid rain, global warming, and damage to the stratospheric ozone. Air pollution soils vegetation and

has almost ceased to be an issue in Asia, as most countries have either completely phased out lead from gasoline or are poised to do so.

[Figure 4] EURO Series of Particulate Matter Emission Standards for Diesel Vehicles



g/kWH = gram per kilowatt hour, EURO = European emission standards.
Source: ADB. 2006.

Aging truck and bus fleets, which typically run on diesel fuel, emit large quantities of PM. Diesel-powered buses and trucks may be completely rebuilt and their engines changed several times (using secondhand imported engines). They, thus, remain in the fleet for a long time despite the introduction of new vehicles that comply with the latest emission standards. For example, ADB (2006a) reports that buses and trucks in Bangkok have an average age of over 12 years; these old pre-EURO(European emission standards) technology diesel buses tend to be heavy polluters (Figure 4). High or gross polluters emit many times more PM than pre-EURO buses which, in turn, emit much more PM than

corrodes buildings, thus deterring investors and tourists and lowering the general quality of life of residents.

new EURO 1 buses. This issue is not confined to Asia. In the USA, some 20% of the vehicle fleet—the oldest with the oldest technology—have been found to be responsible for around 80% of all emissions.

Fiscal and administrative measures governing the assembly or import, registration and use, and emission characteristics of vehicles are often regressive. Import duties and excise taxes in many countries discourage the adoption of new technology. Vehicle registration charges do not differentiate vehicles based on pollution potential or energy consumption. Policies encourage the rebuilding of old diesel vehicles notwithstanding the presence of emission standards for new vehicles. Despite the existence of rudimentary inspection systems in some Asian cities, in-use vehicles continue to spew excessive pollution.

Improved control measures for fuel quality and new vehicle emission standards being implemented in Asia, as documented in Appendix 1 of ADB (2006b), have improved the air quality in many cities (e.g., removal of ambient lead). However, economic growth will increase the number of vehicles and industrial activities, thus raising ambient pollutant levels in the future.

The challenge for policy makers is to set realistic and affordable technology standards that can be maintained locally. Ambitious standards could be counterproductive, as they will raise the prices of new vehicles and make them less affordable; therefore, fewer new units would be bought.

H. Challenges

It is important to seek complementary benefits when developing strategies for transport energy efficiencies (ADB, 2006) to expand and deepen the stakeholder base, and increase the range and

quantity of benefits.

In seeking to articulate the co-benefits, a broader aspect of transport policy must be considered. While objectively calculating energy and emission reductions is possible, measuring the effect at the metropolitan scale is extremely difficult. This is so because (i) the linkages between ground- and macro-level improvements are weak, (ii) zero-sum improvements in one sector may reduce available investments in others, and (iii) measurements are inaccurate.

The push for improvements depends on the government's commitment. At the national level, the interest may be in the country's energy security and compliance with international treaties (e.g., the United Nations Framework Convention on Climate Change - Kyoto); at the local level, traffic congestion and local emissions would be the key issues. Similarly, finance and transport ministries usually have different objectives when dealing with state enterprises that operate buses, trains, airlines, and trucking fleets. For instance, although the ministry of finance plays an important role in implementation, its interest tends to be purely financial (e.g., cutting deficits).

Ⅲ. Options for Energy Efficiency

Energy efficiency strategies should (i) shorten the total number of kilometers traveled by the vehicle, (ii) minimize the vehicle's fuel consumption per kilometer, and (iii) reduce local or tailpipe emissions per unit of fuel.

The full range of available strategies, summarized in Appendix 2, includes (i) vehicle technology change; (ii) fuel quality improvement; (iii) alternative fuels; (iv) transport management,

including traffic restraint measures; (v) public transport; (vi) road-use pricing and (vii) other fiscal and administrative measures.

Appendix 2 amplifies these strategies compared with other technology-based strategies that were considered in ADB (2006b). The key transport planning and policy strategies are analyzed quantitatively in terms of cost effectiveness, energy efficiency (reduced energy use), and CO_2 emissions.

Wright and Fulton (2005), who analyzed a hypothetical developing city of 10 million people making 10 million person-trips per day, described a quantitative approach. The reference case was then put through several scenarios with different mode shares designed to improve energy efficiency and reduce CO_2 emissions (Appendix 1). The cost of the mode shift was assumed to be the infrastructure cost of BRT, improved footpaths, and cycle ways.

Several scenarios were added to the reference case for energy consumption: (i) more fuel-efficient design for new vehicles (all vehicles to be 15% more fuel efficient in the next few years; (ii) electronic road pricing (ERP), as in Singapore; (iii) ERP plus BRT (mode share - 10%); (iv) faster traffic speed (5% faster); (v) road use administrative charges reform (a switch to use charges); (vi) elevated rail MRT (mode share - 5%); (vii) underground rail MRT (mode share - 5%); (viii) BRT (mode share - 5%); and (ix) varying degrees of induced traffic.

The scenarios were ranked from 1 - 12, with 1 being high "good" and 12, low "not so good" in terms of cost effectiveness (i.e., $ per unit reduction for energy or CO_2, as a proxy for energy efficiency). The results of the analysis show that low-cost policy, management, and small-scale transport infrastructure investments and combination of similar measures generally have the highest ranking (Appendix 1).

All strategies share the perception that reductions in energy use, GHG, and local emissions are correlated and would likely be in accord with the expected net economic benefits.

Freight traffic, which comprises 10−20% of total traffic in many developing cities, was not included in the Wright and Fulton analysis; neither were the effects of local emissions and upstream energy usage. However, as stated in Lenzman (1999), these items will likely not affect the conclusions of the analysis.

The effect of induced traffic on energy cost was investigated in Scenario 1, "BRT with mode share of 5%."The results show that cost-effectiveness is highly sensitive to induced traffic, although the ranking of cost-effectiveness is not expected to change under consistent assumptions. Induced traffic can take various forms: (i) additional trips of the same distance or longer and (ii) the same number of trips but longer. Induced traffic will vary according to strategy; one that marginally increases vehicle speed may have more induced traffic than a BRT scenario, which is targeted for current bus users and not designed to attract car drivers.

Similarly, a strategy that uses road pricing or traffic restraint to address directly the factors that induce traffic would be expected to generate less induced traffic than others do.

Except in the most congested cities, induced traffic would likely be less than 50%, denoting that, with appropriate pricing or restraint mechanisms, the cost-effectiveness and overall economic performance of proposed initiatives can be retained.

Ⅳ. Key Findings

Since transport is derived demand, the adoption of appropriate land-use policies can have a huge impact on transport outcomes.

The promotion of urban policies that have the potential to reduce the need to travel is critical. The policies should be shaped by local conditions, including capacity to manage development. Appropriate policies should take into account and attempt to take advantage of market preferences.

Transport contributes to lifting the quality of life and boosts the economy. However, poorly designed and implemented transport projects[13] adversely affect budgets and aggravate traffic congestion, and produce negative energy and emission consequences. Each locality should therefore be carefully examined before selecting transport interventions and exploring the potential for "packaged" interventions.[14]

Land-use and transport policies should be integrated; transport sector plans and their implementation should be compatible and well coordinated. The key transport planning, policy, and management options are presented in the appendixes.

The need for new or expanded roads must be taken in the context of the overall transport framework and evaluated with the same techniques used for other measures. The total social and environmental costs must be considered and safeguards put in place through stakeholder involvement.

Low-cost infrastructure projects and integrated measures usually perform better as regard to energy efficiency and pollution reduction than isolated and high-cost infrastructure projects. There is an artificial division when initiatives are classified by type (i.e., public transport, NMT, traffic management) or responsible agency. For example, well-designed roads ought to include transverse and

13) A generic example may be a new urban expressway that funnels traffic into already congested downtown areas.

14) An example is a packaged approach combining mass rapid transit (MRT), bus rationalization and feeder services, and fiscal constraints for private vehicles.

parallel facilities for cyclists and pedestrians. A new mass transit system (rail or BRT) must be linked to activity areas through feeder services and complementary facilities, such as quality pedestrian and cycle networks, if improved transport were to be achieved.

A comprehensive framework has to consider land use and all modes of transport—from walking and cycling to public transport, cars, motorcycles, and freight movement—because of their role in the economic health of cities.

The co-benefits that ADB (2006b) desire likely exist. Applied measures to reduce energy consumption will minimize GHG production, reduce tailpipe emissions, and increase the economic benefits, such as reduced travel time and savings on vehicle operating cost. Measures must be developed using planning tools and methods that take into account the potential effects of induced traffic.

The "one-size-fits-all" axiom does not apply, however, as development needs vary from city to city. Take the case of the TransMilenio BRT system in Bogota, Colombia, which may well be the prototype (or part of it) of an urban transport strategy in many Asian cities. The layout of the BRT system (e.g., segregated, with its own right-of-way, or segregated in the center of the road, as TransMilenio's) should be designed to match local objectives, the location within the city, and the financial resources of a city. Meanwhile, the big cities in middle-income Asia are aiming to build rail MRTs and the local governments may not welcome the idea of introducing BRTs as well. Mutual exclusivity—using only one mode, either an MRT or a BRT—can be disadvantageous to a city. An integrated, high-quality system combining MRT and BRT, with consistent policies and common ticketing, may be the best way to achieve mobility for all, reduced pollution, and energy

efficiency.

A suitable framework requires deliberation and the inclusion of policy[15] and regulatory measures, investment projects, recurrent programs, and improved management practices. A framework should include: (i) policy, project, and program proposals with analysis, design, the preparation of the cost estimates and bidding documents for physical works, and the identification of implementation needs, such as land acquisition and the timely preparation of operating concessions; (ii) business case proposals with technical, economic, and financial analyses, and the associated safeguards and likely risks in securing the necessary approvals; and (iii) coordinated programs, wherein the relevant projects of all related agencies are scheduled, taking into account economic viability; linkages between policies, projects, and programs; and realistic estimates of the duration of implementation. Thereafter, year-by-year short- and medium-term programs and funding needs can be developed incorporating realistic budget planning.

To have one plan work across sectors is appealing. In practice, however, such a concept is unwieldy and fraught with difficulty. ADB (or other international agencies) will find it extremely challenging to coordinate the manifold strands of a complex multisector approach involving various client agencies, external partners, and internal divisions. Tying project loans with binding conditions on loan disbursement to one sector because of late compliance in a different agency would be troublesome. However, such challenges must be met to attain energy efficiency, environmental sustainability, and efficient transport systems while fully realizing the potential benefits of transport sector interventions in cities.

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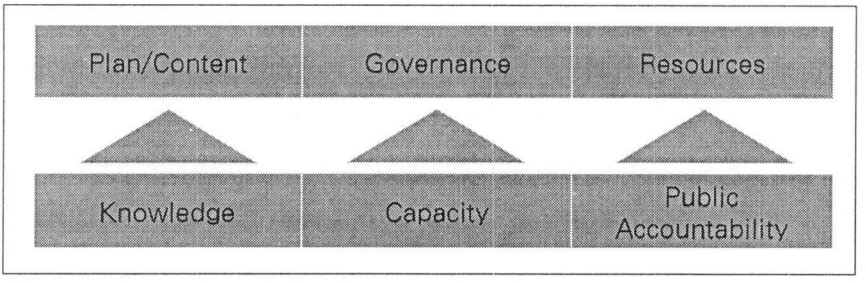
15) Induced traffic may reduce the benefits of an intervention designed to decrease congestion—a possibility that needs to be carefully assessed.

Perhaps a sector-by-sector approach with the centralized coordination of related activities in each sector is more realistic, considering that institutional arrangements are usually fragmented and individual departments rarely coordinate with each other even when they report to the same minister. For a project to be successfully implemented, it must be divided into relatively simple subcomponents that can be managed by a single agency, while forming part of a wider and inclusive development framework.

Because political changes are unpredictable and may occur quickly, differentiating between the conventional components of a suitable planning and implementation framework (Figure 5) is useful. The right plan with the right content, sound governance, adequate financial and human resources, fundamental knowledge, and technical capacity can be prepared or updated in the event of political change. The accountability of politicians and agencies to their constituencies is a valuable means of ensuring that appropriate plans are prepared and implemented, and the necessary resources for new programs, obtained in the wake of satisfactory performance.

[Figure 5] Foundation of a Sustainable Framework



Source: ADB. 2006.

Therefore, knowledge-sharing, training, and capacity development should be the key initiatives for ADB to pursue in promoting energy efficiency, sustainable transport, and the associated

sustainable planning processes.

V. Conclusions

In the push for energy efficiency and sustainability in transport, ADB assistance to DMCs should concentrate in four key areas: (i) knowledge products, improved tools, and related capacity building; (ii) support for developing appropriate frameworks at national and city levels; (iii) strengthened partnerships and common approaches among bilateral and multilateral agencies on a national basis; and (iv) targeted investment to promote leading practices.

ADB (2006b) identified several barriers among DMCs to the implementation of appropriate climate change and energy consumption mitigation strategies, and the development of sustainable urban transport systems: (i) the availability of congruent and consistent knowledge of international best practices on climate change and sustainable transport; (ii) weak empowerment and linkages in many metropolitan areas between urban and transport planning, and traffic management and enforcement; (iii) inadequate accounting tools, so that the economic cost of the externalities of on-road transport is not taken into account; (iv) insufficient information on the true per-kilometer cost of private transport; (v) limited access to capital; (vi) the lack of incentives to invest in better transport systems; (vii) delays in the adoption of new technologies; and (viii) difficulties in developing an optimum investment framework for more climate-friendly transport systems.

Appropriate knowledge products that ADB could support include workshops, conferences, training courses, and manuals to raise the awareness of key issues and good practices. Better data collection, planning tools and models, and monitoring frameworks

are also needed to improve the quality of policy making and infrastructure in terms of relevance (effectiveness), performance (efficiency), and value for money.

Because transport outcomes are determined by the interaction with other sectors (e.g., urban, industry and trade, and energy), coordination with transport agencies and other agencies within governments is vital. A comprehensive review of the transport impacts of ADB's lending to other sectors may prove beneficial. Working with traditional client agencies, such as ministries of environment, transport, roads, and public works, is recommended.

Although the ministry of finance is the customary client for a project loan, it usually attends only to financial issues. Nevertheless, because of its influence, the ministry of finance can also play an important part in promoting sustainable urban transport with sector agencies, as finance and sustainability are often synergistic. ADB may find that pertinent technical assistance (TA)to ministries of finance on key transport sector issues will strengthen the coordination of transport programs and activities between relevant sector agencies.

The private sector will continue to play a significant role in urban transport. The sector should be actively involved to develop effective partnerships in providing financing, efficient development, risk sharing, and undertaking the operations and management of efficient transport systems. Wider stakeholder involvement is also essential to make sure that urban transport systems meet the needs of the urban dwellers.

Local governments often have limited powers, especially in collecting revenues, which may hamper their ability to develop and implement energy-efficient transport and policies. Support for devolution to local government is needed by the transport sector, but not exclusively. ADB can promote the necessary support in

capacity development.

It is critical for partners and donors to take a common approach to transport in a particular city. A stronger partnership is important in matching the strengths of each organization to the circumstances of each city.

Substantial funds are already being spent in developing transport and other infrastructure in Asian cities. Relatively small investments by ADB on appropriate knowledge products, tools, and related capacity building at the national and city levels can make a difference on how infrastructure funds are spent and what measures are put in place to maximize the benefits of committed investments.

The different two approaches are (i) using conventional technical assistance and loans in one or multiple sectors, and (ii) establishing criteria that cities must meet when developing their own sustainable urban transport initiatives to facilitate funding through performance measures. An advantage of the second approach is the ability to establish local ownership, which is particularly useful for piloting sustainable urban transport initiatives with potential for scaling up in a city.

Under a technical assistance, developing a reliable estimate of funding requirements for cities to achieve progress in sustainable and energy efficient urban transport is difficult. A realignment of current spending may largely be what is needed. From ADB's perspective, involvement in sustainable urban transport in a city may start with relatively small targeted TAs, designed to involve key agencies (e.g., transport, finance, land-use planning and management). Lending in small-scale demonstration projects may be a natural follow-on activity.

[Table 4] Classification of Available Improvement Measures

Strategy/Measure	Ability to improve energy efficiency (reduce GHG emissions)	Ability to reduce local emissions	Comment	Likely impact in short to medium term
Vehicle Technology				
Vehicle design–technology and design improvements which directly or indirectly improve fuel efficiency and therefore reduce GHG emissions.	Yes, by reducing vehicle weight and aerodynamic drag with new structural design and materials, smaller engines, etc. (ADB, 2006b).	Yes, through reductions in fuel use	Depends on both manufacturers and government policy to accelerate introduction of new technologies into each country market.	Low impact but still important as this affects new vehicles only.
Standards for new vehicles to reduce emissions and improve fuel economy per power output or distance traveled.	Technologies that reduce (local) emissions may sometimes lead to increased fuel consumption and add to the complexity and weight of engines. Fuel economy standards would be expected to reduce fuel use.	Yes, directly through new technologies for fuel combustion, etc. and installation of after-treatment devices of exhausts	The Philippines, Indonesia, and Viet Nam have developed road maps for EURO II. The People's Republic of China (PRC) will move to EURO IV in 2010 and India will reach EURO III. Thailand and Malaysia will both reach EURO IV light duty standards in 2009. The PRC is the only country in emerging Asia that has implemented fuel economy standards (ADB, 2006b).	Low impact as this affects new vehicles only.
Emission standards for in-use vehicles, the largest component of any vehicle fleet, are needed as vehicle performance deteriorates over time.	Marginal positive effect.	Yes	Existing technological level of vehicles is a constraint–effective regular inspection and maintenance (I/M) is needed to enforce in-use standards. But enforcement is weak in most developing cities.	High impact if effective I/M programs are achievable. Targeted enforcement of "gross polluters" may be more effective.
Fuels				
Unleaded gasoline–removal of lead as additive in gasoline to increase octane level.	Nil	Directly eliminates lead exhaust. Makes possible advanced engine and after-treatment technology for	Almost all countries have completely eliminated leaded gasoline today.	High impact in terms of reduction in lead emissions.

Strategy/Measure	Ability to improve energy efficiency (reduce GHG emissions)	Ability to reduce local emissions	Comment	Likely impact in short to medium term
		gasoline-powered cars and		
		motorcycles (e.g., advanced three-way catalysts with electronic controls for spark timing and air-fuel management)		
Low sulfur diesel fuel	Yes, advanced diesel vehicles using ultra-low sulfur diesel have a higher fuel economy (ADB, 2006b).	Yes	EURO III and IV intermediate standards require lower than 500 ppm and 50 ppm sulfur content, respectively. The major emissions advances occur, however, with the introduction of ultra-low sulfur fuel (<10 ppm) which allows advanced exhaust after-treatment devices to be used that can reduce emissions by up to 95%.	High impact as it directly reduces sulfur levels in all vehicles and appropriate after-treatment devices can be found for almost every vehicle.
Reduction of fuel adulteration by using cheaper inferior or dangerous alternatives	Nil	Yes	Requires appropriate pricing of all fuels and monitoring mechanisms. Adulteration mainly with kerosene is usually only a problem in very poor countries but often difficult to enforce as policies often favor cheaper kerosene which is also used for cooking.	Low
Alternative Fuels				
Biofuels–biomass-derived liquid fuels	Biodiesel has strong impacts on GHG mitigation, since no fossil CO2 is burned as	Yes, but control of PM and other emissions needed.	The principal biofuels commercially available today and suitable for road	Low. It is likely to be several decades before a strategically

Strategy/Measure	Ability to improve energy efficiency (reduce GHG emissions)	Ability to reduce local emissions	Comment	Likely impact in short to medium term
	closed carbon cycle. Net energy balance low in short term but potentially high in the long term (ADB, 2006b).		transport are ethanol for spark ignition (gasoline) engines and vegetable oil-based diesel substitutes for compression ignition (diesel) engines (ADB, 2006b).	important share of liquid fuels for road transport can come from biofuels (ADB, 2006b). More costly to manufacture than hydrocarbon-based fuels.
Liquefied petroleum gas (LPG)	Offers similar CO_2 emissions reduction. GHG emissions are slightly higher than CNG.	Reduces PM and NOx emissions in diesel vehicles	Already represents 10% of all gaseous fuel demand in many countries. Supply limits as usually collected from wells where burned.	Potential to be expanded in taxi and bus fleets.
Electric vehicles–vehicles using batteries either as main or partial motive source	Yes, as vehicles tend to be lighter and less powerful. GHG potential depends on the mode of electricity production (e.g., Hydropower as main source gives low GHG emissions.)	Yes, but depends on mix of power sources	Battery technology imposes range and gross vehicle weight limitations. Hybrid electric-gaseous-fuele d vehicles appear to be being mainstreamed.	Low as these affect new vehicles only and until production costs fall further and limitations on range are removed.
Transport Management				
Traffic signal systems–compute r-controlled traffic signal systems on an area or corridor basis to optimize traffic flow (e.g., green waves)	Yes, from 1 - 10% but there are trade-offs between delay reduction and fuel use reduction.	Yes	There are a wide variety of traffic signal systems; the most advanced are intelligent adaptive systems but the full benefits are not realized in peak periods when roads are clogged. Also require significant maintenance of road-based sensors.	High in cities where management and technical capacity are high. Low, where not.
Incident detecand management–technologies to detect and anticipate incidents and to initiate corrective measures	Yes. In congested environments, incidents contribute to up to half of all congestion and energy use, etc.	Yes	Normally can only be applied to freeways, toll roads, and other limited access road systems.	Medium
Parking reduction and	Low to medium	Depends on measure	Poorly designed parking schemes that	Low to medium but essential component

Strategy/Measure	Ability to improve energy efficiency (reduce GHG emissions)	Ability to reduce local emissions	Comment	Likely impact in short to medium term
management–management of parking on a comprehensive basis to achieve desired objectives such as to maximize parking turnover to favor short-term use instead of long-term all-day commuter parking		implemented and what travel impacts resulted.	are not comprehensive may merely transfer demand and be counterproductive. Relatively simple to implement.	of land-use and traffic strategy.
Traffic restraint measures–physical measures to limit traffic movement in corridors or areas	Low to medium	Low to medium	Physical restraint measures are normally implemented for local reasons and merely transfer travel demand. Measures, such as bans on cars with certain ending numbers on number plates or high-occupancy vehicle lanes, need to be carefully designed to avoid abuse (e.g., Manila's "odd-even" number plate restraint scheme).	Low to medium
Car-free measures –cover a range of measures including temporary measures such as car-free days/ locations to permanent measures such as "pedestrianization" of selected streets or districts (Wright, 2004)	Depends on measure implemented and what travel impacts resulted.	Depends on measure implemented and what travel impacts resulted.	Permanent measures tend to work best in defined areas/ situations (e.g., historic city centers) where and when alternative modes are available. Car-free days/events largely symbolic but important for that reason.	Low to high, depending on objectives and scale and specific circumstances.
Local area traffic management–measures are normally implemented to reduce traffic intrusion and	May increase	May increase	Normally implemented for local reasons and require other traffic to divert.	Low negative

Strategy/Measure	Ability to improve energy efficiency (reduce GHG emissions)	Ability to reduce local emissions	Comment	Likely impact in short to medium term
traffic speeds in sensitive areas (e.g., near schools)				
Freight transport management and efficiency measures–to enable more efficient ordering, dispatch, handling, and shipping of goods	Medium to high, where draconian policies affecting truck movement apply. Also, new technology engines and practices–managed load limits with longer multi-axled vehicles to reduce fuel GHG and local emissions per ton-km of freight.	Medium to high	Measures recognizing importance of truck traffic to economy should seek to reduce impacts of congestion on vehicles. Overall costs of freight transport may be more influenced by nontransport costs however (EPS/PAS, 2005).	High in medium to long term. Significant barriers in many developing countries due to high import duties and little industry interest in life-cycle cost. Many truck operators are undercapitalized.
Other intelligent transport systems (ITS)–in addition to traffic signals, incident management systems, other relevant ITS measures include vehicle fleet tracking and advanced traveler information (Sayeg, 2005)	Low. Depends on ITS application.	Low. Depends on ITS application.	Inmore developed cities, Advanced Real Time Information systems offer potential for motorists to optimize their travel to avoid unduly congested areas thus benefiting all traffic.	Low
Public Transport				
Regulation and management–policy, regulatory, andcontractual measures to encourage greater enterprise management efficiency and investment which can also raise operational efficiency and increase environmental performance	Yes	Yes	Potentially high if appropriate regulation (e.g., through contracts for bus services) specifies standards of vehicle and emissions at the outset	Potentially high as buses tend to carry around 50% of all person-trips in cities. Reductions in PM emissions in downtown areas where buses traverse may have a large health benefit.
Bus priorities–traffic management	Yes	Yes	Improvements in speed reduce emissions and may	Low

Strategy/Measure	Ability to improve energy efficiency (reduce GHG emissions)	Ability to reduce local emissions	Comment	Likely impact in short to medium term
measures including bus lanes to speed buses			make bus services more attractive to motorists.	
BRT–extensive application of bus priority techniques which in the most advanced form involves buses traveling in their own exclusive rights-of-way	Yes, through increases in operating speed and service quality to benefit existing bus users and to attract car drivers	Yes	If major diversion from "car driver" can be achieved, even higher benefits can be achieved.	Medium, if politically acceptable and BRT widely implemented
MRT–rail-based mass transit potentially carrying passenger flows in excess of 40,000 passengers per hour per direction and which is segregated from traffic	Yes, through increases in operating speed and service quality to attract car drivers	Yes	If major diversion from "car driver"can be achieved, even higher benefits can be achieved.	Low as even extensive rail MRT systems such as in Singapore and Hong Kong, China typically carry less than 15% of all person-trips. The potential overall impact would be less than BRT as rail is much more expensive.
Road use pricing–charging for road use on a network, area, or zonal basis	Yes	Yes	Network-based pricing as in Singapore offers the best potential as all parts of the network are treated within a single framework.	Medium to high. Political acceptability is a key barrier.
Other fiscal measures (e.g., adjustment of fixed vehicle registration charges to ongoing use charges)	Yes	Yes	Similar benefits to road use pricing but at lower cost	Low to medium

ADB = Asian Development Bank, BRT = bus rapid transit, CNG = compressed natural gas, CO_2 = carbon dioxide, EPS = Economic and Policy Services, EURO = European emission standards, GHG = greenhouse gas, ITS = intelligent transportation systems, PTS = Policy Appraisal Services Pty Ltd., km = kilometer, NO_x = oxides of nitrogen, ppm = parts per million, PM = particulate matter, % = percent.

Source: ADB. 2006. *Transport Energy Efficiency Study*: Final Report. Manila.

【Table 5】 Ranked Scenarios and Identified Barriers and Opportunities

Scenarios	Description	Barriers to Adoption	Opportunities for Implementa
More fuel-efficient vehicle design for new vehicles-15% better over 20 years (Incremental Cost: $NS)	Vehicle technology and design improvements and standards which directly or indirectly improve fuel efficiency of new vehicles by 15% within 20 years.	Few. Depends on rate on which car industry is willing to introduce changes.	Immediate.
Bicycle mode share increases from 1 - 10% (Capital Cost: $58.2M)	Comprehensive improvements to cycling environment such as new and improved cycle lanes and so on to increase cycling mode split from 1 - 10% of all person-trips.	Few from implementation side. Major impediments may be cultural and attitudinal toward bicycle use. Depends also on ability to segregate and free from traffic and pollution. Security and safety may be issues.	Numerous small-scale opportunities in many cities along, across, and in-between roads and along rivers and waterways. Opportunity to create a network of cycle facilities to trigger increased use and utility.
Bicycle mode share increases from 1 - 5% (Capital Cost: $28.8M)	Comprehensive improvements to cycling environment such as new and improved cycle lanes and so on to increase cycling mode split from 1 - 5% of all person-trips.	Few from implementation side. Major impediments may be cultural and attitudinal toward bicycle use. Depends also on ability to segregate andfree from traffic and pollution. Security and safety may be issues.	Numerous small-scale opportunities in many cities along, across, and in-between roads and along rivers and waterways. Opportunity to create a network of cycle facilities to trigger increased use and utility.
Walking mode share increases from 20 - 25% (Capital Cost: $58.2M)	Comprehensive improvements to walking environment such as new and improved sidewalks, car free areas, and so on to increase walking mode split from 20 - 25% of all person-trips.	Few from implementation side. Could be cultural and attitudinal issues. Can be overcome as better quality and better connected walkways, sidewalks, etc. extended. May require controls over vending activities, etc. to keep uncluttered.	Numerous small-scale opportunities in many cities along, across, and in-between roads and along rivers and waterways. A major need is for basic provision of flat, smooth, uncluttered sidewalks that are well maintained.
Road-use charges administrative improvements-2% increase in speed (Capital Cost:$10M)	Adjustment of fixed vehicle registration charges to ongoing use charges.	Few in practice. Main barrier is that approach is new. May impact on national and local funding arrangements.	Can be designed to be revenue neutral. Implementation cost likely to be lower than figure shown. Would build on current administrative practices. Could also be supported by as-you-drive insurance.
Package: BRT 10%, pedestrian upgrades, cycle ways (Capital Cost: $372M)	A combination of BRT attracting 10% of person-trips and walking and cycling measures.	Few in practice. Mainly ability of BRT to capture "minds" of public and politicians.	Combination of that proposed in other relevant strategies.

Scenarios	Description	Barriers to Adoption	Opportunities for Implementa
BRT mode share increases from 0 - 10% (Capital Cost: $250M)	BRT introduced to attract 10% of all person-trips.	Few in practice. Mainly ability of BRT to capture "minds"of public and politicians. Center-of-road BRT as proposed in many cities is unlikely to be feasible or acceptable in many congested downtown areas until a network is in place which can encourage switching from car driver, etc. to BRT.	Center-of-road BRT more easily implemented in uncongested streets and along new roads. A location-specific approach needs to be taken as developing cities vary considerably in wealth and stage of development. A general principle should be that BRT be made as high quality as possible in terms of investment in stations and vehicles.
BRT mode share increases from 0 - 5% (Capital Cost: $126M)	BRT introduced to attract 5% of all person-trips.	Few in practice. Mainly ability of BRT to capture "minds" of public and politicians.	As above for BRT 10%.
Faster traffic speed–5% increase in speed (Capital Cost: $80M)	Traffic management measures designed to increase vehicle speeds by 5%.	Institutional–role of police and their ability to manage traffic. Ability to maintain road infrastructure also an important barrier.	Immediate but institutional issues should not be underestimated. Appropriate intelligent, dynamic traffic control systems are available.
ERP + BRT 10% (Capital Cost: $450M)	Charging for road use on a network, area, or zonal basis plus BRT system carrying 10% of all person-trips.	Political acceptability of charging for road use.	Combination of that proposed in other relevant strategies.
ERP as in Singapore–5% increase in speed (Capital Cost: $200M)	Charging for road use on a network, area, or zonal basis.	Political acceptability of charging for road use.	Toll roads are "acceptable"and many cities have poorly integrated networks of toll roads that could be rationalized. Opportunity to rationalize and provide greater convenience and fairness by comprehensive road use charging.
Elevated rail MRT rather than BRT 5% (Capital Cost: $1,250M)	Elevated rail MRT introduced to at5% of all person-trips.	Few, mainly financial, particularly in poorer cities.	Politically acceptable with main barrier being cost (several times more expensive than BRT). In-road, elevated MRT in narrow roads may have aesthetic and temporary or permanent traffic impacts.
Underground rail	Underground rail MRT	Few, mainly financial	Politically acceptable with

Scenarios	Description	Barriers to Adoption	Opportunities for Implementa
MRT rather than BRT 5% (Capital Cost: $2,500M)	introduced to attract 5% of all person-trips.	particularly in poorer cities.	main barrier being cost (2 to 3 times elevated MRT).

@= Rank on Energy Reduction, B/C = benefit cost, BRT = bus rapid transit, ERP = electronic road pricing, M = million, MRT = mass rapid transit, NS = not significant, $ = US dollar, % = percent. Source: ADB. 2006. *Transport Energy Efficiency Study RSC-C60344 (REG): Final Report.* Manila.

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도시교통시스템에서의 에너지 효율성

권 은 경* · James Leather**

논문초록

교통수단은 에너지 소비에 있어서 가장 중요하고 급속한 증가세를 보이는 요소이다. 2002-2030년 사이에 매년 전 세계적으로 2.1%, 동아시아 및 태평양에서는 4.3%의 증가세를 보일 것으로 예측된다. 교통분야에서의 에너지 사용 증가는 도심 온실가스 방출량의 1/3 이상을 발생시킨다. 아시아개발은행(ADB)은 (i) 환경을 보존하면서 경제 성장을 지원할 수 있는 에너지, 교통, 환경 계획사업 및 그와 관련된 능력 개발 활동 그리고 (ii) 관련된 도전과제와 해결책에 대한 지식 공유를 촉진할 수 있는 아시아 도시들의 맑은 공기 발의안(the Clean Air Initiative)을 통해 에너지 소비 증가로 야기된 당면과제들을 제기하고 있다. 또한 ADB는 영국 국제개발부의 보충자금과, 2005 G8 의 기후 변화에 대처하는 Gleneagles 실행방안(Gleneagles' Action Plan on Climate Change)의 내용에 따라, 아시아 교통분야의 에너지 효율성과 기후 변화를 기술하고 투자를 인도하기 위한 전체적 투자 구조틀 개발에 기여할 수 있는 분석 작업에 착수하였다. 이 논문은 에너지 소비 및 관련된 세계적 방출을 감소시킬 수 있는 교통 계획과 정책 도구들, 그리고 아시아 도시들의 공기 질 훼손의 주범인 교통수단 배기가스 방출에 초점을 맞추고 있다. 이 논문은 ADB가 어떻게 개발도상 회원국들에게 교통수단 에너지 효율성과 지속가능성을 촉진하도록 유도할 수 있는지에 대한 다음과 같은 네 가지 주요 부문을 명시한다. (i) 지식 산출물, 개선된 도구 및 그와 관련된 능력 개발 (ii) 국가적 · 도시적 차원에서 적절한 구조틀을 개발하는 데에 대한 지원 (iii) 국가적 기초에서 양자간 혹은 다자간 기관들의 강화된 협력관계와 공통된 접근법 그리고 (iv) 선도적 실행을 촉진시킬 수 있는 초점화된 투자가 그것이다

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