

*Special Feature on the Environmentally Sustainable City*

# Transport and Environment in Asian Cities: Reshaping the Issues and Opportunities into a Holistic Framework

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Asian cities have witnessed rapid urbanization and an unprecedented rate of motorization in the last decade. Because of this, negative externalities of urban transport such as congestion and environmental impacts have become serious concerns. A number of past studies in this field have shown that health risks are high in key Asian cities, especially from particulate matters and other pollutants for which urban transport is gradually becoming the dominant source. In this context, this paper presents an overview of the environmental implications of urban transport in Asian cities and what is behind them. It also discusses the emerging policy issues and the commonalities and differences in these cities, including discussions of successes and failures and what have been the underlying reasons. Since mitigation of greenhouse gases has become an international concern in recent years, issues and opportunities for mitigation from the Asian urban transport sector are presented. Finally, this paper discusses ASIF (activity, structure, energy intensity, fuel factors), a holistic transport policy framework for cities, and further proposes a broader framework that adds new dimensions to the ASIF framework. This paper shows that such a framework not only provides guidelines to policymakers on where to start on the transport-environment puzzle but also provides a framework to evaluate the implications of various policies on environment and associated factors.

*Keywords:* Transport, City, Asia, Greenhouse gas, Air pollution

## 1. Introduction

The impacts of urban transport on air pollution are evident in Asian cities and have been gradually increasing over the last few decades (ADB 2003). In Japanese cities such as Kitakyushu, Kawasaki, Osaka, and Tokyo, traditional air pollution from industries—sulfur oxides, smoke, and dust—have dramatically declined in the last four decades, but urban transport-related air pollution, in the form of nitrogen oxides, suspended particulate matter (SPM), and others, are increasingly posing serious challenges to policymakers. A similar trend is being seen in rapidly industrializing cities of North Asia such as Beijing and Shanghai and in cities of Southeast Asia such as Ho Chi Minh, Hanoi, Bangkok, Jakarta, and Manila (Dhakal 2004). Due to rapid motorization and reduced competition to private motorized modes of transport, problems that evolved gradually in last 40 years in developed cities are developing in just 10 years in rapidly industrializing cities, making managing air pollution an urgent and heavy burden.<sup>1</sup> In big cities, industries have been slowly but steadily relocating towards the peripheries

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1. For more discussion of the “telescopic time-space compression” of urban environmental issues, see Marcotullio and Lee 2003.

or outside city boundaries. One study shows evidence of a consistent growth of the tertiary sector and decline in primary industry in 22 East Asian cities (Dhakal and Kaneko 2002). Existing key cities are slowly transforming to become more and more commercial in nature. Accordingly, urban mobility is gradually becoming the dominant factor determining urban air pollution.

The demand for mobility has been a constant among human beings and has taken various forms through the millennia. In the Stone Age, mobility was needed to secure safe places and to hunt animals. In the modern age, the demand for mobility is driven by various physical, psychological, and other needs such as work, shopping, education, and leisure. In essence, the reasons remain the same: the desire to access demanded services and to reach service locations. The modern world has two fundamental options; the first is to bring the locations of services such as work, shopping, education, and leisure closer in physical space, thus reducing the need for mobility; the second is to improve the efficiency of travel to dispersed service locations (in terms of physical comfort, travel time, necessary infrastructure, resource consumption, environmental implications, and so forth), without necessarily reducing the need for mobility. The choice does not seem difficult, but cities are simply too complex. Each city has followed its own evolutionary path, which impedes any easy solution because over time, cities have expanded and sprawled, trade within and across the city boundary has flourished, service demand has grown in physical and non-physical senses, and service locations are spread out all over cities and beyond them. With higher population densities, cities become ever more complex to manage, although opportunities exist to maximize infrastructure efficiency and to take advantage of economies of scale.

The purpose of the preceding paragraph was to put the issue of mobility in perspective and to introduce the idea that a fair balance needs to be struck between reducing the need for mobility and improving the efficiency of mobility—over the last few decades, the focus of discussions in urban mobility has shifted disproportionately from *improving access* to *meeting travel demand efficiently*, . . . With the gradual modernization of human society and economic growth, demand for mobility has tremendously increased yet our approaches have not been very successful in reducing the need for it. Cities in Asia are increasingly becoming motorized and are looking for ways to efficiently meet mobility demand using motorized transport modes, which is gradually overshadowing the alternative of reducing the need for transport. Making this distinction is necessary in contemporary policy discussions as public policies need to give fair attention to both of these issues.

The chief negative externalities of rapidly growing urban mobility demand have emerged as congestion and environmental impacts. However, the major issues in urban mobility are not limited to these two dimensions. Daunting challenges lie in providing mobility opportunities in a just and equitable manner, sustaining infrastructure financing, and governing mobility. However, this paper only aims to discuss and present the issues and challenges around providing environmentally sustainable mobility. For this purpose, the paper discusses implications of urban transport and emerging policy issues in Asian cities. It looks at emissions at the level of local air pollution and the global issue of greenhouse gases. It then tries to conceptualize the chains of cause and effect and their driving forces through the ASIF (action, structure, energy intensity, fuel factors) framework, which has been presented by researchers investigating the transport-energy-emissions conundrum (see Schipper, Marie-Lilliu, and

Gorham 2000). This paper draws upon many past research works, successful and failed cases, empirical evidence, and observations in related fields to broaden this framework by including policy tools, temporal, and stakeholder dimensions. This paper does not aim to completely address all the related issues or to be ambitiously prescriptive; rather it aims to be diagnostic and to discuss existing policies.

## 2. Environmental implications of urban transport in Asian cities

### 2.1. At the local level

Epidemiological studies show that air pollution costs thousands of deaths and leads to a number of health problems in cities. This results in added healthcare costs and loss of productivity. The pollutants linked to urban transport that are typically health concerns are lead (Pb), dust (due to re-suspension), particulate matter (PM), oxides of nitrogen (NO<sub>x</sub>), and volatile organic compounds (VOC).<sup>2</sup> Photochemical oxidant (ozone), another important pollutant, forms from NO<sub>x</sub> and VOCs in the presence of heat and sunlight. Of course transport is only one of the contributors to urban air pollution. But as household cooking switches to modern fuels (natural gas, liquefied petroleum gas, electricity); lower-quality industrial fuels like lignite, low-grade coals, and dirty heavy diesel are replaced by cleaner coals or oils and natural gas; and industries are moved out of cities, the role of transport grows dramatically. One important difference is that stationary sources of air pollution are easy to spot and regulate, and they often cause annoyances to the polluters themselves, while mobile sources like vehicles are harder to spot and regulate, and rarely cause annoyances directly to the polluters.

The impacts from these pollutants are very much location-specific in cities; the more dispersed impacts of carbon dioxide emissions are dealt with later on in this section. Before the phasing out of leaded gasoline, lead was a major health issue. In Bangkok, studies estimated 400 additional deaths per year due to lead's effect (Michaelowa 1997). Several other studies have shown the costs of air pollution in cities. The UrbAir study by the World Bank, conducted in Greater Mumbai, Kathmandu Valley, Jakarta, and Metro Manila, found that urban transport accounted for the majority of air pollutants and the health impacts costs millions of dollars (Shah and Nagpal 1997). Another World Bank study, on Mumbai, Shanghai, Manila, Bangkok, Krakow, and Santiago, showed that the total social cost of air pollution in these cities was as high as US\$(1993)2.6 billion (Lvovsky et al 2000). One 1998 study of Delhi, where the transport sector accounted for over 70 percent of air pollution, suggested that 7,500 premature deaths, 4 million hospital admissions, and 242 million incidences of minor sickness could be avoided if air pollution were brought within World Health Organization (WHO) suggested levels (Xie, Shah, and Brandon 1998). A recent report by the Asian Development Bank stated that in Asian cities, SPM and PM<sub>10</sub> (particulate matter below 10 microns) levels in particular were higher than WHO limits and US Environmental Protection Agency (USEPA) 1997 limits respectively (1990–1999 average, citing WHO's Air Information Management Database). The report showed that SPM concentrations in Shanghai, New Delhi, Mumbai, Guangzhou, Chongquin, Calcutta, Beijing, and Bangkok exceeded WHO limits (90 µg/m<sup>3</sup>) by three, five, three, three, four, four, four, and two times respectively (ADB

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2. There are a few other pollutants, such as carcinogens like poly-nuclear aromatic hydrocarbons and aldehydes.

2003). It also showed that  $PM_{10}$  exceeded the USEPA limit ( $50 \mu\text{g}/\text{m}^3$ ) by several times in a number of cities, most notably over four times in New Delhi and Calcutta. Similarly, a benchmarking report of the Air Pollution in Mega-cities of Asia Project<sup>3</sup> shows that  $\text{NO}_x$  and particulate matters are a serious challenge for Asian cities (Air Pollution in Mega-cities of Asia 2002). Data from Tokyo shows that SPM increased rapidly from  $40 \mu\text{g}/\text{m}^3$  in the early 1980s to over  $70 \mu\text{g}/\text{m}^3$  in the early 1990s; after that SPM has been decreasing or stagnating, but it is becoming increasingly challenging to contain SPM and  $\text{NO}_x$  (Tokyo Metropolitan Government 2004).

All of the above reports show that SPM,  $PM_{10}$ , and  $\text{NO}_x$  are particularly problematic, and the transport sector is one of the major contributors of these pollutants. It is important to note that the health impacts are determined by dose response of the pollutant concentration to the exposed population; ironically, policies in many Asian developing countries are driven by emissions estimates that are reasonable but less efficient. Apart from local air pollution, growing motorization takes a significant toll on traffic flow. In many cities, income is rising but the pace of improvements in efficiency of public transport, especially mass transport systems, has been slow. As a result, Asian cities such as Bangkok, Jakarta, Beijing, Manila, Delhi, and Kathmandu are increasingly dominated by personal lower-occupancy vehicles, exacerbating congestion and pollutant concentrations. Such problems are further aggravated by lack of expansion and improvement of roads. The new challenges facing policymakers now demand mitigating not only air pollution but also congestion.

## **2.2. At the global level**

Many of the issues linked to urban transport revolve around energy use. Oil supply is a major factor in world politics, while rapid motorization threatens energy security. There is a general consensus that oil is going to remain a major transport fuel, and that the world has to confront the environmental implications oil-based transport, for at least the next three to four decades. The latest figures indicate that oil accounts for more than 95 percent of total energy use in transport in almost all Organisation for Economic Cooperation and Development (OECD) countries (Fulton 2001). The situation in Asian cities is little different. Energy use in oil-based urban transport has dramatically increased in Asian cities owing to rapid motorization. In Ho Chi Minh City, the share of transport in total energy use stands at 20 percent. In commerce-dominated cities such as Tokyo and Seoul, the share is well over 35 percent. The rate at which the share of transport in energy use is growing has been phenomenal, too. While in the rapidly growing megacities such as Beijing and Shanghai, the transport sector's share in total energy consumption stands at only seven to nine percent (Dhakar 2004), it doubled between 1990 and 2000, as did the share in Delhi. Energy use by the transport sector has even continued to increase moderately in relatively mature cities such as Tokyo (by a quarter) and Seoul (by a half).<sup>4</sup>

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3. The Air Pollution in the Megacities of Asia (APMA) project was initiated in November 2000 by the United Nations Environment Programme and the WHO in collaboration with the Korea Environment Institute and the Stockholm Environment Institute.

4. Based on presentations by a number of local experts at the International Workshop on Policy Integration Towards Sustainable Urban Energy Use for Cities in Asia: Integrating Local Air Pollution and Greenhouse Gas Emissions Concerns, organized by IGES, 28–30 January 2004, Kanagawa, Japan. For details see [http://www.iges.or.jp/kitakyushu/megacity\\_workshop/index.htm](http://www.iges.or.jp/kitakyushu/megacity_workshop/index.htm).

There is some speculation that vehicles powered by hydrogen fuel cells will evolve in the foreseeable future, but major questions remain over how long this will take and how the hydrogen will be obtained. Fuel-cell systems will definitely be more efficient than the internal combustion engine (ICE) but costs, energy loss, and greenhouse gas emissions in production of hydrogen will determine their real benefits. Some researchers argue that even if hydrogen fuel-cell automobiles became cost-effective today (they are still in the stage of technology development), it would take 50 years before we see improvements in air quality, if we take into account the time required for design, technology refinement, cost reduction through economies of scale, development of supporting infrastructure, marketing, and penetration of the existing fleet.<sup>5</sup> Heywood and Bandivadekar (2003) show that the new technology must account for over 35 percent of new vehicle production and over 35 percent of total mileage driven to have an impact. Penetration into the fleets of the cities of developing Asian countries will take even longer than in the developed economies of the world.

After the Rio Earth Summit, the issue of climate change has been gaining momentum in political, scientific, and all other sectors. The recent ratification of the Kyoto Protocol by Russia has paved the way for the protocol to enter into force in early 2005. Now Annex-I countries<sup>6</sup> are obliged to fulfill Kyoto commitments, and instruments such as the Clean Development Mechanism, joint implementation, and carbon trading will be operational. The role of cities, and especially of urban transport, will be very important because they are major emitters of greenhouse gases.

In a recently published report entitled *Mobility 2030: Meeting the Challenges to Sustainability*, the World Business Council for Sustainable Development (WBCSD) estimated that worldwide transport-related greenhouse gas emissions (well-to-wheel, including air, water, and road transport) would increase from slightly over six gigatons of carbon dioxide (CO<sub>2</sub>)-equivalent in the year 2000 to over 14 gigatons by the year 2050. It also showed that light-duty vehicles were responsible for the majority of emissions, followed by freight trucks and air transport (WBCSD 2004). The International Energy Agency estimates that road transport accounts for the majority of global CO<sub>2</sub> emissions from the transport sector. Road transport alone contributed some 18 percent of the world's total CO<sub>2</sub> emissions from fuel combustion in the year 2000 (International Energy Agency 2002). In OECD countries, this share stands at 23 percent, less in developing countries. At city level, a study carried out by the Institute for Global Environmental Strategies showed that the transport sector contributed only between five and 10 percent of CO<sub>2</sub> emissions from fuel combustion in Beijing and Shanghai in 1985–2000, but the rate of growth was over 10 percent and was accompanied by high levels of PM<sub>10</sub> and NO<sub>x</sub> and by congestion (Dhaka 2004).

The WBCSD study also projected that CO<sub>2</sub> emissions from each mode of transport and each region would increase, with the majority of the additional growth coming from developing regions of the world. It showed that the volume of vehicle activity was a major problem. For example, the drop in energy consumption achieved by improving the energy efficiency of light-duty vehicles and heavy-duty trucks

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5. Personal communications with Prof. John Heywood, Professor of Automotive Science, Massachusetts Institute of Technology, during the OECD Ministerial Roundtable on Sustainable Mobility, September 2004.

6. Developed nations listed in Annex I of the UN Framework Convention on Climate Change.

(by 18 and 29 percent respectively between 2000 and 2050, which is the only expected reducing factor for emissions) would not be able to offset the increase from the projected 123-percent and 241-percent growth in use of these types of vehicle.<sup>7</sup> Indeed, this trend explains why in some cities, for example Mexico City, dramatic improvements in new car emissions have failed to lead to a dramatic improvement in air quality—too many daily travelers are shifting from large buses to cars and minibuses (Schipper and Golub 2003).

The WBSCD report states that China and India alone surpassed the transport-related emissions from the rest of Asia due to their size and rapid rate of motorization in the year 2000, and will continue to do so in 2050. The report assumes that the role of public transport will be undermined by private modes of transport, but it brings the following issue to the forefront: the present need to cope with growing motorization and to find solutions to increasing CO<sub>2</sub> emissions through air-pollution mitigation, energy saving, and congestion mitigation in dense and growing Asian metropolises.

Asian cities, unlike North American and European cities, tend to become denser and to sprawl towards their peripheries. This sprawling can lead to the creation of largely unorganized peri-urban areas that stretch the distribution and transport systems of the city. The emergence of Bangkok's peri-urban areas and Beijing's construction of 14 satellite towns outside its Fifth Ring Road may put additional burdens on these cities if urban functions are not well allocated. On the other hand, the trend of cities to become denser may be desirable from a number of viewpoints, such as higher utilization of urban infrastructure, cost-effectiveness of public transport systems, and compact distribution and supply networks for energy and other services. However, as cities become denser, management challenges increase, especially for air pollution from motor vehicles, congestion, and management of other urban environmental services such as water supply, wastewater, and solid waste disposal.

Recent estimates by the UN Population Division suggest that about half of the megacities (over 10 million population) and medium-sized cities (over 1 million population) worldwide will be in Asia by 2015 (UN 2002). This will certainly mean a huge rise in CO<sub>2</sub> emissions from Asian countries for the reasons already discussed. Sustainable mobility in Asian cities will require an appropriate balance of private and public transport (including mass transport systems) that takes into account air pollution (local and CO<sub>2</sub> emissions), energy saving, and congestion. Although safety, equity, financial stability, and other issues are also prominent in the sustainability-mobility debate, the authors believe that congestion, emissions, and development of public transport (in particular mass transport) will pose more serious challenges than any other issues in the next 20–30 years. The WBSCD study cited above (WBSCD 2004) also supports this argument, as its modeling results indicated that transport-related conventional emissions will decline sharply in OECD countries over the next two decades, while in non-OECD countries lead, carbon monoxide (CO), and VOCs will gradually decrease during this period, but NO<sub>x</sub> and PM<sub>10</sub> will not start to decline for another two decades.

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7. These are global averages. There are variations from region to region.

### 3. Emerging policy issues in Asian cities: commonalities and differences

#### 3.1. Underlying issues

Global and regional discussions of transport and environment policy often show too generalized pictures. These discussions often discount the vast differences that exist amongst cities, countries, and regions. While there are certainly issues that are common to many or all cities, there are also significant differences that can be presented from a number of viewpoints.

##### a. Motorized and non-motorized transport

One of the commonalities between cities is the diminishing role of non-motorized modes of transport. Travel patterns in the USA are dominated by automobile use, while non-motorized modes still account for the largest share of transport use in China (about 40 percent in Beijing and Shanghai). Historically, walking and bicycling have been declining and travel demands are shifting towards faster modes. However, there have been numerous attempts to revive non-motorized modes in certain places. Contrary to the general image of North America, the city of Boulder, Colorado in the United States prides itself upon being a bicycle-friendly city in which any part can be accessed through dedicated cycle lanes. However, the example of human-powered tricycles in Dhaka shows that non-motorized modes do not always produce desirable solutions if they are not well managed, especially if they are mixed with other modes of travel, adding to congestion. Even in Shanghai, bicycles are banned on major roads to reduce congestion.

##### b. Infrastructure issues

Another commonality amongst Asian developing countries is the shortage of road infrastructure in relation to vehicle numbers. For example, the total road length in Beijing nearly doubled in 1979–1999, but vehicles increased by 17 times (He, Zhang, and Huo 2004). The number of vehicle per kilometre of road length (note: not area) in Beijing is over 350, compared with about 200 in Tokyo and about 130 in Shanghai (all figures for the year 2000; see Dhakal 2004). There is, in most cities, a gap between travel demand and transport infrastructure, which is not only limited to normal roads but to expressways, railways, and other modes of travel.

With rising incomes and delays in development of mass transport systems, an increasing number of cars has become a major problem for cities such as Bangkok, Delhi, and Beijing, while in Delhi, Kathmandu, Karachi, and Dhaka, a surge in two-wheelers (motorcycles and mopeds) in addition to cars is choking road networks. To counter the growth of private modes of transport, development of mass transport is essential, but it requires long-term planning. In recent times, some cities have been planning aggressive development of rail-based mass transport systems; for example, Bangkok's expressways and its Bangkok Transit System Skytrain and subway; Delhi's subway; and Beijing's expressways and subway expansion plans to prepare for the 2008 Olympics. This has confronted them with another common challenge: procuring infrastructure financing. Bangkok's failure to build its MRTA subway planned in 1976 and subsequent failure to realize the Hopewell Project (combined MRT and expressways) is generally attributed to financing-related difficulties. In the least-developed countries especially, infrastructure financing is challenging owing to cost-recovery problems. There has been a

trend towards public-private partnerships in the infrastructure sector in recent years. For such mechanisms to work, a sound system needs to be in place that allows the private-sector partners to recover their investments and to reduce the investment risks. Most cities in Asia are still struggling to create appropriate environments for private-sector investment.

Per capita ownership of vehicles in developed cities such Tokyo and Seoul has already reached saturation (2.8 and 4.5 people per vehicle, respectively, in 1999). Per capita vehicle ownership, especially for cars and light-duty vehicles, in Beijing, Shanghai, Bangkok, Jakarta, Manila, Delhi, and Kathmandu, is well below that in OECD countries or Tokyo (people per vehicle for Beijing was 13, for Shanghai 34 in 1999). However, the rate of increase in vehicle ownership in these cities is high (Dhakal 2004). It is also enough to sound alarms given the prevailing levels of air pollution and congestion. The rates of motorization at prevailing household income levels in these cities are higher than at similar levels in Seoul or Tokyo in the past. Only very few cities have tried to cap vehicle numbers as a part of government policy, notably Singapore and Shanghai. Very few have tried to put any direct restrictions on vehicle use besides Singapore; Hong Kong tried in 1983–85 in a pilot scheme that was later dropped (Dhakal 2004).

### **c. Vehicle mix**

Traditionally, analyses of urban transport have looked only at private cars; however, examining the role of two-wheelers is essential to understand motorization in Asian developing countries. Asia accounts for 75 percent of the two-wheelers in the world. China and India alone account for 50 and 20 percent respectively in it (WBCSD 2004). Two-wheelers in Chennai, Shanghai, and Wuhan account for 80 percent of those cities' total vehicle fleets. They account for 50 percent in Mumbai, over 65 percent in Kathmandu, and 40 percent in Kuala Lumpur (WBCSD 2004; Dhakal 2003a).

Two-wheelers are among the most polluting vehicles in the world. Among two-wheelers, two-stroke engines, which dominate fleets in South Asia and much of Southeast Asia, have inferior emission performance since 15 to 40 percent of the fuel-air mixture escapes from the engine through the exhaust port. Poor vehicle maintenance, misuse of lubricants, and adulteration of gasoline exacerbate emissions from two-wheelers (Kojima, Brandon, and Shah 2000). In recent years, there has been an increasing trend toward banning two-stroke two-wheelers for environmental reasons from key cities in Nepal, India, Thailand, and Bangladesh. Shanghai has already banned two-wheelers from major roads. Yet two-wheelers continue to make substantial contributions to air pollution and create traffic chaos in cities.

Two-wheelers skew the perception of motorization too. The WBCSD report notes that when motorized two-wheelers are considered, Mexico City's motorization becomes lower than Chennai's while its per capita income is 10 times higher than Chennai's. In India, two-wheelers are cheap (about US\$200 for a moped or scooter), and as incomes rise, a much larger proportion of the population can own one, which drives the motorization process (WBCSD 2004). Delhi, with US\$800 per capita income, has 120 two-wheelers per thousand population, while Shanghai, with US\$4,000 per capita income, has only 60 two-wheelers per thousand (WCTRS 2004). Vehicle ownership in some Indian cities, Kuala Lumpur, Hanoi, Taipei, and Ho Chi Minh City leaves roughly every household with a private vehicle,



most likely a two-wheeler. It should be noted that real purchasing power in Asian countries is much higher than it looks when per capita incomes are converted into other currencies. Based on purchasing power parity, the per capita GDPs of China and India are closer to four and five times respectively what they are in dollar terms (World Bank 2004). In short, the spread of two-wheelers, for better or worse, has afforded a high degree of individual mobility in urban areas, a level that may be hard to reverse with buses and rail. However, only Asia seems to be inundated by two-wheelers, which are largely absent in other developing regions of the world such as Latin America and Africa. This phenomenon can be attributed to economic protectionism, topography, security, and socio-cultural factors, among others (WCTRS 2004).

Besides the prominence of two-wheelers, the modes of public transport in developing Asian countries are more diverse than in developed countries. In Tokyo and Seoul, modes of transport are largely limited to cars, taxis, buses, surface rail, and subway, while in India, two-wheelers, motorized three-wheelers, bicycles, pedi-cabs, and animal-pulled carts share roads with buses, taxis, and cars (WCTRS 2004). This means there is a wider variety of stakeholders in urban transport bringing more complexities; poverty, equity, political, and social dimensions are all mixed up with transport problems. Looking at the different travel modes and their shares, private transport's modal share in Asian cities is much smaller than it is in developed parts of the world (WCTRS 2004, chapter 2). This brings in the issue of how to avoid the mistakes of developed countries, especially those of North American cities, and how to develop congestion-free and pollution-free transport systems in Asia.

#### **d. Technology issues**

From the technology side, mitigating air pollution from vehicles does not necessarily require further innovations; existing technologies can play a substantial role in achieving this. Since the majority of Asian countries are adopting existing technology rather than creating new technology, one of the central tasks in developing urban transport is finding and utilizing the right technologies to improve emission performance on the streets.

Almost all past studies in the field of vehicular pollution control in Asia have emphasized improving inspection and maintenance systems for vehicles in use (for example, ADB 2003; Faiz, Weaver, and Walsh 1996; Gorham 2002; Kojima, Brandon, and Shah 2002; Kojima and Lovei 2000; Schipper, Marie-Lilliu, and Gorham 2000; Shah and Nagpal 1997; Xie, Shah, and Brandon 1998). This requires improving enforcement mechanisms to ensure high operating fuel efficiency and meeting existing emissions standards. In some cases, such as New Delhi, a complete change in fuel choice (from diesel to compressed natural gas (CNG) for all public transport vehicles) has taken place, with one of the strongest arguments in its favor being that it requires a less stringent inspection and maintenance regime. In Mexico City, private-sector operation of inspection and maintenance systems is being tried (Kojima and Lovei 2001). In Singapore, a scheme of certifying automobile workshops is in place. In Jakarta, computerized inspection and maintenance for non-complying vehicles is being trialed. For new vehicles, at least Euro 1 (European Union Emissions Standard 1) or higher emissions standards have already become the norm in a number of Asian countries (ADB 2003). In India, higher standards for selected cities are being enforced: Delhi, Chennai, Mumbai, and Kolkata introduced Euro 2 in 2001 and Euro 3 is

targeted for 2005 (ADB 2003). Despite the introduction of these standards, inability to phase out decades-old vehicles and non-compliance with emissions standards among both new and old vehicles remain key barriers in many Asian cities.

Studies have reported that information technology can greatly help to reduce congestion. Computerized signal-coordination systems are in place in a number of cities, such as Tokyo, Singapore, and Hong Kong. Dhakal (2004) shows that Singapore's taxi-calling system and electronic road pricing, which use the global positioning system (GPS), have been effective in curbing congestion.

End-of-pipe technologies for gasoline and diesel vehicles, such as three-way catalytic converters and particulate traps, may help to curb local air pollution but they are not effective for reducing greenhouse gases. At vehicle level, greenhouse gas emission can be reduced through energy-efficiency improvements or fuel choice (see a series of reports published by the Pew Center between 2001 and 2003, especially Sperling and Salon 2002). If altogether new vehicle technologies or fuel types are used, only lifecycle analyses can ascertain their overall greenhouse gas emissions. One such study done at the Massachusetts Institute of Technology showed that diesel could help the United States to cut greenhouse gases, but stringent diesel emissions standards for NO<sub>x</sub> and particulate matter threaten this (Weiss et al. 2000). The WBCSD report cited above (WBCSD 2004) provides detailed analyses of various technologies and their well-to-wheel greenhouse gas emissions. It shows that propulsion systems using bio-fuels such as ethanol and bio-diesel have negative well-to-wheel emissions. Hydrogen fuel-cell vehicles have zero tank-to-wheel emissions, but total emissions depend on the source of hydrogen.

### **3.2. Policy and institutional issues**

#### **a. Successes, and the underlying reasons**

Despite the enormous challenges to policymakers in developing environmentally sound transport sectors, there have been successes in a number of areas in Asia. One successful case is the removal of lead from gasoline, which was used as an octane enhancer. Thailand, Bangladesh, India, Nepal, and other countries in Southeast and North Asia have already phased out leaded gasoline successfully. While this process took decades in the early days, for example almost three decades in the United States, Thailand took four to five years to completely phase it out, while Bangladesh took less than a year (Kojima and Lovei 2001).

The second area where significant progress is being made these days is quality of diesel, which is usually determined by its sulfur content. In Japan, distribution of diesel containing less than 50 parts per million (PPM) of sulfur started in 2003 (Dhakal 2003b). Progressively, developing Asian countries are aiming to adopt Euro 2 standards, which essentially require lower than 500 PPM sulfur in diesel. Together with diesel improvements, increasing use of CNG as a substitute for diesel is taking place in cities where CNG is available at reasonable cost. Judicial interventions in Delhi have mandated CNG substitution of diesel for public buses and taxis. A number of other cities are showing increasing interest in CNG as a substitute for diesel to reduce NO<sub>x</sub> and PM<sub>10</sub> levels in the air. However, at the same time, a vigorous debate is taking place, with more people supporting not mandating specific technologies or fuels in cities and instead setting emissions standards regardless of fuel choice. Internationally, Europe is championing the use of low-sulfur diesel and views diesel as a potential fuel for CO<sub>2</sub> mitigation.

Small interventions can play important roles in driving policy in positive directions. There are many examples. One is the successful replacement of smoke-belching diesel three-wheelers by battery-powered electric three-wheelers in Kathmandu in the late 1990s. Kathmandu had had some of the worst air pollution in the previous few years. Since electricity there comes from hydroelectric plants (run-of-river type), use of the new vehicles reduced local pollution as well as greenhouse gas emissions (Dhakal 2004, appendix 2). Jakarta's computerized vehicle inspection and maintenance system (which comes under its Blue Sky Program) is another successful example which closes the loopholes in the inspection and maintenance regime for potential free riders. Successes in controlling two-stroke two-wheelers in South Asian cities are also significant, as these have posed serious air pollution problems for a long time.

Singapore's success in integrating land-use and transport planning is well documented (Lye 2002; Menon 2002; Willoughby 2000). In addition, Singapore's vehicle quota system limits the stock of registered vehicles while congestion charging limits their use (Dhakal 2004 appendix 1). The current debate in Singapore is how to maintain a sound balance in restricting vehicle stocks and congestion charging, because financial resources from the auctioning of vehicle quotas and road pricing exceed what is needed for infrastructure development. There is also disagreement about whether a similar approach would work in other cities, as Singapore is in several ways a unique case. The potential reasons for Singapore's successes are described in box 1. In the past, governments in Thailand, Malaysia, and Indonesia have rejected the results of various studies favoring road pricing as implemented in Singapore, saying that it was locally not feasible. Hong Kong implemented electronic road pricing in the early 1980s on a pilot basis and later scrapped it. However, recent experiences in London and a number of European cities have inspired renewed debate about its feasibility and utility.

Outside Asia, the integrated planning of land use and the bus system in Curitiba in Brazil has been successful. It uses an express-bus system with 58 km of exclusive bus lanes, coordinated with residential and commercial development, with diminishing density of settlement and well-designed road systems (Matsumoto 2003). This does not mean that bus rapid transit (BRT) systems cannot be implemented in already well built-up cities. Bogotá's BRT system is a successful experience in bus-based mass transportation (Matsumoto 2003). Experiences with BRT are few in Asian cities, although one was recently implemented in Jakarta (12.9 km). However, interest in BRT is increasing owing to its less capital-intensive nature and because BRT systems can be implemented in already built-up cities, with proper management.

What determines the success of integrated land-use and transport planning, and of mass transport systems such as BRT and rail, is difficult to say, as each city has unique characteristics. The case studies done at the Institute for Global Environmental Strategies for a wide range of cases dealing with urban transport and emissions suggest that major factors for success are the following:<sup>8</sup>

- Political will and leadership for environmentally friendlier infrastructure development;
- A sound mixture of technology, management, and investment strategies;

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8. The detailed report and case studies are available at <http://host-3.iges.or.jp/APEIS/RISPO/inventory/db/index.html>.

- Right use of economic and fiscal instruments such as single fare-pricing systems for public transport, vehicle taxation, and congestion charging;
- Organizational arrangements for emissions and transport management, especially efficient division of labor and rules for operation in the organization;
- Stakeholder-based planning processes; and
- Capacity to enforce regulations.

#### **b. Failures, and the underlying reasons**

Unfortunately, unsuccessful cases are far more abundant than successes in Asian cities. The most important failures have been in controlling the numbers and use of vehicles in the majority of cities. As a city develops and its income grows, its car ownership and investment in normal roads and expressways both also increase. Often, development of expressways and normal roads is more demanded than providing solutions to congestion and emissions. Experiences in the United States show that the gains from improving fuel economy standards for individual vehicles are exceeded by increases in mileage traveled, attributed largely to needs and behavioral factors. (Fortunately, financial savings from fuel efficiency have not greatly increased travel demand, because fuel is relatively cheap in the United States (Greene and Schafer 2003).) This phenomenon is often referred to as the “rebound effect” (*Energy Policy*, special issue, June 2000).

#### **Box 1. Why did integrated land-use and transport planning work in Singapore?**

Integrated city planning is the keyword in Singapore's success. All the measures it has introduced are part of a comprehensive strategy and are coordinated very closely to produce a comprehensive solution. No single measure can work alone. The right to travel is a basic human right; however, government policies can offer options that encourage travelers to choose modes that are both sustainable in the long term and acceptable to residents. When electronic road pricing (ERP) was implemented in Singapore, commuters had five choices: (1) pay the charges and drive freely, (2) change the time of travel to pay lower charges, (3) use alternative roads, (4) use public transport, or (5) use other schemes, such as park-and-ride (Menon 2002).

Singapore's success also comes in the context of favorable economic, social, and urban conditions. The small size of both the land area and the population has allowed flexible planning. As a city-state, Singapore has only a single tier of government; thus, all the complexities that can arise from multiple layers of authority and a mismatch between local and national priorities are eliminated. The economy of Singapore relies heavily on foreign investment and on transactions related to international trade, commerce, and finance, for which efficient transport and communications are essential. The need to fulfill this condition for economic reasons has contributed to sustainable transport development and concern for the environment. Unlike in other countries, where economic growth is curbed by environmental countermeasures, economic growth in Singapore was actually fostered by improvements in environment and transport.

Box 1—*continued*

A strong government and stable and strong regulations and institutional frameworks for enforcement are other reasons why travel-demand management has worked in Singapore. From the point of view of jurisdiction, the roles and responsibilities of authorities responsible for urban and land use planning, land transport, and environment are clearly demarcated. The land reform process initiated in 1967 allowed the government to acquire most of the land and the housing estates subsequently developed on the city's periphery, and facilitated the development of infrastructure suitable for sound land-use planning. The Housing Development Board (HDB), which was set up in 1960 by the British colonial government, provided housing to just 9 percent of the population in 1960. Because the sweeping powers of the Land Acquisition Act enabled the government to acquire private land for public housing or other development activities, today 85 percent of the population lives in HDB housing complexes.

Another reason for Singapore's success is the periodic adjustment of policies using feedback from the public and other stakeholders, made possible by transparency in policy formulation. Singapore has learned by doing. It recognizes that policies are never perfect and provides for periodic adjustments. For example, ERP charges are subject to review every three months, and charge structures and times change depending on traffic and economic conditions.

Another key to success has been investment in infrastructure. Demand-side management was supplemented by constructing additional road infrastructure, maintaining roads well, coordinating traffic-light systems, and building expressways and MRT. The taxes and fees imposed on vehicles generated huge financial resources, which were used not only invested in demand- and supply-side management but also applied to reducing less-desirable taxes. Willoughby (2000) estimated that annual revenue from road transport was at least three–four times greater than road expenditure.

Some technology factors have also played important roles in Singapore. ERP, for example, depends on sophisticated technology that allows time-of-day pricing which reflects traffic conditions. Its prototype Area Licensing System, in contrast, was a non-technology measure. A computerized traffic control system was already in place by 1986 in central business districts. It was replaced with a more advanced automated traffic signaling system called GLIDE (for "Green Link Determining System"), a traffic-adaptive signal control system monitored centrally to adjust to changing traffic conditions. Efforts are now being made now to create a Global Positioning System (GPS)-based coordinated public taxi-calling system which dispatches taxis automatically from the nearest location. Individual taxi operators are already using GPS. These high-technology measures have provided support to non-technology restrictions on car ownership and use. Some researchers, however, claim that the overall effectiveness of high-technology measures is questionable.

A final reason for the success of Singapore might have been the fact that it is a migrant society with citizens who originated from many countries. Since most were economic migrants in the first place, their opposition to government policies was minimal. Thus, there were no barriers in the form of an organized force of resistance.

*Source:* Dhakal 2004.

Another area of failure of most cities (with Singapore a notable exception) is integrating urban and transport planning. The rates of urbanization in Asian cities are much higher, but planning mechanisms are much weaker, than in other regions of the world (World Bank 2004). Dense Asian cities had developed haphazardly without serious infrastructure planning in the past. Carrying out effective land-use planning for already built-up cities is a difficult task, especially when developing-country governments have scant financial resources and no ownership of land. For more downstream issues such as promoting public/mass transport and emissions standards, the experiences of cities are a combination of failures and successes, from case to case. Broadly, the major reasons for failure of policies in cities of developing countries can be summarized as follows:

- Policy inadequacy: Over-dependency on end-of-pipe solutions and short-term measures; failure to see long-term perspective and accompanying mechanisms; and overwhelmingly negative rebound effects of poorly formulated policies;
- Weak enforcement of existing standards and regulations: Weak inspection and maintenance systems for energy and emissions performance of vehicles;
- Transport and poverty: Complex interrelationship between transport policies and the interests of low-income groups, and little political will to touch this sensitive area;
- Resource constraints: Limited financial and technical resources; and
- Institutional failures: Lack of political will and commitment; lack of management capacity; wrong market signals; and inter- and intra-institutional coordination problems, such as unclear demarcation of authority and responsibilities.

### **3.3. Harnessing local-global benefits: Their synergies and conflicts**

As outlined earlier, mitigating greenhouse gas emissions from the rapidly growing transport sector is essential for the future. Given that the Annex-I nations are still struggling to achieve this, very little is expected from Asian cities. The challenges for Asian cities' policymakers in mitigating greenhouse gases from urban transport range from raising awareness, overcoming resource constraints, and obtaining scientifically sound research and information (Dhakal 2004).

Although cities do not fall into obvious groups, for the sake of highlighting the priorities and differences that affect emission policies Asian cities can be divided into the following three categories:

*Developing cities:* In these cities, the capacity and authority of local policymakers are weaker, resources are scarce, institutions for urban environmental management are less developed, policy-enforcement mechanisms are weaker, the involvement of stakeholders in decision making is less evident, local pollution issues are the priority, and problems are often intricately interwoven with poverty issues. A number of cities in South Asia and Southeast Asia could come into this category, for example Dhaka, Kathmandu, Delhi, Calcutta, and Karachi.

*Rapidly developing/industrializing cities:* In these cities, the capacity of local policymakers is improving rapidly, resources are scarce but starting to build up locally, local institutions are being built up, and while local issues still receive the most attention, there is growing awareness among urban

policymakers of the need to consider emerging issues such as global warming. Beijing, Shanghai, and Bangkok, among others, may belong to this category.

*Relatively developed/mature cities:* In these cities, conditions are better than in the rest of Asia and local governments are under growing pressure to tackle emerging global environmental issues. However, these cities still struggle with finer particulate matter and ozone pollution, and their standards are very stringent compared with those in cities in the other categories. Cities in Northeast Asia, including Japan's cities and key Korean cities, could be examples.

Policymakers in developing countries still view greenhouse gas mitigation as a diversion from their immediate needs and as a barrier to economic growth. The keys to changing such perceptions are to link greenhouse gas mitigation with clear local benefits such as reduced air pollution and energy saving and to facilitate transfer of financial resources from developed countries to developing countries for local benefits (Kojima and Lovei 2001). However, developing integrated policy responses for reducing air pollution, promoting energy efficiency, and mitigating greenhouse gas emissions is an easy task. Energy-efficiency improvement in particular provides an easy entry point for such an integrated response (OECD 1995). In developed countries, while the level of motorization is unparalleled, improvements in the fuel economy of vehicles have played a major role in suppressing air pollution (Kojima and Lovei 2001). Another common entry point for an integrated response is mitigating traffic congestion, which increases vehicle speeds and potentially reduces fuel consumption and emissions. Some studies have reported that an increase in traffic speed from 10 to 20 km/h can cut 40 percent of CO<sub>2</sub> emissions (Kojima and Lovei 2001).

While there is optimism, studies from Mexico and Chile have shown that locally favored options do not always match greenhouse gas mitigation objectives and so the global benefits are limited (Eskeland and Xie 1998). The example of Tokyo is also salutary. In Tokyo, vehicle growth has almost stagnated, vehicles miles traveled are largely unchanged, and there are continued fuel efficiency improvements in all sizes of vehicles. However, CO<sub>2</sub> emissions from transport are still rising in the city, primarily because car owners are progressively shifting towards bigger cars. The conflict between local and global priorities becomes even more evident as NO<sub>x</sub> and SPM pollution remain major issues in Tokyo requiring interventions to control diesel vehicles, which have lower greenhouse gas emissions (Dhaka 2003b). A close look at Asian developing countries shows that technology fix at car tailpipes is a common solution to air pollution problem, but this has no effect on greenhouse gas mitigation. In reality, the precise impacts on greenhouse gas emissions of those measures that are best suited to mitigate priority air pollutants have not been much studied, and their synergies and conflicts are largely unexplored in practice.

Table 1 provides a rough sketch of the potential synergies and conflicts between local pollution and greenhouse gas mitigation measures. The first steps for any integrated approach (apart from fuel efficiency and average vehicle speed improvements) are to identify the impacts and to encourage policymakers in developing countries to implement reasonable measures, providing them with financial tools, for example through the Clean Development Mechanism and/or other multilateral and bilateral

mechanisms. This cannot be achieved without strong will among international institutions and developed countries to involve themselves in developing countries' local environmental problems.

**Table 1.** Indicative synergy and conflicts of local pollution mitigation measures for greenhouse gas mitigation

Local countermeasures	Synergy with global concerns	Conflicts with global concerns
Introducing CNG or propane as fuels	CNG has been introduced for air quality improvement in cities such as Delhi, Beijing, and Bangkok. CNG or propane vehicles emit less NO <sub>x</sub> , PM, and CO <sub>2</sub> than conventional vehicles, generally speaking.	While CNG reduces CO <sub>2</sub> emissions, it may also outweigh CO <sub>2</sub> benefits by increasing unburnt CH <sub>4</sub> (due to poor maintenance) in heavy-duty engines such as those in buses and trucks. A city's inspection and maintenance system may play an important role in determining the actual gains in terms of greenhouse gas emissions. Therefore, engine and fuel management technologies both need to be developed. Effects would be different for dual-fuel or retrofitted vehicles and those exclusively designed for CNG.
Controlling NO <sub>x</sub> and SPM released by diesel vehicles	High-quality diesel fuel, with a maximum sulphur content of 50 PPM, may help reduce CO <sub>2</sub> emissions if additional CO <sub>2</sub> emissions at refineries do not offset such gains.	Since diesel vehicles are major emitters of NO <sub>x</sub> and PM, stringent measures to control diesel vehicles may result in increasing numbers of gasoline vehicles, which emit more CO <sub>2</sub> .
Promoting electric and hybrid vehicles	Electric vehicles have no tailpipe emissions, including all air pollutants and CO <sub>2</sub> . Hybrid vehicles reduce air pollutants and CO <sub>2</sub> significantly.	Electric and hybrid vehicles have poor performance and/or are expensive. The CO <sub>2</sub> benefits from electric vehicles depend on the fuel mix in electricity generation. If most of the electricity is generated by coal, the CO <sub>2</sub> benefits may be negative. Only lifecycle assessments can provide a clear picture.
Introducing category-based emissions/fuel-efficiency standards for vehicles	Such standards help to reduce local air pollutants and CO <sub>2</sub> emissions per vehicle-km for particular vehicle categories (type or size).	If distance traveled by individual vehicles increases or if people switch to vehicles with bigger engines, the total volume of CO <sub>2</sub> might increase even if the standards are met. To reduce the risks of increasing both local pollutants and CO <sub>2</sub> emissions, additional standards based on the average fuel/emission efficiency of a fleet of vehicles (or corporate average fuel efficiency) would be useful.
Promoting mass transport and discouraging use of private cars	Usually such measures can reduce CO <sub>2</sub> emissions because they improve energy performance and reduce gasoline use. This further reduces congestion and associated CO <sub>2</sub> penalties from vehicles.	Inefficiency in operation of mass transport systems may tend to reduce their occupancy and promote private modes of transport, which are usually more CO <sub>2</sub> intensive.



Table 1—*continued*

Local countermeasures	Synergy with global concerns	Conflicts with global concerns
Introducing reformulated gasoline.	Reformulated gasolines can help reduce smog, VOC, and toxic air pollutant emissions.	Reformulated gasoline compromises with fuel economy nominally by 1 or 2%; therefore, CO <sub>2</sub> might increase.
Improving fuel quality of existing fuels	Little effect.	Little effect.
Inspection and maintenance systems; changing driving conditions and driving behaviors	May improve fuel efficiency and thereby reduce CO <sub>2</sub> emissions.	Rebound effects need to be monitored.
Congestion pricing and traffic management	Reduces congestion, discourages car use, and results in fuel savings; however the exact impact on CO <sub>2</sub> emissions depends on various factors.	No conflict.
Controlling sprawl and promoting reasonable urban population density	Potentially, may reduce energy use (and CO <sub>2</sub> emissions) from urban transport and households.	Not very clear.

Source: Dhakal 2004.

#### 4. Conceptualizing the challenges into a holistic framework

Understanding the urban transport-energy-environment conundrum is more complex than it may seem. The issues to be addressed range from urban planning to emissions control, present to future, local to global environmental issues, technical to human behavior issues, regulation to volunteerism, and a complex interplay of stakeholders from ordinary citizens to the private sector to different levels of government. At first sight, it may look chaotic and policymakers are often confused about where to start thinking about the emissions problem. One of the major limitations of measures that are implemented for curbing emissions in developing Asian cities has been that they treat emissions only at vehicle level. Therefore, they often neglect to take into account all the associated factors and ultimately discount cause-effect relationships between the various drivers, leading to failure of the policies. They may view urban planning as a very different issue from transport planning, transport planning as very different from environmental planning, public transport as very different from emissions control, and so forth. One widely used and long-established approach for emissions analysis is to view emissions in relation to travel volume, fuel efficiency, and vehicle stock. In this framework, emissions are viewed as a vehicle problem, mostly technical in nature. This pulls policymakers in developing countries towards short-term solutions, which often serve the interests of the political establishment. Therefore, a framework is needed that provides the whole picture as well as the causes and their interrelations, with simple illustrations.

Lee Schipper and his colleagues have proposed such a framework, which looks beyond vehicles and addresses issues at the level of travel modes, travel demand, and accessibility (Schipper, Marie-Lilliu,

and Gorham 2000). It searches for solutions in the context of urban transport as a whole (not only vehicles) and emphasizes integrated planning. It essentially provides the conceptual basis for all the discussions made in earlier sections. In this framework, emissions from transport are seen as the result of four factors: activity, structure, energy intensity, and fuel factors; hence its name, ASIF. Mathematically it can be represented as follows:

$$E = A \times S_i \times I_i \times F_{i,j}$$

where  $E$  is the emissions from a particular transport mode,  $A$  is total travel volume,  $S$  is a vector of the modal shares,  $I$  is the energy intensity of each mode (in pass-km or ton-km)  $i$ , and  $F_{i,j}$  represents the sum of each of the fuels  $j$  in mode  $i$ . Each of these components is affected by various factors, such as prices, policies, and technologies (Schipper, Marie-Lilliu, and Gorham 2000). The ASIF framework provides a holistic way of looking into emissions problems as well as a tool for policy analysis.

Intervening in activity and structure (AS), by its nature, is a long-term and proactive approach that warrants consistent action over time. Asian cities have had some limited success in intervening in AS (for example, Singapore and a few Malaysian cities). On the contrary, interventions targeting energy intensity and fuel factors (IF) are the most attractive to policymakers in Asian cities; they are, in general, short-term measures but widely used. More importantly for policymakers, behavioral and lifestyle factors govern AS, while technology factors govern IF. A reasonable balance between interventions in AS and IF, though necessary, is rarely found. Table 2 shows a few of the factors that affect AS and IF, and related challenges in Asian cities.

**Table 2.** Factors and challenges in the ASIF framework

Components	Major factors/indicators	Related challenges in Asian cities
AS	<ul style="list-style-type: none"> <li>• Income</li> <li>• Rate of urbanization</li> <li>• Urban form</li> <li>• Urban functions</li> <li>• Rate of motorization</li> <li>• Non-motorized travel modes</li> <li>• Modal mix, para-transit</li> <li>• Utilization rate of private transport modes</li> </ul>	<ul style="list-style-type: none"> <li>• Reorganizing urban activities towards reducing the need for motorized travel</li> <li>• Improving the efficiency of public transport and mass transport systems</li> <li>• Limiting private transport such as cars and two-wheelers and their rate of use</li> <li>• Reducing congestion by increasing the efficiency of the transport infrastructure</li> </ul>
IF	<ul style="list-style-type: none"> <li>• Energy efficiency of modes and vehicles</li> <li>• Size, engine type, and age of vehicles</li> <li>• Occupancy rates (capacity mix and utilization)</li> <li>• Congestion</li> <li>• Fuel quality: lead, sulfur content, reformulation, octane enhancement</li> <li>• Fuel choice: CNG vs. diesel, electricity, gasoline, bio-fuels</li> <li>• Emissions control technologies</li> </ul>	<ul style="list-style-type: none"> <li>• Controlling tailpipe emissions through relevant technology</li> <li>• Improving energy efficiency of existing vehicles and other travel modes</li> <li>• Choosing alternative fuels such as electricity, CNG, and bio-fuels and making them cost-efficient</li> <li>• Improving inspection and maintenance systems for in-use vehicles</li> <li>• Banning superannuated vehicles and promoting fuel-efficient vehicles</li> </ul>

When the ASIF framework is applied exclusively to CO<sub>2</sub> mitigation policies, the type of issues and places where solutions should be focused is described in table 3.

**Table 3.** Framework for CO<sub>2</sub> reduction from urban transport

Nature of strategies	Action categories	Major CO <sub>2</sub> reduction measures	Individual strategies
Strategies largely related to behavior and lifestyle	Travel activity	Reduce travel distances.	Reduce the travel distance of travel modes that produce more greenhouse gases.
	Structure of modes	Restrain demand and use of vehicles.	Restrain demand and use of cars and two-wheelers. Promote public/mass transport modes that produce less CO <sub>2</sub> . Promote non-motorized modes for short journeys.
Strategies largely related to technology and behavior	Energy intensity of travel mode	Improve vehicle energy efficiency. Increase vehicle occupancy. Promote intelligent transport systems.	Increase energy efficiency of conventional ICE vehicles through promoting new technology and smaller vehicles, reducing congestion, accelerating penetration of efficient vehicles in fleets, and improving inspection and maintenance systems. Switch to electric propulsion system—battery, hybrid, fuel cells. Increase vehicle occupancy through car sharing and others. Introduce leapfrogging technologies in niche sectors.
	Fuel quality and choice	Shift to fuels emitting less greenhouse gas.	Maximize benefits from fuel interventions on air pollution reduction, especially CNG and diesel retrofitting and new engines. Introduce bio-fuels such as ethanol. Improve quality of conventional fuels.

*Source:* Prepared by the author following Schipper, Marie-Lilliu, and Gorham 2000 and Sperling and Salon 2002 in Dhakal 2004.

The policymaking usefulness of this framework is evident. It goes beyond indicating the driving factors and provides guidelines to policymakers for where to seek solutions as well and identify the overall implications of their policies. Table 4 outlines some of the potential policies and their relationships with components of the ASIF framework.

**Table 4.** Interactions of selected policies and ASIF components

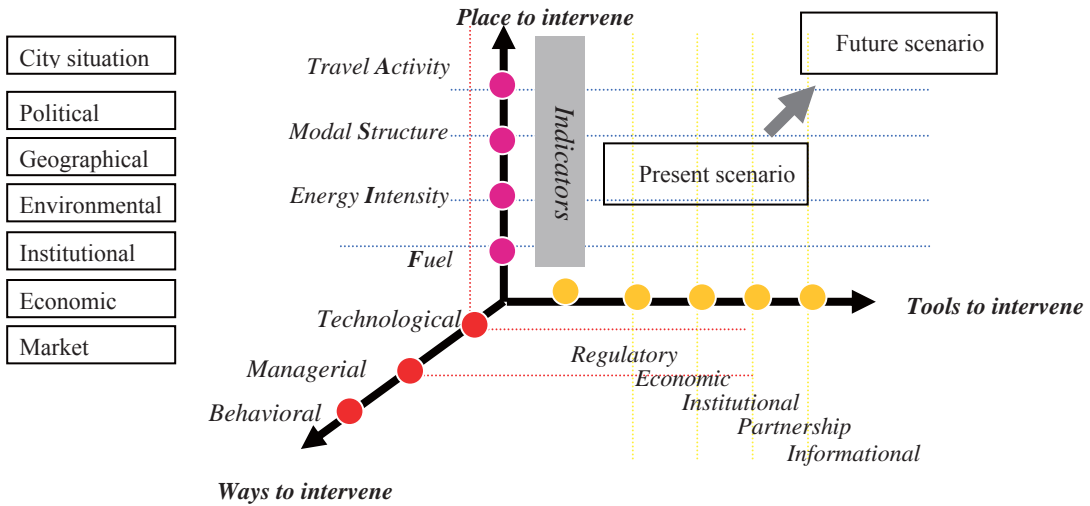
Policy group:	Policies to change fuel price		Policies to influence traffic flow		Policies to influence public attitudes towards transport and energy consumption
Examples:	Fuel tax	Carbon tax	Enhancing throughput (capacity expansion, computerized traffic management)	Restraining traffic flow (traffic calming, diversions, speed limits)	Media campaigns, youth education, information-exchange projects
Activity	Slightly restrains activity, low elasticity		Induces more activity	Restrains activity	Potential improvements
Structure	Slight shift, low cross-elasticities		Favors cars	Favors collective and non-motorized modes	Potential improvements
Intensity	Reduction in medium to long term; can increase utilization rate of travel modes		Not much impact, except some loss due to decrease in capacity utilization of modes	Not much impact, except some increase in capacity utilization of travel modes	Potential improvements
Fuel quality/choice	No impact	Favors low-carbon fuels	No impact	No impact	Potential improvements

Source: Gorham 1999.

An attempt to model Singapore's policies into the ASIF framework is made in table 5. It shows that the key to Singapore's success lies in the fact that its approach was balanced in terms of AS and IF. Although Singapore could be a unique case, some of the tools it employed to tackle various components of the ASIF framework were eye-openers to many countries.

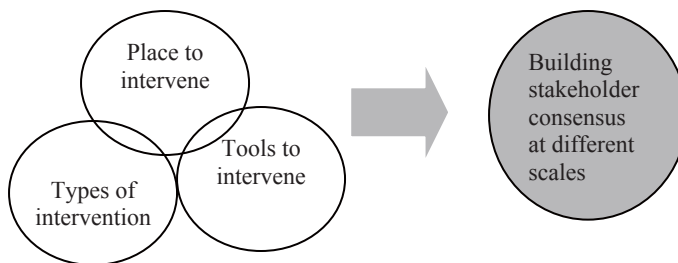
The problem with too great a focus on I and F is that A and S are skyrocketing in most developing countries' urban areas. The number of two-wheelers doubled in major Indian cities in less than 10 years, and the number of cars in Chinese cities is set to double in less than five years. Even if these vehicles are relatively clean, their impact in terms of both increased distances traveled and increased pollution/passenger-km compared with bus and rail (not to mention non-motorized transport modes) means that overall pollution from transport can be rising even if actual vehicles (and their fuels) are improving. And let us not forget that while higher incomes drive the ownership and use of private vehicles, the same higher incomes permit the use of more-expensive cleaner fuels and vehicles. What is needed is a way of reining in emissions from all vehicles more rapidly than the fleet and its use grow.

As an answer, this paper proposes a broader framework for policymakers to consider while dealing with urban transport and environment issues, as shown in figure 1. This framework first requires



**Figure 1.** Proposed broader analysis framework

thinking where to intervene. The potential areas of intervention are the four components of the ASIF framework. Interventions in single components and combinations can be of three types: technological, managerial, or behavioral changes; or combinations of these. Since policies are implemented through tools, the key tools for intervening are of the following natures: regulatory, economic (market-based or fiscal), institutional, partnership, and informational (awareness raising and information dissemination). If we superimpose two more dimensions onto this framework, mainly temporal dynamics and stakeholder considerations, the framework becomes complete (see figure 2).



**Figure 2.** Additional dimensions to the broader analysis framework

**Table 5.** Fitting Singapore's actions into the ASIF framework (only direct effects considered)—indicative only

Impacts of:	Economic growth	Vehicle quota system (supply-side control)	Electronic road pricing, area licensing system (demand-side control)	Reducing parking supply and raising parking charges	Developing transport infrastructure	Integrated land-use and transportation planning, including housing	Euro 2 standards (year 2001), high charges for older vehicles while reapplying for vehicle license, high penalty for smoky vehicles, video camera-based inspection for smoky vehicles, frequent mandatory inspection for older vehicles, certification scheme for automobile workshops, tax rebates for clean vehicles
On							
Activity	Increase	Activity per car may have increased, impact on total activity by car decreased	Activity of travel by car decreased	No change	Not very clear due to quota system, congestion pricing, etc. in place	Decreased activity	No effect
Structure	Could have made car-dependent society if no strong urban policies were implemented	Increased trends towards using public transport	Increased share of public and mass transport modes	Car being expensive may have reduced their modal share	Helped to improve efficiency of public and mass transportation	Development of coordinated mass transport (rail and bus) reduced need to use cars	No effect
Intensity	Facilitated acquisition of state-of-art technology in all travel modes; could have reduced occupancy in mass transport if car-restraining policies had not been implemented	No effect	Improved due to better traffic flows and perhaps increased occupancy	No effect	Increased flow contributing to improved intensity	No effect	Significantly improved intensity
Fuel quality/mix	Facilitated use of better-quality fuels	No effect, except on electricity used by rail					Improved fuels

Note: Analysis of Singapore's successful experience and its relevance to other cities can be found in Dhakal 2004, appendix 1.

## 5. Conclusion

Air pollution poses serious health concerns in dense Asian cities. Urban transport is increasingly becoming the dominant contributor of this air pollution due to rapid motorization. In particular, PM<sub>10</sub>, SPM, and NO<sub>x</sub> levels in many cities are already alarmingly high, while presence of finer particulates is increasing. Since the rate of motorization is already high at current income levels in key Asian cities, the potential future impacts on local and global environments from cities with fast-growing economies are causing serious alarm.

A few key observations are made in this paper. The first of these is that cities are trying to develop efficient transport, but they are not paying attention to reducing transport needs, which cause more pressures downstream, such as congestion and emissions. Limited successes have been achieved in Asian cities in integrated land-use, transport, and environmental planning.

Secondly, choice of transport modes has been skewed towards private modes in the early stages of economic development due to the slow pace of improvements in public transport and lack of mass transport infrastructure. However, on an emissions-per-passenger-km basis, public and mass transport are far preferable to private transport. Private modes include relatively expensive vehicles like cars for high-income groups as well as cheaper modes for mid- and low-income groups, such as two-wheelers (motorcycles and mopeds). In essence, all segments of city populations are driving the motorization process. As a result, non-motorized modes of transport are largely marginalized in cities. They still account for the largest shares of journeys in a few cities, but these shares are constantly declining.

Thirdly, the gap between demand for motorized travel and capacity of infrastructure such as roads remains wide in most cities, aggravating congestion as well as air pollution. This raises the need for investment strategies for developing cities that lack financial resources. The main source of investment is likely to be mechanisms such as public-private partnerships, but these require the creation of enabling environments for private investment and mitigation of investment risks. When transport is intertwined with poverty issues in less-developed cities, cost-recovery strategies must take into account equity considerations. Such complexities are indeed barriers. However, development of additional infrastructure for road transport often creates more demand for travel and is not a lasting solution to congestion and emissions problems. Policies to expand and improve road infrastructure need to give careful attention to how to restrain additional travel activity.

This raises a fourth important observation: that the major failure of cities lies in their inability to restrain growth of the vehicle stock and reduce the amount of travel by each vehicle. There have been very few bold moves in this direction in Asian cities, although Singapore is far ahead of rest of the world in doing so. Singapore may be a unique case for many reasons, but some form of restriction on the growth of vehicle stocks and travel (such as congestion pricing) is absolutely necessary in dense Asian cities.

A daunting task for reducing air pollution from vehicle emissions is shifting to cleaner vehicles, through introducing new vehicle technologies, improving energy efficiency, introducing tailpipe

emission-control technologies, or improving fuel quality and widening fuel choice. Currently, emissions standards for new vehicles in the majority of Asian countries, including many least-developed countries, conform to at least Euro 1. Efforts are now underway to bring standards in line with Euro 2 or its equivalent, and this process needs to be accelerated.

The fifth major observation of this paper is the need to improve the performance of the existing vehicles in use. Despite penetration of Euro I-compliant vehicles, the fleets in developing Asian countries are still dominated by decades-old vehicles whose fuel efficiency and emissions performance are poorer. One of the ways to do this is to implement early vehicle retirement and scrapping programs. However, inferior performance is not limited to old vehicles, but is also often seen in new vehicles that violate existing emissions standards because of corruption or weakness in the mechanisms to enforce the standards. Serious institutional strengthening is necessary in Asian cities to improve inspection and maintenance regimes for vehicles.

The sixth major observation relates to fuels. Low-sulfur diesel is slowly penetrating the market while alternative fuels such as CNG are increasingly being used. These developments are positive, as traditional diesel is a major culprit for PM<sub>10</sub>, SPM, and NO<sub>x</sub> pollution. No significant penetration of fuel-cell vehicles is expected in the next four decades in Asian cities unless a major techno-economic and market breakthrough occurs.

The prospects for reducing greenhouse gas emissions from urban transportation are mixed in Asian cities given their existing priorities. The mitigation of greenhouse gases can be achieved through improvements of energy efficiency in existing transport modes and through shifting to cleaner modes of transport and mass transport. At the level of vehicles, fuel efficiency can reduce greenhouse gas emissions only if it is not offset by growth in travel activity. Since the priorities of developing countries are on mitigating localized air pollution, greenhouse gas concerns need to be integrated into overall urban planning as well as into air pollution management. Since the synergies and conflicts between various air-pollution-mitigation measures and greenhouse gas mitigation are not yet very clear, more studies are necessary. The progress of integrated approaches or any measures to mitigate greenhouse gas emissions from urban transport in Asia largely depend on international support to developing countries, such as those under the Kyoto Protocol and other multilateral and bilateral support.

This paper notes that the environmental problems from urban transportation in Asian cities are largely viewed by policymakers at the level of emissions at vehicle tailpipes, so travel activities, their structures, and other driving forces are generally ignored. The revised ASIF framework presented in this paper is useful for policymakers since it can provide guidelines for strategic approaches to deal with emissions as well as tools to evaluate the impacts of various aspects of policies on emissions and their root causes. Although there are practical problems for implementing holistic approaches in cities because of institutional set-ups and capacities, it is essential that these barriers are overcome. Finally, the prospects for mitigating emissions from urban transport in Asia are not all bad. Many systemic, technological, and behavioral strategies are working, although their progress is a little slow.



## References

- ADB. *See* Asian Development Bank.
- Asian Development Bank. 2003. *Reducing vehicles emissions in Asia: Policy guidelines for reducing vehicle emissions in Asia*. Manila: Asian Development Bank.
- Air Pollution in Mega-cities of Asia. 2002. *Benchmarking urban air quality management and practices in major and mega cities of Asia—Stage I*. Seoul: Korea Environment Institute.
- Dhakai, S. 2004. *Urban energy use and green house gas emissions in Asian mega-cities: Policies for a sustainable future*. Kanagawa, Japan: Institute for Global Environmental Strategies (IGES).
- Dhakai, S. 2003b. Assessment of local strategies for countering greenhouse gas emissions: Case of Tokyo. Urban Environmental Management Project working paper. Kanagawa: IGES. [http://host-3.iges.or.jp/en/ue/pdf/dhakai/dhakai\\_tokyo.pdf](http://host-3.iges.or.jp/en/ue/pdf/dhakai/dhakai_tokyo.pdf).
- Dhakai, S. 2003a. Implications of transportation policies on energy and environment in Kathmandu Valley, Nepal. *Energy Policy* 31(14): 1,493–1,507.
- Dhakai, S. and S. Kaneko. 2002. Urban energy use in Asian mega-cities: Is Tokyo a desirable model? In *Proceedings of IGES/APN Mega-City Workshop on Policy Integration of Energy Related Issues in Asian Cities, 23–23 January, 2002, Kitakyushu, Japan*, 173–181. Kanagawa: IGES..
- Eskeland, G. S. and Jian Xie. 1998. Acting globally while thinking locally: Is global the environment protected by transport emission control programs? Policy Research Working Paper 1,975. Public Economics, Development Research Group, and Global Environment Unit. Washington, DC: World Bank
- Faiz, A., C. Weaver, and M. Walsh. 1996. *Air pollution from motor vehicles: standards and technologies for controlling emissions*. Washington, DC: World Bank.
- Fulton, L. 2001. Saving oil and reducing CO2 emissions in transport: Options and strategies. Paper presented at the Workshop on Good Practices, Policies and Measures, Copenhagen, Denmark, 8–10 October 2001.
- Gorham, R. 1999. *Mitigation of greenhouse gas emission from the transportation sector: Analytical methods and policy measures*. Berkeley, USA: Lawrence Berkeley Laboratory (LBNL-42259).
- Gorham, R. 2002. *Air pollution from ground transportation: An assessment of causes, strategies and tactics, and proposed actions for the international community*. New York: Global Initiatives on Transport Emissions (a partnership of United Nations and the World Bank).
- Greene, D. and A. Schafer. 2003. *Reducing greenhouse gas emissions from US transportation*. Washington, DC: Pew Center on Global Change.
- He, K., Q. Zhang, and H. Huo. 2004. *Integrating global environmental concerns into local environmental planning in Beijing: Policy analysis*. Kanagawa: IGES.
- Heywood, J. B. and A. Bandivadekar. 2004. Assessment of future ICE and fuel cell powdered vehicles, and their potential impacts. Paper presented at the Tenth Annual Diesel Engine Emission Reduction ( DEER) Conference, San Diego, USA, 29 August–2 September 2004.
- International Energy Agency. 2002. *CO2 emissions from fuel combustion 1971–2000* (2002 edition). Paris: International Energy Agency.
- Kojima, M. and M. Lovei. 2001. *Coordinating transport, environment and energy policies for urban air quality management: World bank perspectives*. Washington, DC: World Bank.
- Kojima, M., C. Brandon, and J. Shah. 2000. *Improving urban air quality in South Asia by reducing emissions from two-stroke engine vehicles*. Washington, DC: World Bank.
- Lvovsky, K., G. Hughes, D. Maddison, B. Ostro, and D. Pearce. 2000. Environmental costs of fossil fuels: A rapid assessment method with application to six cities. Pollution Management series. Paper no. 78. Washington, DC: World Bank.

- Lye, L. H. 2002. Environmental taxation in the regulation of traffic and the control of vehicular pollution in Singapore. Paper presented at the Third Annual Global Conference on Environmental Taxation, Woodstock, USA, 12–13 April 2002.
- Marcotullio, P. and Y.-S. Lee. 2003. Urban transitions and urban transportation systems. *International Development Planning Review* 24(3):325–354.
- Matsumoto, N. 2003. Integration of land use and bus systems in Curitiba, Brazil. In the Asian Pacific Environmental Innovation Strategies Project Good Practice Inventory. <http://host-3.iges.or.jp/APEIS/RISPO/inventory/db/pdf/0001.pdf>.
- Menon, A. P. G. 2002. Travel demand management in Singapore: Why did it work? Paper presented at the Regional Workshop on Transport Planning, Demand Management and Air Quality, 26–27 February 2002, Manila.
- Michaelowa, A. 1997. Phasing out lead in gasoline: How developing countries can learn from the experiences of the industrialized world. In *World development aid and joint venture finance 1997/98*, ed. A. Fairclough, 268–272, London: Kensington Publications Ltd.
- OECD. See Organisation for Economic Cooperation and Development.
- Organisation for Economic Cooperation and Development. 1995. *Urban energy handbook: Good local practice*. Paris: OECD.
- Schipper, L., C. Marie-Lilliu, and R. Gorham. 2000. *Flexing the link between transport and greenhouse gas emission: A path for the World Bank*. Paris: International Energy Agency.
- Schipper, L. and A. Golub 2003. Transportation and environment in Mexico City: Reviving a bus system or giving in to the auto? In *Proceedings of the ECEEE 2003 Workshop*. France: European Council for an Energy Efficient Economy.
- Shah, J. and T. Nagpal. 1997. *Urban air quality management strategies in Asia*. Set of four World Bank Technical Papers: Kathmandu Valley (no. 378), Greater Mumbai (no. 381), Jakarta (no. 379), and Metro Manila (no. 380). Washington, DC: World Bank.
- Sperling, D. and D. Salon. 2002. *Transportation in developing countries: An overview of greenhouse gas reduction strategies*. Washington, DC: Pew Center on Global Climate Change.
- Tokyo Metropolitan Government. 2004. Website of the Tokyo Metropolitan Government: [http://www.kankyo.metro.tokyo.jp/kouhou/english2002/honpen/main\\_1.html](http://www.kankyo.metro.tokyo.jp/kouhou/english2002/honpen/main_1.html), accessed 7 December 2004.
- UN. 2002. *World urbanization prospects (2002 revisions)*. New York: UN Population Division.
- WBCSD. See World Business Council for Sustainable Development.
- World Business Council for Sustainable Development. 2004. *Mobility 2030: Meeting the challenges to sustainability*. Geneva, Switzerland: Sustainable Mobility Project, WBCSD.
- WCTRS. See World Conference on Transport Research Society.
- World Conference on Transport Research Society. 2004. *Urban transport and the environment: An international perspective*, WCTRS and Institute for Transport Policy Studies. Oxford, UK: Elsevier Ltd.
- Weiss M. A., J. B. Heywood, E. M. Drake, A. Schafer, and F. AuYeung. 2000. On the road in 2020: A life-cycle analysis of new automobile technologies. Massachusetts Institute of Technology Energy Laboratory Report MIT EL 00-003. Massachusetts, USA: Massachusetts Institute of Technology. <http://lfee.mit.edu/publications/PDF/el00-003.pdf>.
- Willoughby, C. 2000. Singapore's experience in managing motorization and its relevance to other countries. Discussion paper TWU-43. Washington, DC: World Bank Transportation Division.
- World Bank. 2004. *World Development Indicators 2004*. Washington, DC: World Bank.
- Xie, J., J. Shah, and C. Brandon. 1998. *Fighting urban transport air pollution for local and global good: The case of two-stroke engine three-wheelers in Delhi*. Washington, DC: World Bank.