CHAPTER 2:
Trends and Challenges in Asia

Emerging Asia is one of the most rapidly changing areas in the world and this directly impacts the global and local emissions from the region's on-road transportation.

A. POPULATION GROWTH AND URBANIZATION

1. Rapidly Increasing Growth in Population and GDP in Asia

Of the approximately 6.5 billion people on the planet today, half live in emerging Asia (including the PRC and India), while only about one fifth live in the more developed regions.[12] By 2030, the world's population is projected to grow to around 8.2 billion people and the population of emerging Asia is expected to increase by more than 750 million (to a total of more than 4 billion) (United Nations [UN] 2004).

Economic and energy-demand growth (and GhG emissions) are tightly linked, so it is important to look at the region's expected GDP growth. Emerging Asia's robust economic expansion is expected to continue, with the rapidly expanding economies of the PRC, India, Indonesia, and Malaysia leading emerging Asia to an average annual growth through 2030 of more than 5%. This will create a combined output that will approach that of Europe (Intergovernmental Panel on Climate Change 2001). Such sustained high economic growth will be accompanied by rising incomes and consumption (Ali 2005). The main engines of growth are expected to be the PRC and India, which by 2006 expectations should have growth rates of 9.2% and 6.6% respectively. India has been the second-fastest growing economy in the world over the last 15 years after the PRC, and surpassed the US in 2005 by becoming the second most preferred economy in which to invest (AT Kearney 2005).[13]

2. Population Growth and Uncontrolled Urbanization

While the PRC's population is expected to grow from 1.27 billion in 2000 to 1.44 billion by 2025 (13%), its urban population is expected to increase from 35.8% (in 2000) to 57.2%. Moreover, combining the two effects gives an 81% growth in people living in cities. India's total population is expected to grow even more (37%, from 1.02 billion to 1.40 billion) in the same period to almost match the PRC; its urban population is expected to increase from 27.7% (in 2000) to 37.8%, for a combined 87% growth in people living in cities. The urban population of the other countries in emerging Asia is expected to double in the same time span (UN 2004). The future urban population growth in most Asian countries will drive increasing motorization and will have serious consequences for urban road congestion and air pollution as vehicle numbers continue to grow.

This overall urban expansion will be reflected in large city growth. Already, emerging Asia contains 10 of the world's 25 largest cities, and these are among the fastest-growing (World Resources Institute 1996). Projected 2015 populations of the largest cities in emerging Asia show four (Bombay, Shanghai, Jakarta, and Karachi) in the 20–30 million range and a further nine cities with 10–20 million (UN 2004).

ADB has estimated that 80% of the region's new economic growth will be generated in its urban economies (Lohani 2005a) since these provide the bulk of jobs and employment opportunities. A large

12 The more developed regions comprise Europe plus Northern America, Australia/New Zealand, and Japan (see UN definition of regions).
13 AT Kearney's FDI Confidence Index ranking is 1–PRC, 2–India, 3–US (2004).

number of their residents, however, will remain poor. About 70% (or 800 million) of the world's poor live in Asia and although poverty is widely considered to be a rural phenomenon, the incidence of urban and periurban poverty is significant and growing; about 240 to 260 million poor people in Asia reside in urban areas (Lohani 2005b).

The rapid growth in urbanization in Asia has mostly been poorly planned or unplanned and is often a consequence of a growing private sector involvement. Most Asian cities lack effective metropolitan-area land-use planning due to weak institutional capacity, lack of political will, and overlapping or conflicting institutional mandates. They are inadequately prepared to design and achieve a citywide urban development that reduces the travel demand while coping with this explosive growth. This has led to accelerating ad hoc urban sprawl that, together with the increase in purchasing power, has generated a pressure for enhanced personal mobility that is being met by rapidly increasing motorization. In the case of emerging Asia, this has often resulted in the purchase of 2-wheelers, which provide cheap and readily accessible personal mobility. These now dominate the vehicle fleet in terms of absolute numbers in almost all cities and countries in Asia.

With the historic emphasis on managing traffic growth rather than reducing travel demand, most Asian countries, with notable exceptions such as Singapore, have not resolved how to internalize the externalities of personal transport—which is "subsidized" in the sense that car owners (who are the minority in the population) do not pay the full cost of the resources they use or the congestion and pollution that they cause for the vast majority of passengers who have to travel by public transport. The impact of one person is small but when totaled across the population of vehicle owners, this impact amounts to considerable harm to society. This will only be resolved when urban growth is designed and managed in a way that promotes equity and improves access to goods and services while minimizing travel demand.

B. TRANSPORT DEMAND

Over the short term, the sensitivity of demand for vehicles to changes in GDP and in vehicle price is somewhat elastic as their purchase can often be delayed, but in the long term it has low elasticity, indicating that personal mobility is considered by many as essential to everyday living[14] and that it has few substitutes. In emerging Asia, the price elasticity of demand for automotive fuel is slightly larger (in absolute value) than in the countries of the Organisation for Economic Co-operation and Development (OECD), but even so, in the long run, it is inelastic (less than –0.6). In the short term, the sensitivity of gasoline demand to price tends to be very low (around –0.2), although in the longer term it may affect the decision of what car size to buy.

This indicates that fuel and vehicle taxation by themselves will have a less than direct impact on traffic demand, e.g., a 10% increase in fuel prices may change the number of liters of fuel sold by less than 6% and vehicle-kilometers traveled by even less. Thus, other measures are required as well to stem the tide of explosive growth in personal motorization and the externalities it produces.

Several successful examples of transport demand management practices are being enforced to shift at least part of the burden of pollution and congestion to those that produce it, but these have yet to be widely adopted (Box 1).

The vehicle quota system in Singapore employs an open bidding process for certificates of entitlement (to own a vehicle); this is combined with a high initial registration cost (around 150% of the vehicle's market value), an annual road tax that increases with engine capacity and has a surcharge for older vehicles, and Electronic Road Pricing based on a spatial and temporal pay-as-you-use principle to control the movement of vehicles and ensure that congestion does not worsen. In other cities, road and congestion pricing programs, park and ride schemes, and even parking fees may be used to control the movement of private motor vehicles to areas with high vehicle concentration, such as business districts to address congestion and access problems. At the same time, this makes available an auxiliary source of funds for public transport improvements.

C. MOTORIZATION

As the per capita income of urban dwellers in Asia increases in real terms, vehicle ownership likewise will increase and generally follow a path similar to that taken by developed

[14] In developed economies, the short-term price elasticity of demand for cars is around –1.2 to –1.5, while the long-term elasticity is around –0.2; these are expected to not differ much in emerging Asian economies (Taylor 1966, 1970; Bohi 1981).

Box 1: Shanghai's Comprehensive Transportation Plan

Among major Chinese cities, Shanghai has one of the lowest ratios of cars to population, even though it has one of the highest gross domestic product per capita. This situation has been achieved through a deliberate effort by the municipal government to preserve the city's character and environment, largely through the use of regulations, incentives, and fees. Under the current 5-year plan, the policy to expand automobile ownership and use is coordinated at the national level; Shanghai is therefore in the process of adjusting its planning to allow for the implications of the expected population and motorization growth.

In 1992, a consortium of municipal organizations completed the Shanghai Comprehensive Transportation Planning system (SCTP1). Since then, the population and the state of motorization have changed as a result of the economic development policies. At the end of 2000, a revised plan—SCTP2—was announced, based on the second citywide transportation research survey in 1995 and a series of other commissioned studies.

These studies highlighted a series of specific problems with the current transportation system:

- The different travel modes within the public transportation system lack integration.
- The capacity of roads and rail network coverage is insufficient.
- The public transport service level is inefficient because the roads are crowded, bus schedules lag (and compete ineffectually with bicycles and motorcycles); the rail transportation system is also not used efficiently.
- Traffic flow and environmental quality are not good. Pedestrians, bicycles, and autos are jammed together, resulting in high accident rates and worsening pollution, particularly from motorcycles.

SCTP2 will attempt to prepare Shanghai to meet these future challenges and, in doing so, will adopt a focus that extends beyond the city center to the entire metropolitan area.

The passenger transport system will embrace four distinct public transport services: rail, bus, taxi, and ferry. The rail system will be expanded, with a capacity ratio of rail transport to buses of 6:4. The road system will have three levels: citywide freeway, town-wide artery, and interborough main streets. Traditional public ground transportation is expected to carry more than half of the passenger trips, serving short- and medium-distance passengers and those traveling to areas not covered by rail. Within the public ground transportation system, priority for parking, traffic flow, and passenger transfer nodes will be given to buses. To help limit congestion, the number of taxis will be controlled to reduce the vacancy rate from 50% to 30%. The role of ferries also will be reduced, with an emphasis on providing more service for bicycles. Finally, terminals will be built to facilitate passenger use of the multimodal system.

The road system is being designed specifically to increase the capacity of the downtown street area. New radial arteries will serve the new suburban cities, airports, and industrial areas, with speed limits higher than those on ring roads and internodal connectors, for both passengers and freight. Part of the road system will be designated for freight to expedite commercial activity without causing excess congestion of central areas. Bicycle lanes will be constructed, and an effective separation of motor vehicles and nonmotorized vehicles will be maintained. Similarly, the pedestrian environment will be protected, with walk signals at crossings and pedestrian malls in commercial areas. A new comprehensive parking system, with fees and space designed to limit auto traffic in the city center, will include public parking lots for the transportation nodes in the suburbs.

Perhaps most important, a traffic management system will be developed to manage the time and space distribution of traffic flow, using methods such as land use management, toll fees, parking restrictions, information guidance for drivers, and restricted area policies. The goal will be to create a modern traffic environment suitable for an international metropolis. The Adaptive Signal Timing System will be expanded and improved. A major feature of the new system will be an Intelligent Transportation System (ITS) based on information technology. The main information resources of the ITS will include real-time traffic flow, socioeconomic information, parking availability, vehicular traffic, freight traffic, police status, and a basic geographic information system. The ITS will enable the Shanghai authorities to monitor and respond to changes in the vehicle population and patterns of use, to employ new roads and other facilities rapidly after they are brought into service, and to evaluate continually the effectiveness of the transportation management system to provide optimal service at all times.

Safety will be a primary goal of the traffic management system, and safeguards for pedestrians and bicycles will receive high priority. Among the measures being considered are designating exclusive lanes for buses in the downtown area, controlling the emissions and noise of motor vehicles, separating motor vehicles from nonmotorized vehicles and pedestrians from vehicles, optimizing signal time slots to reduce the emissions caused by deceleration and low speed, reducing the traffic accident frequency, strengthening inspection requirements for vehicles and roads, and accelerating the replacement of old, poor, and damaged cars to improve the overall standard of Shanghai's road transportation system.

Source: Lu Ximing 2003.

countries, except that Asia has a higher percentage of 2-wheelers than in most developed markets (Figure 8). The 10 countries in the world with the highest private-vehicle future demand index are in Asia, including the PRC, India, and Indonesia, three of the world's four most populous countries.[15]

Consumer demand for personalized transportation, of which the 2-wheeler provides an initial low-cost rung that in most Asian countries accounts for 50–80% of the vehicle fleet, will drive global sales as the ability to afford them rises to match the desire to buy. Increasing individual mobility for the middle-class groups will make it particularly difficult to achieve the paradigm shift toward greater use of mass transport unless substantial governmental intervention is employed. This highlights the danger that many countries in Asia will have difficulty in replicating the growth track in mobility that many European nations have been able to adopt, which is more focused on well developed mass public transport systems (in other countries, such as the US, Canada, and Australia, high-growth personal mobility is the norm). Singapore is a good benchmark for other Asian countries. It has demonstrated, through an integrated and comprehensive approach, the benefits of a long-term commitment to reducing the need for personal motorized transport.

International experience suggests that at the current and future income levels in emerging Asia, car and SUV ownership rates are likely to grow much faster than GDP and start to displace 2-wheelers.[16] Motorization in Asia is rising very rapidly, with some countries' 4-wheeler fleets[17] doubling every 5–7 years. Emerging Asian countries are expected to integrate an additional 35 million vehicles (excluding 2- and 3-wheelers) into their fleets between 2006 and 2009, with the PRC alone accounting for around 80% of that increase.

SUVs in Asia show an increasing market share, offering the key benefits of luxury cars: prestige/status, interior space and comfort, and protection/safety, through a combination of size and road presence that other vehicles do not afford. SUVs also offer practical benefits, as they can handle poor road surface conditions. Unfortunately, from an energy efficiency point of view, SUVs weigh more than cars and often have higher air and rolling resistance, all of which have a detrimental effect on fuel economy and increase GhG emissions. In the US, the market preference for SUVs has led to worsening fleet average fuel economies, despite the fuel economy improvements made to individual vehicles.

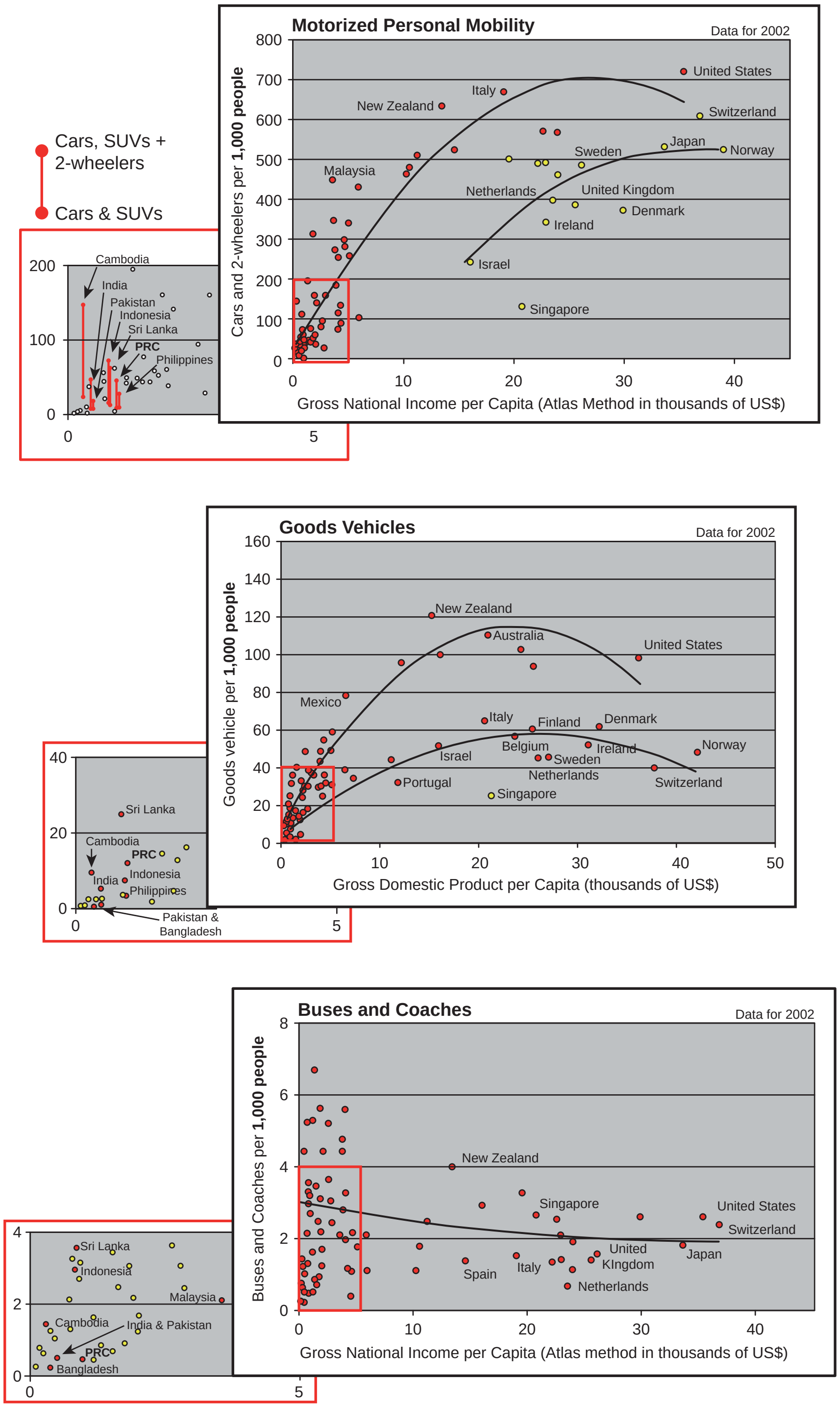
At present, the number of personal vehicles for every 1,000 people in Asia remains modest: about 45 vehicles per 1,000 persons in the PRC (of which fewer than 10 are 4-wheelers) versus 530 per 1,000 persons in Japan (of which 430 are 4-wheelers). The sheer size of Asian countries as the PRC and India can mean that in a relatively short time,

[15] This index measures the relationship between current ownership levels and future intentions to purchase a vehicle, highlighting countries of high future demand. The 10 highest in order were: PRC; Indonesia; India; Thailand; Republic of Korea; Hong Kong, China; Philippines; Malaysia; Singapore; and Taipei,China (Matsuoka 2005).

[16] Particularly between $3,000 and $10,000 of GDP per capita in purchasing power parity terms (IMF 2006).

[17] Cars and SUVs (plus pickups when used as personal transport, as in the US).

Figure 8: Asian Cars, Sport Utility Vehicles, 2-wheelers, Goods Vehicles, and Buses per 1,000 People



GDI = gross domestic investment; GDP = gross domestic product; PRC = People's Republic of China; SUV = sport utility vehicle.

Source: Country GDI, GDP and population: World Bank's *World Development Indicators 2002*; total motor vehicles and passenger cars: International Road Federation 2004, complimented by vehicle inventory data from individual countries.

the PRC and later also India will have vehicle fleet numbers comparable to those of the US (Figure 8). This combination of accelerating incomes, urban growth, and accelerating vehicle ownership, if left unchecked, runs the risk of severely constraining the future economic advancement of Asian cities and economies.

In Europe, diesel vehicles have grown from 14% of sales in 1990 to 44% of all cars sold today (Nash 2005) and dominate the new luxury vehicle market. A similar tendency is occurring in emerging Asia with diesel SUVs. The PRC and Malaysia are the only markets in emerging Asia where diesel currently has a noticeably lower penetration (Keiko Hirota 2005).

D. FREIGHT AND INTERCITY TRAVEL

For goods vehicles (short and long haul), a similar situation exists; the PRC and India report 12 and 5 goods vehicles per 1,000 people, respectively, and run the risk of climbing the high-growth curve shown in Figure 8. In Europe, freight has historically kept to the lower growth-rate curve, mainly due to the modal share of rail, in some cases inland waterways, and shorter distances. This is now changing, however: rail's modal share in Europe is dropping as supplier and distribution networks increase; the largest growth in fuel use for on-road transport is expected to be from trucks. By 2010, the fuel demand for trucks is forecast to exceed that of cars and motorcycles. As before, Singapore is a benchmark.

In many cities in emerging Asia, urban freight is restricted to nocturnal operation to reduce the impact of high-emission long-distance vehicles on air quality and traffic congestion. Most cities lack adequate distribution centers outside their metropolitan areas to forward shipments efficiently in less-intrusive light- and medium-duty commercial vehicles.

In emerging Asia, intercity road networks and road conditions—i.e., surface quality, carrying capacity, grading, and through-traffic sharing road space with pedestrians, animals, and nonmotorized transport (NMT) with little traffic sense or order—are normally not conducive to the high-speed, low-cost, efficient goods and passenger transport that the growing economy requires. Substantial investment and road safety training (starting at the primary school level) is necessary to shorten travel times between cities and reduce accidents and costs. More bypasses are needed to keep metropolitan areas free of unnecessary through-traffic; these will simultaneously reduce congestion and journey travel time.

As GDP increases in emerging Asia, supplier and distribution goods transport requirements will also increase to include greater geographical coverage, requiring a marked efficiency improvement from for-hire carriers and wholly-owned fleets. In many of these countries, legislative reforms and highway construction are accelerating, but need to move faster to promote the more efficient operation and lower GhG emissions—on a ton-kilometer basis—of larger, high-capacity trucks and highway tractor-trailer combinations that historically have been absent from their goods-vehicle fleets and replace the standard 10–15-ton truck traditionally used in most of emerging Asia.

For buses and intercity coaches, the PRC and India both report less than one bus per 1,000 people. The context for public transport in Asia is complicated by the large number of public transport vehicles that are specific to Asia and the developing countries. These include motorized 3-wheelers,[18] of which there are hundreds of thousands in countries as India, Pakistan, and the Philippines. In 2004, India had more than 3 million 3-wheelers in service, mostly with gasoline 2-stroke engines (61%), 4-stroke engines (24%), and diesel (15%) engines. The Philippines has more than 1 million tricycles, which are motorcycles equipped with a sidecar for the transport of passengers and goods. Figure 8 does not transmit the fragmented nature of mass transport in emerging nations; it does not include these motorized 3-wheelers or the custom-built vehicles found throughout the region.[19]

E. PUBLIC TRANSPORT AND NONMOTORIZED TRANSPORT

1. Public Transport

Most cities in emerging Asia can be characterized as having large-scale and growing urbanization with high-density inner city areas and inadequate road space; a large part of the growth takes place at the edges of the cities, resulting in

[18] Three-wheelers include small taxis such as autorickshaws in India and Sri Lanka and baby taxis in Bangladesh, usually equipped to carry three passengers.

[19] Such as jeepneys in the Philippines, *tuk-tuks* in Thailand, and *bemos* in Indonesia.

a decrease in overall density. They typically still have a high modal share of public transport, which is used by all of the population that does not own a car or 2-wheeler. The rapid growth in motorization in most cities, however, is causing the relative share of public transport to decline.

Although shining exceptions exist, most cities in emerging Asia offer a low quality of service in their public transport: although it is low-cost and relatively fast, it is often overcrowded, dirty, and highly polluting and has important personal security and safety issues. Accessibility issues are often evident: high entrance deck heights on buses, for example, effectively bar entry to women with small children and the elderly.

While most cities in emerging Asia have formal bus services, a greater percentage of passenger trips are conducted on informal buses and paratransit vehicles. These provide a cheap, convenient service to the traveler because a large number of vehicles—far more than would be needed if they were all full-sized buses—are willing to pick up and drop passengers at any point along the route. However, these large numbers of informally operated and often inadequately maintained vehicles, competing for passengers, obstruct the flow of traffic and are a substantial source of local (pollutants) and global (GhGs) emissions.

In recent years, several cities in the region have put in place rail-based public transport systems, either in the form of light rail, (Bangkok, Manila, Shanghai) and metro (Beijing, Delhi, Nanjing, Shanghai) and many other cities have planned to put in place such systems. Rail-based public transport systems tend to have a high public profile, but they are responsible for a relatively small proportion of overall trips (usually less than 10%), while in all cases requiring large subsidies for construction and operation. The rail systems are supported by taxis and 2- and 3-wheelers: motorbikes and *tuk-tuks* in Thailand, tricycles in the Philippines, autorickshaws, *bajaj* in India, and of course human-powered rickshaws, that are also informally operated.

A current trend in many cities is toward bus rapid transit (BRT), which consists of high-capacity (usually articulated) buses operating in exclusive segregated bus lanes, with rapid loading and unloading of passengers at stations that provide electronic fare pre-payment and obstacle-free waiting areas and level access to the buses. The system includes centralized coordinated fleet control, providing monitoring and communications to schedule services and real-time response to contingencies, and is usually accompanied by traffic-flow improvement measures, including bus-priority traffic lights, elimination of left turns, continuity given to right turns, and improved signposting. These ground-level modern, high-quality bus corridors are often the result of a public-private partnership (PPP), in which the public sector is responsible for the investment to deploy the required infrastructure, and have been demonstrated to supply carrying capacities rivaling metro or other rail-based transport[20] without the need for subsidized operation.

Informal public transport is characterized by the appearance of many owner-operators or small-to-medium-size operations where staff is employed mostly on the boundary system without health benefits and avoiding tax. The vehicles typically operate all day (independent of the demand) with ad hoc scheduling and informal maintenance that stretches the operational life of each vehicle. They compete for passengers, occupy multiple road lanes, and are a major cause of congestion and air pollution. They are usually a major source of employment and their members actively defend the status quo.

Although some cities (such as Hanoi and Bangalore) report increasing bus ridership (after having lost almost all bus services following the large-scale introduction of 2-wheelers), in emerging Asia, mass transit is generally not an attractive option for anybody who has access to personal transport (car, SUV, or 2-wheeler). Many modern routes (for example, the Skytrain in Bangkok or the metro in Delhi) lose attractiveness when the journey endpoints are far from stations. Modernization of the transport system, preferably as a door-to-door solution, to attract passengers who own vehicles, is substantially more difficult when most mass transit vehicles are in the informal sector.

The informal sector is generally not interested in promoting or accepting long-term transport policies and severely hampers the mobilization of additional capital. While it is now realized that mass transit systems need to be improved (Reddy 2006), in any move forward (i.e., the introduction of BRT), the emphasis needs to be on shifting operators from the informal to the formal sector and on PPPs. BRT (as in Beijing, Kunming, and Xi'an in the PRC[21] and Jakarta, Indonesia) is seen as a valid option for improving

[20] The Transmilenio system in Bogotá, Colombia has demonstrated its ability to carry a peak flow of up to 36,000 passengers per hour per direction.

[21] The Energy Foundation, a partnership launched in 1991 by major foundations, has initiated a sustainable transportation project in the PRC. See Energy Foundation 2006.

bus operation at high-flow levels without the need for continuous external subsidies—something that rail, light-rail, and metro cannot live without. Currently, more cities in Asia are planning BRT systems than rail-based solutions.

The largely informal nature of public transport in emerging Asia restricts modernization in other ways. Most cities do not have any mechanism in place to monitor the performance of the transport system (which requires a data collection and analysis capability to monitor modal split, passenger- and vehicle-kilometer-traveled, activity data by subsector and routes, environmental performance, safety and access, etc.); often no clear guidance is available on the role of public versus private transport or, associated with this, the incentives/disincentives to develop public versus private transport.

When strong governmental action is taken as in Delhi and Dhaka, the externalities of public transport can be substantially improved. Modern buses can generate orders-of-magnitude fewer emissions per passenger-km than private cars and substantially reduce congestion if car usage within the metropolitan areas is inhibited and modal shift is induced (Box 2).

In September 2005, the PRC State Council Office issued a nationwide memo—Suggestions on giving the highest priority to urban public transportation development (Ministry of Construction, PRC et al. 2006)—that assigns top priority to developing urban public transportation as an important measure to increase energy efficiency in the transport sector and alleviate congestion. These guidelines directly promote the development of multimode intelligent public transportation systems (including BRT) with priority treatment being given to public transport over private vehicles. The need to modify laws, regulations, and standards is emphasized to promote well-regulated development and reform the investment and financing support for privately operated, government-supervised urban public transport systems.

Box 2: Application of ASIF Framework in South Asian Cities

Three South Asian cities—Bangalore, Dhaka, and Colombo—were selected as case study sites to analyze the transportation, energy demand, and emissions scenarios over the next 15 years (to 2020) using the "Activity-Structure-Intensity-Fuel (ASIF)" analytical framework. Although the types of data available in the three cities vary widely and there are deficiencies and inconsistencies in the available data, analysis of the results shows each city roughly doubling motor vehicle populations, due to the forecast rise in income levels in the business-as-usual scenario, and tripling of fuel use and CO_2 emissions between 2005 and 2020. Analysis of the city data shows that further strengthening and augmenting bus services, with commensurate increases in ridership, will provide multiple benefits: reduction in traffic congestion, fuel savings, pollution reduction, and CO_2 mitigation.

An increase in public transport share from 62% to 80% in Bangalore leads to a fuel saving of 765,320 tons of oil equivalent, which is equivalent to about 21% of the fuel consumed in the baseline case. The other advantages that ensue are a 23% reduction in total vehicles (642,328), road space creation (equivalent to removing 418,210 cars from the road), and less traffic congestion. Air pollution in the city drops significantly: a 40% drop in carbon monoxide (CO), 46% in hydrocarbons (HC), 6% in nitrogen oxides (NO_x), and 29% in particulate matter (PM). The total carbon dioxide (CO_2) mitigation potential over the 15-year period is 13%.

An increase in public transport share from 24% to 60% in Dhaka leads to a fuel saving of 106,360 tons of oil equivalent, which is equivalent to about 15% of the fuel consumed in the baseline case. The other advantages that ensue are a 39% reduction in total vehicles (99,294), road space creation (equivalent to removing 78,718 cars from the road), and reduced traffic congestion. Air pollution in the city drops significantly: a 24% drop in CO, 26% in HC, $<1\%$ in NO_x, and 13% in PM. The total CO_2 mitigation potential over the 15-year period is 9%.

A marginal increase in public transport share from 76% to 80% in Colombo leads to a fuel saving of 104,720 tons of oil equivalent, which is equivalent to about 3% of the fuel consumed in the baseline case. The other advantages that ensue are a 5% reduction in total vehicles (47,716), road space creation (equivalent to removing 62,152 cars from the road), and reduced traffic congestion. However, air pollution in the city does not drop much, as the city already depends heavily on public transport and the CO_2 mitigation potential is around 2%.

Source: R.K. Bose. 2006.

2. Nonmotorized Transport

Walking and NMT have traditionally been the main means of transport in emerging Asia, but these are becoming more difficult and less socially acceptable in many Asian cities. Many bicycle lanes built in the PRC and Viet Nam in the 1960s and 1970s are now being taken over by cars or are being systematically removed. Bike and *becak* lanes, which were also built in several Indonesian cities, such as Surabaya, in the 1970s, have subsequently been removed. In Hanoi at present, only students use bicycles and these change to motorized 2-wheelers as soon as it is financially feasible. In many cities, rickshaws are restricted to certain streets because they slow the traffic for cars and SUVs. However, in the 1990s, a resurgence occurred, with Bangkok, Kuala Lumpur, and Manila all constructing new, separate bicycle facilities. In India in recent years, modern human-powered rickshaws have been introduced in several cities, such as Agra, Delhi, Lucknow, Jaipur, and Vrindavan. The 2006 India Urban Transport Policy makes specific reference to the need to maintain and expand the share of NMT in urban transport.

Urban walking in most Asian cities involves threading one's way along narrow, uneven (or nonexistent) pavements past street vendors, urban furniture, and parked cars in a noisy, polluted environment where it is difficult to advance at a steady speed. The necessary revival of walking and NMT as effective mobility options will require a change in vision for many Asian cities to actively build pro-pedestrian zones and pavements free of obstructions and invest in segregated walkways and bikeways to provide the safety and user-friendliness that these activities require.

When increased pedestrian areas and nonmotorized vehicles are bundled with high-speed public transport, it is possible to reduce GhG and local emissions and provide a more enticing urban environment and economy. In the Dongshan District in Guangzhou, the street was raised to a single flat pedestrian level giving people, not cars, the intrinsic right of way (Lohani 2005b). An elevated pedestrian network in Bangkok, underneath the Skytrain stations, shields pedestrians from traffic and noise and links shopping centers in the nearby buildings, generating income both for the stores and for Skytrain. This is similar to the elevated network of pedestrian walkways at the Ayala Center in Makati City, Metro Manila, which are linked to the MRT station, providing better access and comfort to commuters.

F. VEHICLE, ENGINE, AND FUELS TECHNOLOGIES

1. New Vehicle Technology

Vehicle, engine, and fuels technologies are currently available to reduce emissions substantially to the point where local emissions and air quality are not now considered as problems in many developed countries.

All countries in emerging Asia now sell unleaded gasoline,[22] which has enabled vehicle emissions technology changes (such as catalytic converters) to be introduced. This rapid elimination of leaded fuel is one of the success stories in Asia, which demonstrates how rapidly effective policy changes can be brought about.

A clear global consensus exists on how to obtain very low emissions levels in gasoline vehicles from 4-stroke engines (advanced three-way catalysts with sophisticated electronic controls for spark timing and air-fuel management) and 2-stroke engines, if they are to continue in production, need to meet the same levels. The European Union (EU) is combining the move to ever stricter emission limits with a voluntary agreement with vehicle manufacturers to improve the fuel economy of light-duty vehicles; however, implementing similar technology changes in many countries in emerging Asia is slow.

Several emerging Asian countries have no formal fuel quality or vehicle emissions road maps in place. These include Pakistan, Bhutan, and Cambodia (CAI-Asia 2006b). Others, such as Indonesia, the Philippines, and Viet Nam, have developed road maps for European emissions standards (EURO) II[23] but have not yet finalized the way forward to EURO IV. In 2010, the PRC will move to EURO IV and India will reach EURO III nationwide, although both have prior introduction in major cities. Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, and Ahmedabad have had EURO III standards since 2005 and Beijing will adopt EURO

22 Indonesia continues to sell both leaded and unleaded fuel.

23 The European Union adopted EURO II, III, and IV standards for light-duty vehicles in 1996, 2000, and 2005, respectively, and will go to EURO V in 2008.

IV in 2007. Thailand and Malaysia will both reach EURO IV light-duty standards in 2009. So far, only Hong Kong, China has indicated that it is considering the adoption of EURO V standards. The PRC is the only country in emerging Asia that has implemented fuel economy standards (Box 3).

Diesel vehicles, which traditionally have been seen as part of the problem because of their visible exhaust smoke and high ultrafine PM emissions, are rapidly becoming an integral part of the solution when advanced standards are introduced following the availability of ultra-low-sulfur

Box 3: Vehicle Fuel Efficiency Standards in the People's Republic of China

In recent years, rapid economic (GDP) growth in the People's Republic of China (PRC), coupled with the need to activate internal consumption, has fueled a rapid expansion of the Chinese vehicle fleet. In 2005, the PRC had an active population of around 32 million vehicles (of 4 or more wheels), plus 57 million 2- and 3-wheelers. Over the coming 20 years, the vehicle population is expected to grow by almost five times to 183 million, plus 194 million 2- and 3-wheelers (Segment Y Ltd. 2005). This growth will cause vehicle fuel consumption to increase substantially and cause major fuel security, traffic congestion, and pollution concerns.

The PRC is a country with few oil resources and became a net oil importer in 1993. The domestic supply of crude oil is stable at about 160 million metric tons per year but is expected to drop within this 20-year period, while on-road transportation by itself can be expected to require around 300 million metric tons by 2025 unless a systematic control strategy is put in place to correct this tendency.

The Government decided in 2002 to establish a framework, including government cooperation and research team and international support, to develop vehicle fuel efficiency standards and regulations. After 2 years of studies and negotiations, the first fuel efficiency standard, *Fuel Consumption Limits for Light Duty Passenger Vehicles*, was published on 2 September 2004, for implementation as of July 2005. The main goal of this regulation was to help control the national total oil consumption at less than 400 million metric tons per year.

The components of the vehicle fuel efficiency standard were (i) the development of weight class-based maximum fuel consumption standards; (ii) an overall per-distance fuel consumption reduction of 15%; and (iii) a more stringent standard for heavier vehicle classes to prevent a shift to heavier vehicles and encourage the use of economic compact cars. The first phase of the standard, targeting a reduction of 5% in per-distance fuel consumption, was implemented

Figure A: Fuel Consumption Standards for MT Cars

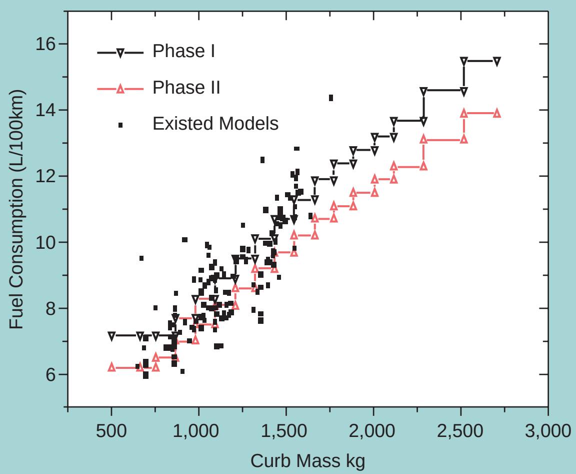
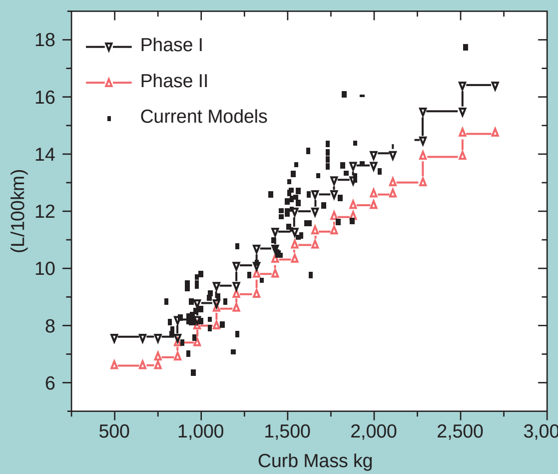


Figure B: Fuel Consumption Standards for AT Cars, SUVs, and 3+ Rows Minivans



L/100km = liters per 100 kilometers; AT = automatic transmission; MT = manual transmission; SUV = sport utility vehicle.

in 2005, and a second phase, with a goal of 10% reduction in fuel consumption for each weight category, is scheduled for 2008. Figures A and B show the final standards for manual transmission and automatic transmission light-duty vehicles, respectively. This Chinese standard is more stringent than the US standard, given that the limits are maximum values instead of average values and that the phase two standard is for 2008 model-year vehicles. However, the technical requirements of this standard are not as stringent as those of the EU or Japan.

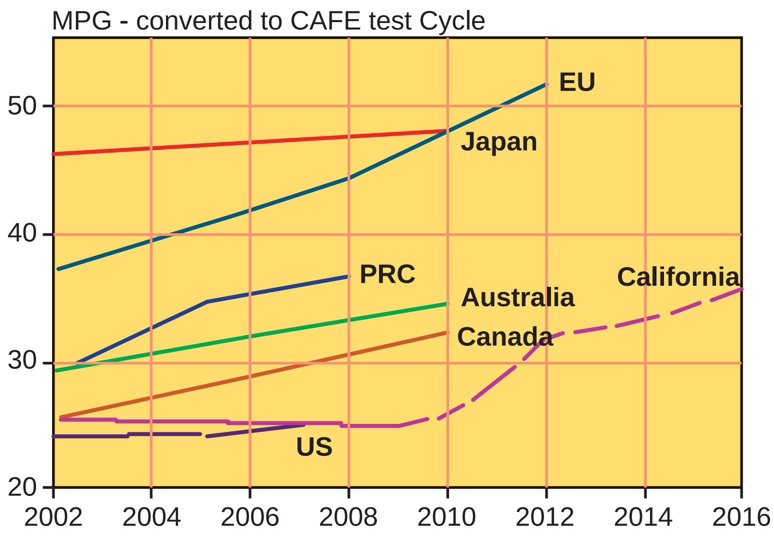
With the implementation of this fuel economy standard, 13 million tons of fuel is forecast to be saved in 2020 and 31 million tons in 2030. However, more stringent fuel economy standards need to come into force after 2009. A further reduction of 25% in vehicle fuel consumption to 5.6 L/100km (the European requirement for 2008) should be established by 2012 for light-duty passenger cars and a fuel consumption level of about 4.8 L/100 km should be developed to catch up with Europe and Japan by around 2016. If this were implemented, an additional 19 million tons of oil could be saved in 2020 and 60 million tons in 2030.

Source: He Kebin et al. 2006.

diesel, which generates emission levels comparable to the best gasoline engines and with a higher fuel economy level. Diesel-powered cars and SUVs are achieving 20–40% better fuel economy, with lower GhG emissions, than their gasoline-powered equivalents.

Many new vehicle technologies also contribute to improvements in GhG emissions: reducing vehicle weight and aerodynamic drag with new structure design and materials, turbocharging, smaller engines, light-duty hybrids, low rolling-resistance tires, low-friction lubricants, idle-stop features, variable valve control, variable compression ratios, and advanced air-conditioning technology are all leading to improvements. The limits to the higher fuel economy performance of light-duty vehicles in the EU (with fleet-average GhG emissions of less than 140 grams of CO_2 per kilometer[24] [km]) are seen to be currently defined by the

Figure 9: Comparison of Fuel Economy and GhG Emission Standards Normalized by CAFE-converted Miles per Gallon



CAFE = Combined Average Fleet Economy; EU = European Union; GhG = greenhouse gases; MPG = miles per gallon; PRC = People's Republic of China; US = United States.
Source: Feng and Sauer. 2004.

24 This is equivalent to 18.8 km/L for a gasoline vehicle on the US Combined Average Fleet Economy (CAFE) test cycle.

restricted acceptance among consumers of the smaller, lighter cars. Long-term innovations are envisaged, such as hybrid heavy-duty vehicles, alternative fuels, and the use of hydrogen fuel cells, that will achieve important improvements in per-vehicle GhG emissions.

This combination of engine and vehicle technology has allowed several countries to enact fuel economy and GhG emission standards. Figure 9 shows that the EU and Japan have the most effective light vehicle fuel economy standards, followed by the new PRC standards. The impact of these standards is relatively small at first, but grows significantly as the new-technology vehicles replace older vehicles in the in-use fleet.

Improving the information to the consumer about the fuel economy and CO_2 emissions performance of new vehicles, as is being enabled in the EU for new passenger cars, is an important step toward incorporating better technology vehicles into the in-use fleet (EU 2002). To be effective, these labels should be clearly visible, color-coded, and indicating vehicle usage costs.

Airconditioning systems in vehicles are particularly prone to leakage and most use a hydrofluorocarbon called R-134a, which has a GhG warming potential 1,300 times more potent than CO_2. By 2010, the use of R-134a is expected to contribute more than 4% to total GhG emissions. This impact rises to 7% if the extra fuel consumption used for the air conditioning is added in. Recognizing this, the EU published a new regulation this year to phase out the use of R-134a in new cars beginning in 2011. It is likely to be replaced with other hydrofluorocarbon refrigerants with lower warming potentials or new technology, possibly employing CO_2 as a refrigerant (Fairley 2006).

The EU has not placed the same emphasis on reducing emissions from motorcycles.[25] As of 2006, all new motorcycles in the EU have to meet EURO III limits, which can be achieved quite easily with current automotive technologies, such as fuel injection systems and catalytic converters. Even when the most stringent of currently agreed requirements are applied, motorcycles will be required only to reach EURO III standards, while passenger cars are already on the stricter EURO IV.

Both the PRC and India have adopted strict limits for motorcycles, with 1.5 g/km (hydrocarbons [HC] + NO_x).[26] The 2-stroke engines that meet these are fitted with catalytic converters. In 2003, 91% of the motorcycles produced in the PRC were already 4-stroke (Fu 2004). India will go to a limit of 1.0 g/km (HC + NO_x) in 2008–2010, which will require further technological improvement. The massive shift of two-wheeled vehicles from 2-stroke to 4-stroke engines in India is strongly influenced by changing customer preferences, in addition to the stringent emission standards (Iyer 2006).

The lower-capacity motorcycles that dominate the Asian market have a clear advantage in GhG emissions: since substantial development focused on improving their fuel economy has taken place, their levels tend to be less than half those of small cars, though their emissions performance generally lags behind that of the EU. "The exception to this observation is the standards and technologies for two- and three-wheelers in some of the major Asian countries such as India, Taipei,China, and Thailand" (British Motorcycle Federation [BMF] 2003). Another exception may be electric bicycles (Box 4).

Substantial development of 3-wheeler engines has occurred aimed toward gaseous fuels. Cities as Delhi and Dhaka have required their 3-wheelers to operate on compressed natural gas (CNG), yielding substantial advantages in local pollutants.[27]

The major lessons learned from the past 25 years highlight the advantages of reducing the implementation lags in introducing tighter standards as much as possible. Emerging Asia can be seen as catching up in terms of technology standards, but still has a lag of 5 or more years in most countries and vehicle segments compared to the EU. Since improvements in emissions performance and fuel economy are being developed in parallel, particularly in the EU and Japan, local air quality and climate change can both benefit

[25] Although motorcycles are not a major means of transport in most of Europe, global annual motorcycle production in 2003 was around 30 million units (Japan Automobile Manufacturers Association [JAMA] 2006).

[26] The drive cycles in the two countries are different, however. The 2005 limit for 3-wheelers in the PRC is 1.9 g/km (HC + NO_x).

[27] Approximately 16% of the Indian 3-wheeler market consists of 4-stroke CNG-fueled units.

Box 4: Electric Bicycles in the People's Republic of China

The People's Republic of China (PRC) is the world's biggest producer of bicycles;[a] 79 million units were manufactured in 2004, of which 22–25 million were for the Chinese domestic market, down from a peak of 40 million just a few years ago. The Government's policies on promoting cars have had a discouraging effect on cycling and the removal of many bike lanes has been seen as a necessary measure for accommodating increasing car use (Fairley 2006). In Beijing, only 20% of commuters rode bikes in 2002, compared to 60% in 1998. However, many cycle paths are being built in the old town areas and newly built communities for the 2008 Beijing Games (Ma et al. 2004).

While bicycle sales have been waning, electric bicycles have increased in popularity. Some 260 companies in the PRC are estimated to be making electric bikes and their components (Promotion Association of Electric Bicycle [PAEB] 2005); approximately 7.5 million electric bicycles were sold in the PRC in 2004, rising to around 9 million in 2005, despite being banned in some key cities. The output of electric bikes is expected to maintain an annual growth rate of at least 80% in the coming 5 years (http://english.cri.cn/855/2006/05/16/262@89748.htm). These bikes provide an attractive option for commuters, service people, and couriers who have a need for motorized personal transportation.[b]

This dramatic growth has been largely due to legislation banning gasoline-fueled scooters and bicycles, introduced from 1996 onwards in several major Chinese cities, including Beijing and Shanghai. A 2002 report entitled *How to Manage the Development of Electric Bicycles in Beijing*, released by the Beijing Traffic Development Research Center, concluded that electric bicycles were "not in keeping with Beijing's image as a major world capital" and recommended that they be phased out. A bulletin, released by the Beijing Municipal Public Security Bureau in 2002, announced that all the electric bicycles would be forbidden in Beijing. On 30 December 2005, the Beijing Municipal Public Security Bureau announced a new policy,

allowing electric bicycles to be licensed from 4 January 2006 (www.chinadaily.com.cn/english/doc/2006-01/01/content_508528.htm).

Electric bicycles come in many versions and fierce brand competition is ongoing, with market leaders, such as Fushida, Yadi, and Xinri holding about a 70% share (Li Zhiguo 2006). They have a top speed of 20–30 kilometers (km) per hour and a range of 25–100 km. During operation, they emit zero local air pollution, but they do use about 2 kilowatt-hours of electricity per 100 km. Power ranges between 200 and 600 watts and they take around 6–8 hours to charge (Cherry 2006).

[a] Followed by Taipei,China and India.

[b] Increasing travel distances have also had a discouraging effect on commuters.

Source: Author.

from a rapid incorporation of new technology and from other measures that promote fleet renewal. The expected high growth in light-duty Asian fleets assists in this per-vehicle improvement although the near-term vision is not so clear for heavy-duty fleets.

2. Diesel

As diesel emission standards ramp up to technologically demanding levels, the sulfur concentration in the fuel needs to be progressively reduced. The EURO III and EURO IV intermediate standards require less than 500 part per million (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 such as diesel particle traps to be used that can reduce emissions by up to 95%.[28]

Many are arguing (e.g., Walsh and Enstrat 2003) that the considerable investment required to equip refineries and fuel distribution systems to be able to deliver diesel with these low levels of sulfur can be reduced by leapfrogging directly to the ultra-low levels. Even though the required investment is high, in the US context and following US accounting practices, the ratio of benefits to costs ranged from 5:1 to 40:1. In the PRC, a ratio of benefits to costs ranged from 7:1 to 22:1 over a time frame of 2020–2030, with small positive net benefits even in 2010 (Blumberg 2006).

3. Biofuels

Internal combustion engines will continue to be the dominant on-road transport power source in 2030, using mostly liquid fuels. Within the range of liquid fuels, biofuels provide the best option to reduce the GhG footprint of transport fuels by replacing a significant share of these fossil fuels (Biofuels Research Advisory Council [BIOFRAC] 2006).

The principal biomass-derived liquid fuels commercially available today and suitable for road transport are ethanol—for spark ignition (gasoline) engines—and vegetable oil-based diesel substitutes for compression ignition (diesel) engines. Ethanol is derived primarily from corn (US) and sugar (Brazil), but can also be produced from sugar beets, molasses, cassava, and wheat. The diesel substitutes are made from a wide range of vegetable oils (e.g., rapeseed, soy, palm, coconut, and jatropha) to fuels that are completely compatible with fossil diesel fuel, both as a mixture of any fraction and in pure neat form.[29] However, most vehicle manufacturers do not consider neat biodiesel as an acceptable option. Fuel additives are also produced from biomass; Bio-ETBE (ethyl-tertio-butyl-ether) produced from bioethanol and Bio-MTBE (methyl-tertio-butyl-ether) produced from biomethanol are used as components to increase octane ratings of gasoline and to reduce knocking.

While biofuel programs started over 3 decades ago in a few countries, only recently did they gain broad-based interest, this mainly due to the increase in oil prices and government incentives to make investments profitable and address national foreign exchange, fuel diversification, and security concerns. In 2004, 33 billion liters of ethanol were produced, accounting for about 2% of gasoline production worldwide;[30] 2.2 billion liters of biodiesel (accounting for around 0.33% of worldwide diesel production) were also produced that year, principally in Germany, France, and Italy with small amounts in the Philippines and Malaysia.[31]

"Second generation" biofuels are now being developed from a wider range of feedstock that increase the fraction of bio-component availability and reduce the cost of the avoided CO_2 by utilizing biomass fractions that are presently discarded and making the best use of the whole plant. Tables 1 and 2 show the current and next generation of liquid biofuels to substituting for gasoline and diesel as transport fuels, together with their principal feedstocks and conversion processes, net energy balances, and GhG emissions reductions (Institute for Energy and Environmental Research 2005). Since different amounts of energy are used in producing a biofuel compared with a petroleum-based fuel, a life cycle analysis (LCA) must be used to compare the net GhG emissions performance of different fuels.

[28] Europe (EURO V) has chosen slightly less stringent emissions standards than the US and by using mainly selective catalytic reduction techniques are further improving diesel fuel economy and GhG emissions.

[29] These are principally vegetable methyl esters; in some countries (e.g., UK), waste oils and greases are used to produce biodiesel fuel.

[30] About 15 billion liters of ethanol from sugar cane in Brazil, 13 billion liters from corn in the US, 2 billion liters from the PRC, 0.2 billion liters from Thailand, and the rest from other countries—compared to gasoline worldwide production in 2004 of 1,200 billion liters.

[31] From coconut oil and palm oil, respectively.

The present production of ethanol from corn in the US yields limited GhG savings,[32] but these savings could be increased if biomass residues from corn production were used for heat and power generation in the ethanol production process.[33] Prof. Eric Larson of Princeton University, in the Global Environment Fund (GEF)/Scientific and Technical Advisory Panel (STAP) report, concluded: "Very broadly, grain or seed-based biofuels (e.g., corn ethanol or rapeseed methyl ester) might give 20–30% GhG reductions per vehicle-km relative to petroleum fuels, sugar beets might give 40–50% reductions, sugarcane (average SE Brazil) gives 90% reductions, future advanced cellulosic conversion [to ethanol, Fischer-Tropsch (FT), or dimethylester (DME)] from perennial energy crops might give 80–90+% reductions. Biofuels production with carbon capture and storage (a longer-term option) will give >100% reductions" (Larson 2005).

In Asia, investment in new biodiesel production capacity is increasing, with coconut oil, palm oil, and jatropha as feedstock. The Philippines has a commercial coco biodiesel (coco methyl ester) industry producing the equivalent of about 1% of diesel fuel use (Karunungan 2005); Malaysia is gearing up for increased production of palm oil and the development of a palm oil biodiesel production capacity. However, it is likely to be several

Table 1: Bioethanol to Replace Gasoline: A Climate Change Perspective

Feedstock	Production Status and Regions	Current Life Cycle GhG Emissions Reduction Relative to Gasoline	Biofuels Yield per Hectare	Costs	Net Energy Balance
Grains (wheat, maize)	Large scale and commercial (US, Europe, PRC)	None to moderate with maize, but improvements possible	Moderate	Moderate	Currently low
Sugar beets	Large scale and commercial (Europe)	Up to 50%	Moderate	Moderate	Currently low
Sugar cane	Large scale and commercial (Brazil, India, Thailand)	Brazilian ethanol has highest GhG reduction (≈90%) and lowest cost. Biomass energy used in the production process.	High	Low	Medium
Ligno-cellulosic biomass	"Next generation" biofuel. Pilot plants in Sweden, Spain, Canada, Denmark	High; 70–90% estimated; can be close to 100% in principle	High	High	High (expected)

GhG = greenhouse gases; PRC = People's Republic of China; US = United States.
Source: International Energy Agency (IEA) 2004.

[32] Up to about 13%, according to Farrel (2006).

[33] The reduction achieved by using corn-based E85 is only moderate because (i) significant amounts of GhG emissions are generated during corn farming and in corn ethanol production plants; (ii) diesel fuel, liquefied petroleum gas (LPG), and other fossil fuels are consumed during corn farming; (iii) a large amount of nitrogen fertilizer is also used for corn farming, and manufacture of nitrogen fertilizer and its nitrification and denitrification in cornfields produce a large amount of GhG emissions; and (iv) usually, natural gas or coal is used in corn ethanol plants to generate steam (Brinkman et al. 2005).

Table 2: Biodiesel Fuels to Replace Diesel: A Climate Change Perspective

Feedstock	Production Status and Regions	Current GhG Emissions Reduction Relative to Petrodiesel	Biofuels Yield per Hectare	Costs	Net Energy Balance
Oil seeds (rape, soy)	Medium-scale, mature and evolving (US, Europe)	Up to ≈70% reduction	Low	Moderate	3.2 for soy biodiesel vs. 0.8 for petrodiesel
Coconut oil to CME	Medium commercial (Philippines)	No LCA has been conducted yet (expected to be moderate)	Moderate to High	Low-moderate	LCA needed
Palm oil	Small-scale, commercial (Malaysia, Indonesia)	No LCA has been conducted yet (expected to be moderate).	Moderate to High	Low-moderate	LCA needed
Jatropha	Pilot-scale, pre-commercial (PRC, India)	No LCA has been conducted yet (expected to be moderate to high).	Moderate to High	Low-moderate	LCA needed
Biomass to liquids	"Next Generation" biofuel. Fischer-Brown biodiesel pre commercial (Demo plants in Germany and Sweden)	High (IEA)	High	High	LCA needed For many combinations

CME = cocomethyl ester; GhG = greenhouse gases; IEA = International Energy Agency; LCA = life cycle analysis; PRC = People's Republic of China; US = United States.
Source: IEA. 2004.

decades before a strategically important share of liquid fuels for road transport can come from biofuels, and that assumes that the economic and policy signals support production and use of these fuels.

Biomethane is identical to conventional natural gas in terms of fuel use, meaning that vehicles running on natural gas can run on the renewable variant, too, as it becomes available. Like natural gas, biomethane boasts low emissions but is carbon negative in that CO_2 emissions from biomethane vehicles have a lower warming effect than methane escaping to the atmosphere. Studies in Europe have found that biomethane is one of the most cost-effective biofuels and could feasibly replace up to 27% of conventional transportation fuels (European Natural Gas Vehicle Association 2006).

4. Compressed Natural Gas and Liquified Petroleum Gas

Natural gas is a mixture of hydrocarbons, mainly methane (ca. 90% CH_4), with smaller amounts of ethane, propane, and CO_2. It is collected from gas wells and in association with crude oil production. CNG is used to run buses and light-duty vehicles, including 3-wheelers mainly in urban environments, propelled by energy security concerns and air quality consideration with the goal of minimizing tailpipe particulate emissions to negligible levels.

At present, CNG engines are slightly less efficient than gasoline engines. In the future, improvements in spark ignition engines could bring CNG close to diesel. For conversions from gasoline into CNG, depending on fuel system design and conversion quality, actual emissions in some cases will be higher than before conversion. Methane has a global warming potential 21 times greater than CO_2 and any methane leakages, especially in refilling and end-use, can potentially negate all GhG savings from using CNG as fuel. A strong regulatory regime of inspection and maintenance of retail site equipment is needed if this risk is to be minimized.

As of 2006, over 5.5 million natural gas vehicles are estimated to be in use worldwide, about 1.5 million of them in emerging Asia.[34] Growth in CNG vehicle populations has been very rapid over the last 2 years in Bangladesh,

[34] Of which Pakistan has 1 million; India, 335,000; PRC, 127,000; Bangladesh, 55,000; Malaysia, 19,000; and Thailand about 11,000 vehicles (International Association of Natural Gas Vehicles 2007).

PRC, Malaysia, Pakistan, and Thailand. Pakistan is the largest user of CNG in Asia, and the Thai Government is aiming to convert half a million vehicles to run on CNG by 2010 to help reduce the country's dependence on oil (http://just-auto.com 2006).

In India, the Supreme Court, ruling in 1998, mandated CNG as the fuel for public transport in Delhi to control pollution. In 2002, a further ruling directed the Union government to give priority in CNG use to the transport sector and a further four cities have implemented programs for urban transport.[35]

Liquified petroleum gas (LPG) consists mainly of propane with propylene, butane, and butylenes in various proportions according to its origin. The components of LPG are gases at normal temperatures and pressures and the fuel is easily stored in a steel cylinder as a liquid. Its ease of transport and storage makes it applicable even in smaller vehicles and LPG presents an opportunity as a vehicle fuel for cities that do not have pipeline or sea access to CNG.

In 2004, approximately 10 million LPG vehicles were in use worldwide, concentrated in only a few countries. It is widely used in Europe and in five countries; LPG accounts for more than 10% of the total automotive fuel demand.[36] Fuel diversity and security issues have enticed governments to offer attractive incentives for its use: In Republic of Korea over 10% of all registered vehicles are fueled by LPG; in Japan over 90% of the taxi fleet uses this fuel; Thailand introduced this fuel to the Tuk-Tuk 3-wheeler segment; and Hong Kong, China is replacing 18,000 diesel taxis to achieve important reductions in PM and NO_x emissions (Walsh and Kolke 2003; Ha and Tsang 2003; US Department of Energy 2002).

While these gaseous fuels do impact local emissions, their contribution toward meeting the combined energy policy targets of enhanced long-term supply security and significant CO_2 emission mitigation in Asia is limited now and will continue to be limited in the future.[37]

5. Hydrogen

Hydrogen has great potential as an energy carrier. Vehicles with hydrogen-powered fuel cells and electric motors or internal combustion engines are being tested by most manufacturers, and many of these efforts are led by the California Fuel Cell Partnership, a grouping of car companies, power companies, and fuel cell manufacturers. The total number of fuel cell cars now in early demonstration is around 600 (H2 Expo 2005).

Fundamental research is being carried out toward extending the use of hydrogen as an automotive fuel. Key areas include greatly reducing the cost of hydrogen produced from nonfossil resources (such as nuclear, photoelectrochemical, photobiological, and thin-film solar processes); improving battery performance, weight, cost, and capacity; improving the cost and performance of fuel cells; low-pressure storage of hydrogen in vehicles; and reducing the GhG emissions during the manufacture of hydrogen from coal.

Over the next several decades, hydrogen-fueled vehicles can be expected to grow in importance in the world automotive market, but are not expected to achieve a significant share within the time frame of this analysis until the specific GhG avoidance costs of hydrogen options are brought down to levels similar to those of other technological routes discussed in this document (Figure 10). It is important that continual research and development be funded for hydrogen-fueled vehicles (Friedrich 2006).

6. Need to Control In-use Vehicle Emissions

Proper maintenance is important to control emissions over the life of the vehicle, but in most parts of Asia, owners generally do not give much consideration to maintenance. A fully implemented and enforced inspection and certification (I&C) program supported by adequate maintenance has shown to bring about reductions in NO_x emissions of 2–5%, PM_{10} emissions of 2–15%, and fuel consumption and GhG emissions by around the same amount (2–17%); the higher numbers apply to the less advanced vehicle fleets commonly found in Asia.

In Bangkok, privately-owned urban bus fleets have de-rated their engines to avoid fines for visible smoke, which, combined with driver training and a driver incentive scheme to use less fuel, has improved their fuel

[35] These are Ahmedabad, Lucknow, Kanpur, and Hyderabad. If the national gas grid is implemented, 22 cities will be enabled.

[36] Republic of Korea, followed by Japan, Poland, Turkey, and Australia, account for more than half the world on-road transport consumption. In Republic of Korea, Bulgaria, Turkey, and Lithuania, however, LPG represents more than 10% of the total vehicle fuel consumption (World Liquid Petroleum Gas Association).

[37] In light-duty vehicles, a fuel economy improvement of between 3.5% and 12.6% was reported in Arizona, USA due to the implementation of a vehicle inspection and maintenance program when their vehicle fleet had a technology level similar to that found today in many parts of emerging Asia. Since it can be expected that the vehicles in Arizona were on the whole better maintained than their counterparts in emerging Asia, similar or larger gains should be possible today in Asia (Gielen and Unander 2005).

economy by over 30%.[38] In India's "golden triangle," traffic police empowerment has virtually eliminated the smoky diesel problem. B.E.S.T, the Mumbai bus operator, has also reported substantially improved fuel consumption through better maintenance and driver training originally incorporated due to pressure to eliminate visible smoke.

Studies performed in Jakarta indicated that the wide-scale adoption of preventive inspection and maintenance programs for in-use vehicles can help improve overall fleet fuel efficiency by 3–4% and substantially reduce exhaust emissions (Pramono and Heuberger 2001). Under a separate Swiss contact program in Jakarta, 5,245 buses from nine companies were subjected to I&C testing and an improved maintenance regime over a 2-year period, resulting in a 5.5% improvement in fuel efficiency; in India, the Society of Indian Automobile Manufacturers reported a fuel economy improvement of up to 17% from their 2-wheeler voluntary clinics (GTZ 2003).

These examples illustrate the fact that well-managed I&C programs can have a considerable positive impact on vehicle fuel efficiency if implemented across the entire in-use vehicle fleet. However, majority of I&C programs in Asia have been of an ad hoc nature. Few countries in emerging Asia have been able to implement a structured and well-enforced I&C program that targets large numbers of grossly polluting in-use vehicles on a regular basis. Effective I&C programs require setting in-use emission standards that are achievable by a majority of vehicles with good maintenance, and tightening them over time with the objective of removing grossly polluting vehicles from the road. Such programs can lead to the replacement of damaged catalytic converters and can be used, with the corresponding regulatory measures, as a low-cost means of preventing the import of grossly polluting used vehicles into the country.

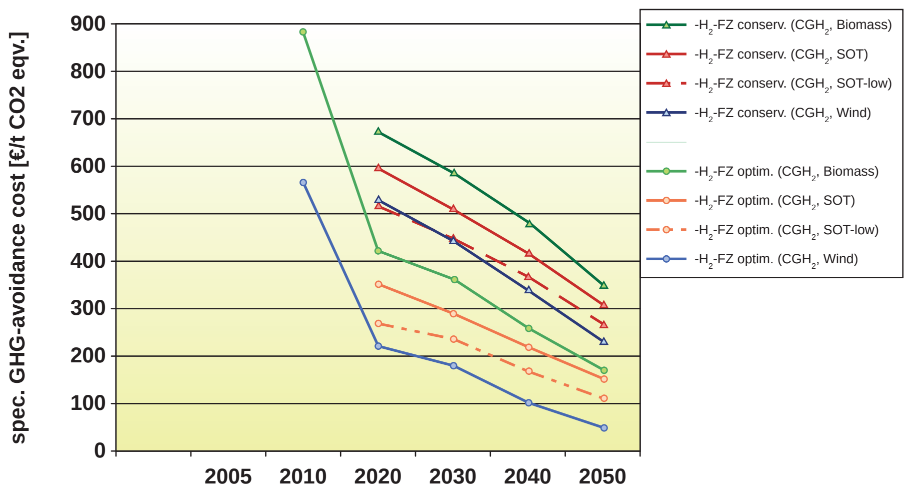
Many cities and countries are now actively promoting the retrofitting of high-urban-usage diesel vehicles with particulate filters. Though costly, the impact on emissions appears to be very favorable, but such retrofits do not have a positive impact on fuel economy. Other retrofit programs being piloted at present in the Philippines to install direct injection systems to in-use 2-stroke 2- and 3-wheelers can have regional importance. In this case, both emissions and CO_2 emissions may improve greatly.

G. IMPACT ON CLIMATE CHANGE AND LOCAL EMISSIONS

1. Greenhouse Gases

From 1990 to 2002, the total energy sector CO_2-equivalent emissions of the PRC, India, and emerging Asia combined grew from 37% to 48% of the OECD total,

Figure 10: Specific GhG Avoidance Cost of Hydrogen Options



CGH_2 = compressed gaseous hydrogen; CO_2 = carbon dioxide, H_2-FZ = hydrogen fuel cell; GhG = greenhouse gas; SOT = solar thermal.

Sources: Wuppertal Institute for Climate, Environment and Energy (WI) / Institute for Energy and Environmental Research (IFEU) / German Aerospace Center (DLR)

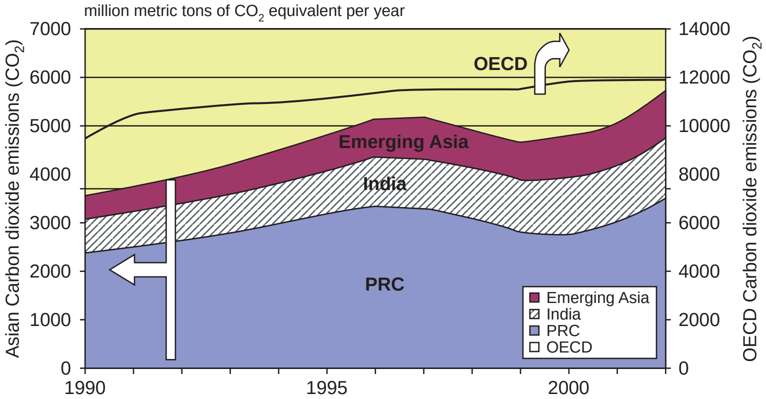
[38] Interviews with owners of privately-operated buses running on routes concessioned from the Bangkok Mass Transit Authority, April 2003.

with the major growth component coming from the PRC (Figure 11, Box 5).

Energy use in the transportation sector is currently dominated by petroleum product fuels and is growing fast. From 1971 to 1999, the combined CO_2-equivalent emissions from the transportation sector in emerging Asia grew faster than in developed economies, from 6% to 17% of the OECD total in this period (Figure 12).

This rate of growth is accelerating. Even if Asia were to follow the EU lead and adopt improvements in car fuel economy similar to those planned for the EU,[39] with the emerging Asia fleet increasing more than five times by 2030 and assuming efficiency gains and favorable changes in fleet mix, these are expected to still result in a fuels and GhG emissions growth of at least three times the 2000 levels (calculated from Fulton and Eads 2004).[40] Such a

Figure 11: Total Energy Sector CO_2-equivalent Emissions of the People's Republic of China, India, and Emerging Asia

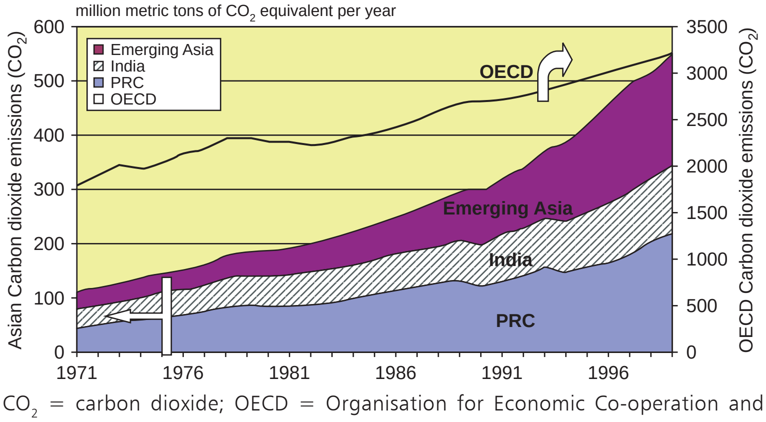


CO_2 = carbon dioxide; OECD = Organisation for Economic Co-operation and Development; PRC = People's Republic of China.

Note: The PRC, India, and emerging Asia relate to the scale on the left-hand side of the graph and OECD relates to the scale on the right-hand side.

Source: Carbon Dioxide Information Analysis Center (CDIAC). 2005.

Figure 12: CO_2-equivalent Emissions from Transportation in the People's Republic of China, India, and Emerging Asia



CO_2 = carbon dioxide; OECD = Organisation for Economic Co-operation and Development; PRC = People's Republic of China.

Note: The PRC, India, and emerging Asia relate to the scale on the left-hand side of the graph and OECD relates to the scale on the right-hand side.

Source: IEA. 2004.

[39] The fuel economy benchmark for 2012 is expected to be 27% better than 10 years earlier (European Federation for Transport and Environment 2006).

[40] Current projections from the PRC and India give higher numbers, however.

Box 5: Greenhouse Gas Scenarios from Road Transportation in Delhi

Delhi is a rapidly expanding megacity whose population of 13 million people in 2001 is expected to surpass 22 million by 2020. In 2000, it had about 2.6 million motor vehicles on-road (200 for every 1,000 inhabitants), a rate far higher than most cities with similar incomes. Rising incomes, combined with demand for greater personal mobility and inadequate public transport, will inevitably result in continuing increases in personal vehicle utilization and ownership, especially inexpensive scooters and motorcycles, and also cars.

In Delhi, GhG emissions from road transportation are expected to soar. Two GhG scenarios were created to characterize what is likely and what is possible. The first (high-GhG) scenario is an extrapolation of trends in Delhi, modified to reflect policies and commitments, but without taking into account the Supreme Court directives.

The second (low-GhG) scenario is an extrapolation of trends in Delhi taking into account the Supreme Court directives and premised on strong political and institutional leadership to enhance the economic, social, and environmental performance of Delhi's transportation system. In this scenario, conventional-sized cars drop from 30% to 19% of motorized travel between 2000 and 2020, and mass transit increases its share from 49% to 53%. More efficient scooters and minicars account for most of the remaining motorized travel, and bicycling becomes more important, especially for the poor.

The following important observations stand out:

- GhG emissions are expected to increase more than fourfold in the high-GhG, or business-as-usual, scenario but only double in the low-GhG scenario.
- Transportation policies are readily available that will not only slow emissions growth but also significantly improve local environmental, economic, and social conditions.
- Improved technology would maximize the efficiency of automobiles, buses, and other modes of transportation and could play a key role in reducing emission increases.

Keeping many travel mode options available—including small compact cars and new efficient scooters and motorcycles—will help individuals at various income levels meet their mobility needs.

In summary, GhG associated with road transportation will increase dramatically in Delhi in the coming decades, but many opportunities to slow the growth in vehicle use, pollution, GhGs, and traffic congestion are at hand at modest cost. Strong leadership is needed.

Source: Bose and Sperling. 2001.

decrease in the rate of growth might appear as a favorable development but it needs to be realized that the tripling in 2000 levels does not compare well with the EU and the Japanese Kyoto commitment for the same period, which is to reduce GhG emissions to 1990 levels. However, the EU will likely not reach its target, citing their high growth in GhG from transport as the overarching reason.

The growing number of private vehicles is a key determinant for fuel use and consequently for GhG emissions. Some efforts have been made to improve the fuel economy by issuing fuel economy standards. In the EU, a voluntary agreement with the association of vehicle manufacturers set a GhG standard for 2002 of 165 g/km CO_2. This was achieved because diesel-fueled vehicles are on average 10% lower in GhG emissions than gasoline (155 vs. 172 g/km CO_2). The agreement set a standard of 140 g/km CO_2 for 2008, with a possible extension to 120 g/km CO_2 for 2012.

Between 1995 and 2002, Japan also made a significant improvement in its fleet average fuel economy to tighter levels than the EU, and is now in the process of proposing stricter fuel efficiency standards. Assuming no change in the vehicle mix, these targets imply a 23% improvement in 2010 in gasoline passenger vehicle fuel economy and a 14% improvement in diesel fuel economy, compared with the 1995 fleet average of 14.6 km/L. According to the Japanese Government, this improvement will result in an average fleet fuel economy of Japanese vehicles of 15.1 km/L by 2010.

In the US, the Corporate Average Fuel Economy (CAFE) program, which was established in 1975 with the goal of reducing the country's dependence on foreign oil, maintains an important distinction between passenger cars and light trucks, with each having their own standard. This distinction was originally included when light trucks were a small percentage of the vehicle fleet. But with the increasing popularity of SUVs, this has changed. The CAFE standard for passenger cars has remained constant since 1985 at 27.5 miles per gallon (mpg), while the standard for light trucks was increased from 20.7 mpg in 2004 to 21.0 mpg for 2005.[41] The law also allows special treatment of vehicle fuel economy calculations for certain groups of vehicles. The overall result has been a 7% decrease in the light-duty fleet fuel economy since 1988, associated with the rapid growth of light trucks used as passenger vehicles (Feng and Sauer 2004).

Most emerging Asian nations, however, with the marked exception of the PRC, have not implemented fuel economy standards; in many countries, the increase in average vehicle weight due to the desirability of SUVs—and the move from 2-wheelers to cars—increases the difficulty of improving fuel economy.

Despite its large and growing contribution to overall GhG emissions, transportation is the sector where the least progress has been made in addressing cost-effective reductions. It is one of the last major sectors considered under the Global Environment Facility and only two transport projects to date are in condition to sell carbon bonds through the United Nations Framework Convention on Climate Change Clean Development Mechanism.[42] All incremental actions in these fields should help improve (reduce) the high growth perspective currently envisaged.

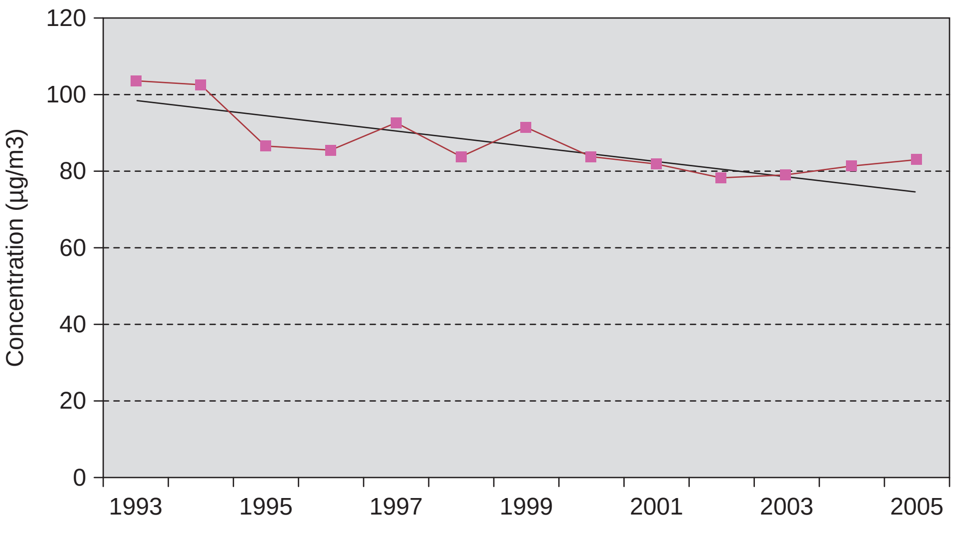
7. Local Pollutants

Many cities in Asia face problems with urban ambient air quality. In most cases, the transport sector is one of the most significant contributors to air pollution and tends to be geographically concentrated and especially damaging at street level where people live and work, including the poor and vulnerable groups such as the young and elderly who have limited mobility (ADB 2003).

The pollutants of main concern are PM, especially ultrafine particles, NO_x, and HC. Increasing NO_x levels contribute to an increase in ozone levels. An ongoing study by the CAI-Asia (2006) summarizing air quality data from 20 cities in Asia shows that, on average, pollution levels for PM_{10} have decreased approximately 20% over the last decade (Figure 13).

The burden of evidence that demonstrates the high impact of local pollution on the environment and human health is increasing. Ultrafine particles, such as those emitted by uncontrolled diesel vehicles, have

Figure 13: PM_{10} Trends for Selected Major Cities in Asia (1993–2005)



µg/m3 = microgram per cubic meter; PM_{10} = particulate matter.
Source: CAI-Asia. 2006.

[41] Further standards of 21.6 mpg for 2006 and 22.2 mpg for 2007 are also established.

[42] The Bogota "Transmilenio" project has a CDM-approved methodology and Mexico City signed an Emissions Reduction Purchase Agreement in 2005 with the Spanish Carbon Fund for Verified Emissions Reductions from its BRT pilot corridor.

been shown to have significant health impact costs and differences between regions are insignificant.[43] A pooled estimate of 39 studies (Borja-Aburto et al. 2001) showed a weighted estimate of a 1.01% increase in general, nonaccidental mortality for each 10 μg/m3 increase in PM_{10}.[44]

The costs of vehicle-generated air pollution are significant (Lohani 2005b) and are likely to increase if the growth in the vehicle fleet is faster than improvements in average in-use vehicle emissions.

H. CONGESTION AND ROAD SAFETY

The substantial growth in vehicle populations is clearly evident in the urban areas throughout the region in the form of increased congestion and road safety concerns, especially for the poor.

Authorities in many Asian megacities have now realized that it is physically impossible to build road infrastructure capacity faster than the growth rate in vehicle ownership and thus to reduce congestion. The recently adopted Urban Transport Policy in India calls for a more equitable road space focusing on people rather than vehicles (Ministry of Urban Development—Government of India [MUD-GOI] 2006). Additional innovative and equitable solutions are required. The UN (1999) and Allport (1996), quoted in Moriarty (2000), among others, have also recognized that simply providing more road space, even if the associated land and capital could be made available, is not a solution. Given the substantial private-vehicle future demand and ever-increasing space requirement caused by the move from 2- to 4-wheelers, any attempt to increase road space will quickly be absorbed by higher car ownership and use, with no long-term improvement in traffic speeds, air quality, or GhG emissions (Moriarty 2000).

Ten years ago, the peak-hour average speed for Asian cities was estimated to be 16 km/h, and many cities experienced much lower speeds (Kutoba 1996; Lewis 1994; UN 2004). Evidently, cars in many Asian cities spend much of their time stationary in traffic jams and this is worsening rapidly over time. As travel time per km increases, the fuel consumption per km increases substantially (as illustrated in Figure 14) with attendant increases in air pollution and GhG emissions (UN 2004).

The free mixing of pedestrians, NMTs, and animals with through-traffic on most of Asia's highways causes a high toll in road safety and directly impacts traffic speed and journey time. In Southeast Asia, inadequate road safety will cause 385,000 road deaths and 24 million injuries in the next 5 years, incurring more than $88 billion in economic losses, according to ADB-sponsored studies. Some 75,000 persons were killed and more than 4.7 million were injured in road crashes in Southeast Asian countries during 2003, with annual economic losses estimated at $15 billion, or 2.2% of the region's total gross domestic product (ADB 2005). Such huge recurring losses are not socially acceptable and, while great strides have been made to improve the safety of occupants in new vehicles, little attention—or funding—has been given in emerging Asia to improving road safety for pedestrians together with NMT and 2- and 3-wheeler users.

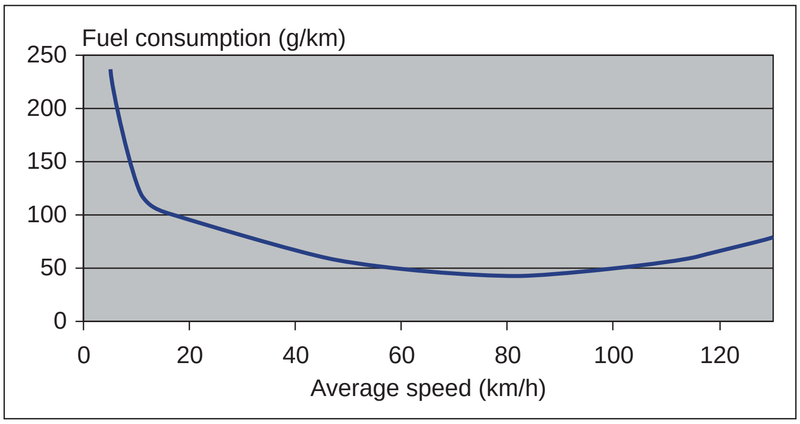
I. CONCLUSION

The trends and challenges presented in this chapter are each by themselves already serious; taken together they show the lack of sustainability of the mobility model that Asian cities have followed in the last few decades and that, unless a paradigm shift occurs, will prevail in the years to come. Emerging Asia is faced with these challenges, which need to be resolved for high economic growth to continue and improvements in quality of life to be sustainable. The growth of GhG emissions is directly related to GDP-inspired increases in passenger and freight intercity transport and increasing personal mobility, which also cause other national concerns in terms of energy security and imports, and local problems such as congestion, pollution, and poor road safety that together seriously risk restricting the high economic growth that originally caused them. Many of these challenges, even in the most optimistic scenarios, will get worse. A series of policy interventions that have co-benefits in each area needs to be urgently implemented for emerging Asia to reach its true potential.

43 A review of Asian health impacts studies conducted as part of the CAI-Asia Public Health and Air Pollution in Asia Program concluded that the Asian response to air pollution in terms of health impacts is largely the same as in Europe and the US. See Health Effects Institute (HEI) (2004) and Mar et al. (2005).

44 With a 95% confidence interval of 0.83–1.18% change for each 10 μg/m3 increase in PM_{10}.

Figure 14: Relationship between Average Speed and Fuel Consumption for a EURO II 1.4–2.0 Liter Displacement Gasoline Passenger Car



g/km = grams per kilometer; km/h =kilometers per hour.
Note: These calculations use the EEA, COPERT II formulae.
Source: World Bank. 1998.

Any vision on economic development, urbanization, and motorization for the period to 2025 involves a "post-Kyoto" view in which countries in emerging Asia will have to buy into the facts of climate change. Within this time frame, the largest countries will be solidly established among the largest worldwide emitters of GhG and will have to face the paradigm shift that is presented here. Delaying action and doing so at considerably higher levels of personal mobility, as currently forecast based on historic tendencies, will cause a greater cultural and economic shock than taking action today. Any delay in generating this paradigm shift will have severe long-term implications for the social and economic development of emerging Asia.