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Publication Stock No. 110202

Published by the Asian Development Bank
P.O. Box 789, 0980 Manila, Philippines

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Preface

Concerned with the increasing levels of air pollution caused by motor vehicles in Asia's major cities, Asian Development Bank initiated a project on *Reducing Vehicle Emissions* in November 2000. The project collected and disseminated information on policies to reduce vehicle emissions through the Reducing Vehicle Emissions in Asia website (http://www.adb.org/vehicle-emissions), an information portal on international, regional, national and city level experiences in reducing vehicle emissions.

Through five workshops, the project provided a venue for the sharing of experiences between countries in Asia and the introduction of best practices on reducing vehicle emissions from other regions—

- **Fuel Quality, Alternative Fuels, and Advanced Vehicle Technology** held on 2–4 May 2001 in New Delhi, India,
- **Reducing Emissions from Two and Three Wheelers** held on 5–7 September 2001 in Hanoi, Viet Nam,
- **Strengthening Vehicle Inspection and Maintenance** held on 7–9 November 2001 in Chongqing, PRC,
- **Transport Planning, Demand Management and Air Quality** held on 26–27 February 2002 in Manila, Philippines, and
- **Concluding Workshop on Reducing Vehicle Emissions** held on 28 February–1 March 2002 in Manila, Philippines.

The project supported the formation of multi-sector action plan groups and the formulation of three action plans—"Integrated Vehicle Emission Reduction Strategy for Greater Jakarta, Indonesia," "Strengthening Vehicle Inspection and Maintenance in Chongqing, People's Republic of China," and "Integrated Action Plan to Reduce Vehicle Emissions in Viet Nam." It provided resources for two studies—"Study on Air Quality in Jakarta, Indonesia: Future Trends, Health Impacts, Economic Value and Policy Options" and "Pricing and Infrastructure Costing for Supply and Distribution of CNG and ULSD to the Transport Sector in Mumbai, India."

The *Policy Guidelines for Reducing Vehicle Emissions in Asia* consist of five main books with these titles:

- Reducing Vehicle Emissions in Asia
- Cleaner Fuels
- Cleaner Two and Three Wheelers
- Vehicle Emissions Standards and Inspection and Maintenance
- Transport Planning and Traffic Management for Better Air Quality

These books come with a common appendix on the *Adverse Health and Environmental Effects from Vehicle Emissions* printed as a separate book to clearly demonstrate the health and environmental impacts caused by air pollution from vehicles.

These policy guidelines, which are based on the five workshops organized by the project, provide an in-depth analysis of the different components of an integrated strategy to reduce pollution from vehicles in Asia. Policymakers in Asia will have to combine the general principles outlined in the policy guidelines with their knowledge of the local situation in their countries and cities to arrive at effective strategies.

The *Reducing Vehicle Emissions* project produced its final report in a CD-ROM containing the workshop presentations, action plans, studies, and policy guidelines.

Abbreviations

ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
CNG	compressed natural gas
CO	carbon monoxide
COPD	chronic obstructive pulmonary disease
ESCAP	Economic and Social Commission for Asia and the Pacific
GNP	gross national product
g/km	gram per kilometer
g/l	gram per liter
HC	hydrocarbon
I/M	inspection and maintenance
kPa	kilopascal
LPG	liquified petroleum gas
mg/m^3	microgram per cubic meter
NMV	nonmotorized vehicle
NO_x	nitrogen oxides
ppm	parts per million
PM	particulate matter
PM_{10}	particulate matter less than 10 microns
psi	pound per square inch
RPM	revolutions per minute
RVP	Reid vapor pressure
SMS	short messaging service
SPM	suspended particulate matter
TDM	travel demand management
TSM	transport systems management
TSP	total suspended particulate
ULSD	ultra low sulfur diesel
VOC	volatile organic compounds
WHO	World Health Organization

What is the problem?

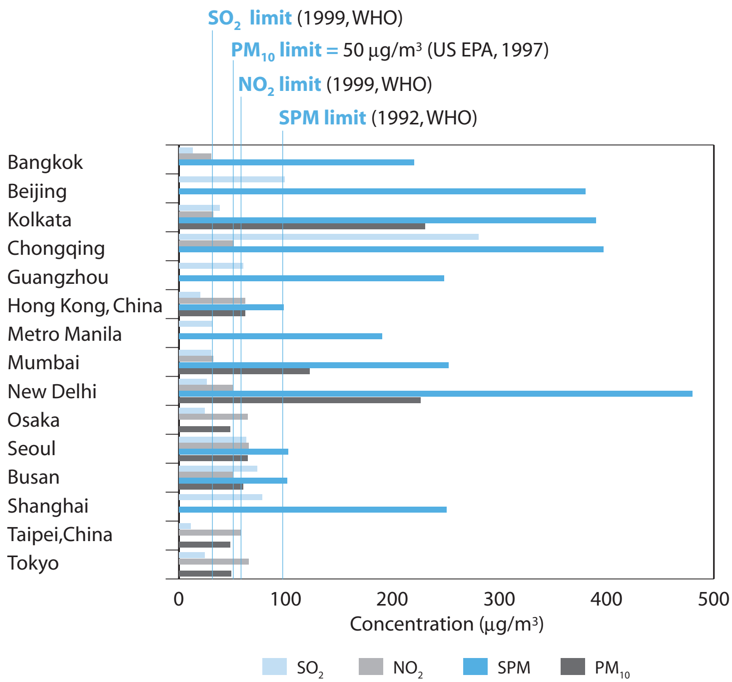
The growth in mobility in Asia helps Asian countries in their economic development. At the same time the increased air pollution that is associated with the growth in mobility also has a negative impact on development. More people die prematurely or get sick more often because of increased pollution. This results in considerable financial and economic costs for households and the national economies in Asia.

For Asia, far less research has been carried out on the impact of air pollution on the health of its citizens. This is a reflection of the general weak capacity in Asian countries to undertake research on the health impact of air pollution in Asia

In many cases, air quality in Asian cities does not meet the standards set by World Health Organization (WHO). Pollution levels above the WHO standards mean that the health of people breathing the air is negatively affected. Figure 1 shows the average air quality in 15 mega cities in Asia from 1990 to 1999, in relation to the WHO air quality standards and the United States Environmental Protection Agency (US EPA) standards for particulate matter less than 10 microns (PM_{10}). It can be seen that especially suspended particulate matter (SPM) and PM_{10} is a serious problem.

Research carried out in the US and Europe, clearly established the relationship between exposure to air pollution and health problems such as cardiovascular disease, asthma and other respiratory diseases. For Asia, far less research has been carried out on the impact of air pollution on the health of its citizens. This is a reflection of the general weak capacity in Asian countries to undertake research on the health impact of air pollution in Asia. Also, comprehensive baseline data on air quality and health problems are often not available or not very reliable when available. The

Figure 1
Average Annual Pollution Concentrations, by city (1990-1999)



Source: World Health Organization (WHO), Air Information Management Database

World Health Organization estimates of mortality indicate that on a yearly basis about 800,000 people die prematurely because of exposure to urban outdoor air pollution. Of these, about 500,000 are believed to be in Asia. The burden of disease expressed in Disability Adjusted Life Years (DALY) indicates that out of the 6.4 million affected, 3.8 million are in Asia.[1] Individual health impact studies carried out in Asia are in line with these general estimates. The same negative impacts which were reported in health impact studies carried out in other parts of the world also occur in Asia. Air pollution, in addition to health impacts, also leads to substantial financial and economic costs to households, industry and government in Asia. The great differences in the range of the health cost estimates reported in the succeeding paragraphs in a number of Asian cities illustrate the need for more comprehensive air quality impact studies in Asia.

- The Shanghai Energy Option and Health Impact Study estimated the number of excess chronic obstructive pulmonary diseases (COPD) in Shanghai due to total suspended particulate matter (TSP) at 173,500 in 1990. The number of excess chronic bronchitis cases in urban districts of Shanghai due to TSP exposure in 1999 was estimated at 30,800, among which 15,200 occurred in people 45-60 years of age. Improvements in TSP levels due to various types of interventions reduced the number of excess deaths associated with TSP exposure from 2,300-9,000 in the ten urban districts of Shanghai in 1990 to 450-2,000 in 1999, a 78-80% reduction compared to1990.[2]
- In Taipei, China, researchers observed associations between asthma development and a number of individual pollutants, with an aggregate increase in prevalence by as much as 29%. The researchers surveyed 165,173 high school students aged 11 to 16 in two communities. It was observed that there is a statistically significant association between outdoor air pollution and asthma taking into consideration different confounding variables that may influence the results.[3] A similar study in Hong Kong, China on school children aged 8-12, found that as air pollution increased, the ability to breathe normally, as measured by the lung function tests, dropped and the prevalence of respiratory complaints increased.[4]
- A 1997 World Bank study on New Delhi, India illustrates the positive significant relationship between particulate pollution and daily non-traumatic deaths, as well as deaths from certain causes (respiratory and cardiovascular problems) for certain age groups. It was projected that a 100 mg/m^3 increase in total suspended particulates (TSP) in New Delhi would result in a loss of about 51,403 life years. This is equivalent to about 1,385 lives in a year, distributed among different age groups. During the study period (between 1991-1994), the average TSP level in New Delhi was 378 mg/m^3—approximately five times the WHO annual

Box 1 Health impacts of common pollutants

Carbon monoxide (CO) affects especially persons with heart disease, and fetuses.

Nitrogen oxides (NO_x) is linked to a wide range of respiratory problems; cough, runny nose, and sore throat are among the most common.

Ozone can cause chest pain, coughing, and shortness of breath. When inhaled, ozone can cause temporary decreases in lung function of 15 to over 20% in healthy adults.

Lead exposure will lead to a decrease in intelligence quotient and can, in some cases, also lead to premature deaths.

Particulate matter (PM) is associated with premature death, aggravation of respiratory and cardiovascular disease, and decrease in lung function.

average standard.[5] Another World Bank study concluded that air pollution in Mumbai, India causes 2,800 cases of premature mortality, 60 million respiratory symptom days, and 19 million restricted activity days, all of which are valued at a total cost of 18 billion Indian rupees per year.[6]

- Findings from a World Bank study in Bangkok, Thailand estimated a financial loss due to air pollution for exposed families at 131 baht per family per month. The benefits derived from a 20 mg/m^3 reduction in annual average PM_{10} concentrations in Bangkok were expected to result in an estimated savings of US$1.6 billion to US$4.2 billion.[7] A more recent estimate of the World Bank on the health costs of PM_{10} amounts to US$424 million for 2000.[8]
- In Jakarta, Indonesia, studies of Ostro (1994) and DeShazo (1996) estimated the annual cost to have reached $2.16 billion (equivalent to 2% of GNP) from the health effects of particulates and lead that exceeded levels of WHO standards.[9] In Thailand, studying the effects of the same pollutants, O'Connor (1994) found that the costs amount to $1.6 billion, also equivalent to 2 percent of GNP.[10] Another study conducted by the World Bank reported that particulate matter in Jakarta, Indonesia resulted to a total of 4,364

premature deaths, 32 million restricted activity days, 101 million respiratory symptom days, innumerable emergency room visits, asthma attacks, cases of bronchitis in children, and hospital admissions.

- In the Philippines, a WHO-sponsored study on the exposure of a sample population to vehicular emissions in 1990 and 1991 in Manila showed that chronic respiratory symptoms are significantly higher among jeepney (local transport mode) drivers than commuters and air-conditioned bus drivers. The study showed relative exposure of a sample population within a day is directly proportional to the risk of contracting or aggravating respiratory diseases. The total estimated damage to health was valued at US$11.36 million to US$17.03 million during 1994 in Metro Manila using the contingent valuation method where the respondents were asked about their willingness-to-pay to reduce damage. This estimate was considered very low because the respondents were not aware of dose-response relationships.[11] A more recent study estimates the costs of PM emissions in the Metro Manila area at US$392 million per year based on the number of excess deaths and occurrence of chronic bronchitis for 2001.[12]

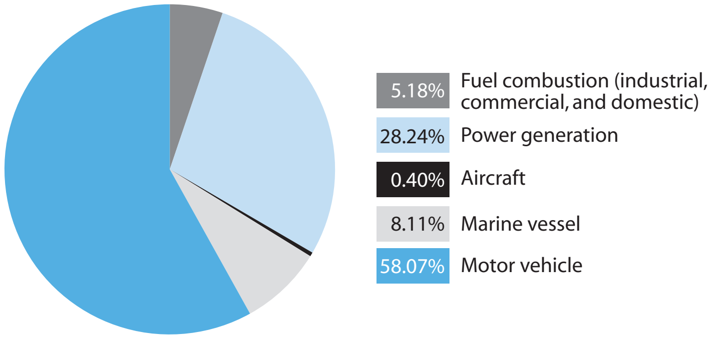
Why is there a problem?

Air pollution in Asian cities comes from different sources such as mobile sources like buses, trucks, cars or motorcycles; stationary sources or industries; or from area sources like garbage burning. Studies, such as the one on the Asian Brown Cloud, demonstrate that the air quality in a particular location is also influenced by pollution generated elsewhere and which is transported through the atmosphere.[13]

In the majority of Asian cities, mobile sources are the most significant contributor to air pollution. This is especially so for PM, CO and NO_x, the pollutants that most often do not meet the ambient air quality standards. Mobile sources are expected to continue to be the main source of pollution in the future. There is still a very large unsatisfied demand among households and individuals who would like to buy a motorcycle or a car once they can afford it. Most cities in Asia do not have adequate plans to improve public transportation to a level that will convince vehicle owners to use public transport more frequently instead of using a car or motorcycle. Considering that Hong Kong, China is one of the few cities in Asia that has adequate public transportation system in place, it is significant that motor vehicles remain to be the major source of particulate matter emissions (Figure 2). Another reason why it is likely that mobile sources will remain the dominant source of pollution is that it is relatively easier to control pollution from new stationary sources through imposing restrictions in location or technology used.

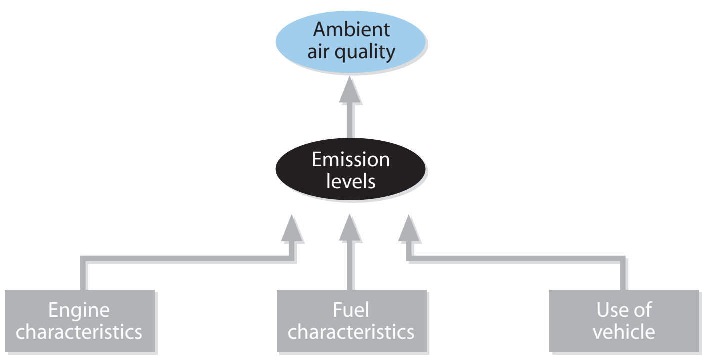
Most cities in Asia do not have adequate plans to improve public transportation to a level that will convince vehicle owners to use public transport more frequently instead of using a car or motorcycle

Figure 2
Hong Kong, China Particulate Matter Source Apportionment for 1999



The level of pollution by individual vehicles is influenced by a number of factors. Important are the engine characteristics and the use of emission control devices such as a catalytic converter. Related to this is the maintenance of the engine and pollution control devices where used. Fuel type and quality is the second main factor which determines the level of emissions. In gasoline, the amount of lead used to be most important, but now that most Asian countries have banned the sale of leaded gasoline, attention has been shifted to sulfur, benzene and aromatics. For diesel, the sulfur levels are the most important parameter determining the emission levels. Emission levels are also influenced by the manner a vehicle is used. Cars in heavy traffic which have to stop repeatedly because of traffic congestion pollute considerably more than cars which operate in free flow conditions.

Figure 3
Factors Influencing Levels of Vehicle Emissions



What will happen to the pollution from vehicles in Asia if nothing is done?

Motorization in Asian countries is growing at different rates (see Figure 4). Influenced by the population growth and the growth in affluence, the number of vehicles in Asia will continue to grow, with the possible exception of Singapore and Hong Kong, China where active controls have been put in place to limit the number of vehicles and where alternative public transport options have been implemented.

The large majority of additional vehicles will be new ones. However, every year there is a substantial number of rebuilt vehicles added to the fleet. These are often buses or other public transport utility vehicles built around second hand engines imported from either Japan or other places where stringent in-use emissions and safety requirements have made these engines obsolete. These are typically vehicles which are used intensively and not maintained very well. At present, vehicles in Asia have a longer useful life than in major industrialized countries. These factors, in combination, will lead to a situation with a growing number of vehicles on the road many of which do not have proper emission controls in place.

As a consequence of the growth in the number of vehicles in Asia, the number of people dying prematurely will increase, labor productivity and quality of life due to exposure to poor air quality will be negatively affected

The example of Jakarta shows that emission loads for key pollutants in Jakarta will go up by as much as 2–3 times if no action is taken (see Figure 5).[14] This in a situation where present ambi-

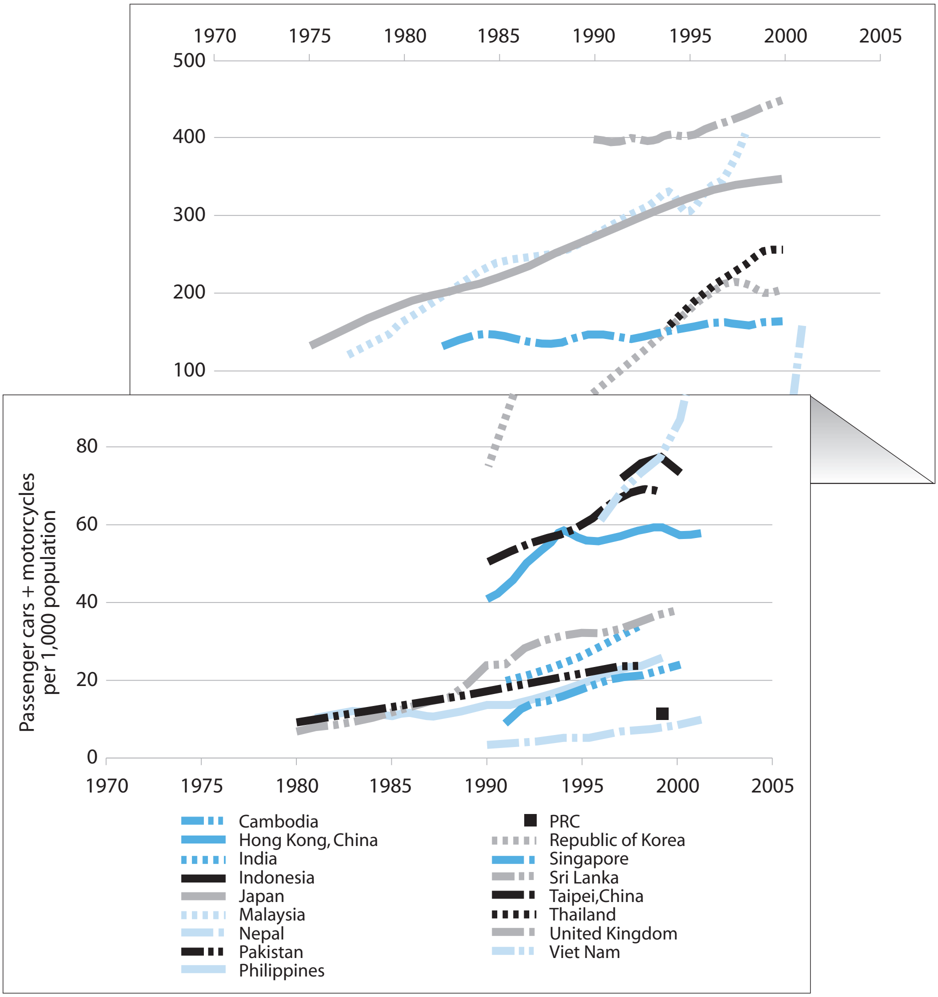


Figure 4
Selected Motorization Trends

Notes

1. Motorization includes registered private cars and motorcycles
2. Vehicle registrations in some developing countries are known to overstate actual in-use fleet. In Thailand, for example, the in-use fleet was half of the 1999 registered fleet

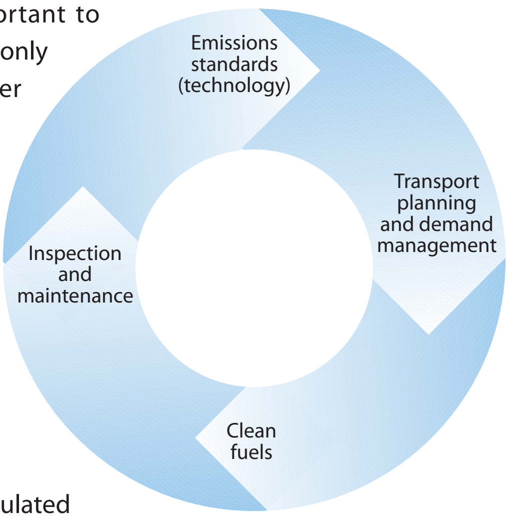
Sources: Cambodia Ministry of Public Works and Transport; Hong Kong, China Transport Department website; Paper on "Modeling Anthropogenic Emissions from Energy Activities in India: Generation and Source Characterization" of the Ohio Supercomputer Center website; Indonesian Police Department (Ditlantas Polri); Japan Statistics Bureau and Statistics Center website; Malaysian Roads General Information 1999 of Malaysia Road Transport Department; Nepal Department of Transport Management; Pakistan Statistical Yearbook 2000, Federal Bureau of Statistics; Philippines Department of Transportation and Communication; PRC "World Development Indicators 2001" of World Bank website; Statistical Yearbook 2001 of Republic of Korea Ministry of Construction and Transportation; Singapore Land Transport Authority website; Sri Lanka Ministry of Transport; Taipei,China Department of Transportation website; Thailand Department of Land Transport, Ministry of Transport and Communications; "Transport Statistics Great Britain: 2002 Edition" of United Kingdom Department of Transport website; Vietnam Register; Population statistics for all countries from University of Utrecht website

Solutions to the problem

The need for an integrated, location specific strategy

Pollution from mobile sources is caused by several factors. The relative weight of these factors will be different from place to place. Solutions adopted to address pollution from mobile sources need to be integrated solutions which address the most common contributing factors (1) improvements in emissions standards and technology; (2) improved inspection and maintenance; (3) cleaner fuels; and (4) improved transport planning and traffic demand management. Although, the strategies adopted will differ from place to place, due to the specific nature of the problem to be addressed, it is important to realize that some of the measures can only be taken together with specific other measures. This is especially true for the imposition of tighter emissions standards, both for new and in-use vehicles, which cannot be done without the imposition of stricter standards for cleaner fuels.

Figure 6
Elements of a Comprehensive Vehicle Pollution Control Strategy



Emissions standards and vehicle technology

Emissions from motor vehicles are regulated through new vehicle standards and through in-use standards. The responsibility for setting vehicle standards rests usually with the national government. In some countries in Asia, local government agencies have the mandate to set in-use standards provided that these are more strict than national standards.

Imposing tighter vehicle emissions standards does not usually result in direct additional costs for the government. Costs are usually passed on completely to vehicle owners. Governments can stimulate the purchase of cleaner vehicles by giving tax credits to buyers of vehicles that produce fewer emissions than the current emissions standards, as has been successfully done in some European countries.

New vehicle standards

The majority of governments in Asia have adopted the Euro emissions standards for new gasoline and diesel vehicles. This makes it easier for Asian countries to benefit from the experiences of those countries, which have adopted Euro standards, in deciding when and how fast to tighten emissions standards. Obviously, the use of the same type of standards across Asia also has great advantages for the auto industry.

New vehicle standards must be closely linked to fuel requirements as more advanced engine and emission control technologies are not functional or diminished by lead in gasoline and sulfur levels in diesel or gasoline. If the long-term aim is to introduce Euro 4 for light duty vehicles and Euro 5 standards for heavy duty diesel vehicles, it is important that the corresponding main gasoline and diesel specifications specified in Table 1 are adopted simultaneously.

Table 1
European Standards for Gasoline and Diesel Fuel that Coincide with Gasoline- and Diesel-Fuelled Vehicle Standards

	Gasoline		Diesel
Standard	**Lead**	**Sulfur (ppm)**	**Sulfur (ppm)**
Euro 1	0	NA	NA
Euro 2	0	500	500
Euro 3	0	150	350
Euro 4	0	50[a]	50[a]
Euro 5[b]	NA	NA	50[a]

ppm = parts per million, NA = not applicable
[a] 10 PPM is in the late stages of Adoption by the European Union
[b] Heavy Duty Diesel Engines Only

In developing more stringent emissions standards, countries in Asia should agree to harmonize standards. This is in the interest of the auto industry, since it will reduce the complexity of the industry. This will lead to cost savings for the auto industry, which can be passed on to the consumer. Harmonized emissions standards will facilitate the adoption of harmonized test procedures. This makes it easier for governments in Asia to ensure that vehicles sold in the Asian market meet appropriate emissions standards. Harmonization can best be done in the context of the World Forum for Harmonization of Vehicle Regulations (WP 29),[15] whereby regional coordination and consultation can also take place through regional bodies such as ESCAP or ASEAN and multisectoral bodies such as the Clean Air Initiative for Asian Cities.

A short- and medium-term plan for adopting vehicle and fuel standards should be adopted by governments in Asia so that the vehicle and fuels industry will have sufficient time to adapt. In Europe it was decided that the most strict emissions standards for light duty vehicles, Euro 4, will become effective by 2005. Based on expected developments in engine technology and fuel refining, the longer-term goal for each country in Asia should be parity with European new vehicle (Euro 4 for light duty vehicles and Euro 5 for heavy duty) standards and fuel standards by 2010 at the latest. Vehicles complying with 2010 US standards would also be acceptable. As Table 2 indicates, Asian countries still have long way to go in order to achieve this aim. There are only a few countries that at present have announced standards that go beyond Euro 2.

To determine whether new vehicles entering the market meet the emissions standards, tests of these new models are carried out which are known as type approval tests. These are comprehensive and in-depth tests. In addition to emission tests, a larger number of tests is also carried out to test the roadworthiness of the vehicles. Not all countries in Asia have the facilities to carry out type approval testing. While it is desirable that in the medium or long term such a capacity be established, development of type approval facilities should not be prioritized at the expense of

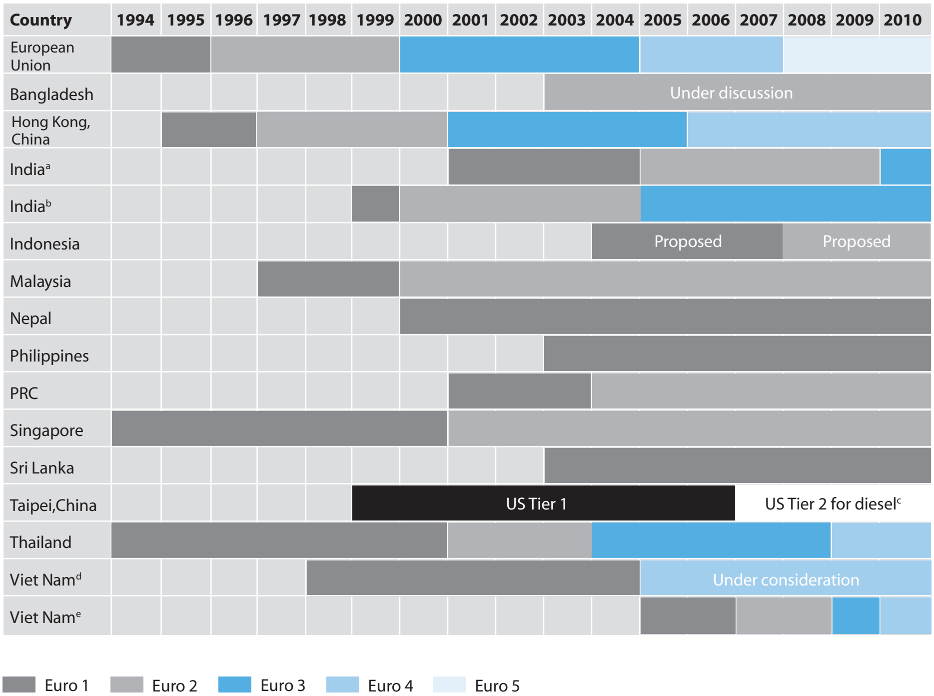


Table 2
Emissions Standards for New Vehicles (Light Duty) in Asia

[a] Entire country
[b] Delhi and other cities; Euro 2 introduced in Mumbai, Kolkata and Chennai in 2001; Euro 2 in Bangalore, Hyderabad, Kanpur, Pune and Ahmedabad in 2003; Euro 3 to be introduced in Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad and Ahmedabad in 2005
[c] Gasoline vehicles under consideration
[d] For gasoline vehicles
[e] For diesel vehicles

implementing actual control measures to reduce pollution from mobile sources. In the interim, the most commonly used arrangement is to accept the test results of the vehicle type in the country of origin.

Because the number of two- and three-wheeled vehicles is much greater in Asia than in other parts of the world and the pollution from these vehicles is so severe, especially in places where 2-stroke engines are most common, it is important to have separate emission standards for two- and three-wheeled vehicles.

Country	Effectivity	Vehicle Type	Standards: CO	HC	$HC + NO_x$	Remarks
Bangladesh	—	—	3.5 g/km	—	2.0 g/km	Under discussion test = ECE R40
Cambodia	current	2-stroke	4.0%	3,000 ppm	—	Idle test
	current	4-stroke	4.0%	2,400 ppm	—	Idle test
Hong Kong, China	current	4-stroke	13.0 g/km	3.0 g/km	0.3 g/km (NO_x only)	
	current	2-stroke	8.0 g/km	4.0 g/km	0.1 g/km (NO_x only)	
India	2000	2- and 4-stroke	2.0 g/km	—	2 g/km	As per IDC
	2005 proposed	2- and 4-stroke	1.5 g/km	—	1.5 g/km	As per IDC; Deterioration factor = 1.2
	2005	3-wheel gas	2.25 g/km	—	2.0 g/km	
	2005	3-wheel diesel	1.0 g/km	—	0.85 g/km	
Indonesia	2001	2- and 4-stroke	12.0 g/km	—	10.0 g/km	ECE R47
	2004	2- and 4-stroke	8.0 g/km	—	5.0 g/km	ECE R47
	2007 proposed	2- and 4-stroke	5.0 g/km	—	3.0 g/km	ECE R47
Japan	current	2-stroke	14.4 g/km	5.26 g/km	—	
	current	4-stroke	20.0 g/km	2.93 g/km	—	
Malaysia	2003 proposed	2-stroke	8.0 g/km	4.0 g/km	0.1 g/km (NO_x only)	97/24/EC
	2003 proposed	4-stroke	13.0 g/km	3.0 g/km	0.3 g/km (NO_x only)	97/24/EC
Philippines	current	2- and 4-stroke	6.0%	—	—	Idle test
	2003	2- and 4-stroke	4.5%	—	—	Idle test
PRC	2003	2-stroke	4.0%	4,000 ppm	—	Idle test
	2003	4-stroke	4.0%	1,000 ppm	—	Idle test
Beijing	2001	2-stroke	1.50%	3,000 ppm	—	Idle test
	2001	4-stroke	1.50%	300 ppm	—	Idle test
Singapore	current	2- and 4-stroke	12.0 g/km	—	5.0 g/km	must comply with US 40 CFR 86.410-80
Sri Lanka	current	2- and 4-stroke	6.0 g/km	—	—	Low-idling
Taipei,China	current	2- and 4-stroke	4.0%	6,000 ppm	—	Idle warm test
	2004, January	2- and 4-stroke	3.0%	2,000 ppm	—	Idle cold test
Thailand	current	2- and 4-stroke	4.5 g/km	3.0 g/km	—	Free acceleration; 30% white smoke
	2003, July	2- and 4-stroke	3.5 g/km	—	2.0 g/km	Evaporative emission 2g test; 15% white smoke
	2004, July	2- and 4-stroke	3.5 g/km	—	1.8 g/km	Without evaporative emission standard;15% white smoke
Viet Nam	2004 proposed	2- and 4-stroke	4.5 g/km	—	3.0 g/km	
	2007 proposed	2- and 4-stroke	3.5 g/km	—	2.0 g/km	
	2004 proposed	Moped	6.0 g/km	—	3.0 g/km	For 3 and 4 wheelers multiply by 2
	2007 proposed	2-wheel Moped	1.0 g/km	—	1.2 g/km	
	2007 proposed	3- and 4-wheel Moped	3.5 g/km	—	2.4 g/km	

97/24/EC = Directive 97/24/EC of the European Parliament and of the Council of 17 June 1997 on certain components and characteristics of two or three-wheel motor vehicles, CO = carbon monoxide, ECE R40 = Economic Commission for Europe Regulation 40 - Emission of gaseous pollutants of motorcycles, ECE R47 = Economic Commission for Europe Regulation 47 - Emission of gaseous pollutants of mopeds, g/km = gram per kilometer, HC = hydrocarbons, IDC = Indian Drive Cycle, NOx = nitrogen oxides, ppm = parts per million, US 40 CFR 86.410-80 = United States Code of Federal Regulations (US 40 CFR 86.410-80) emissions standard

Table 3
Emissions Standards for New Motorcycles in Asia

In this case it is recommended that countries in Asia must consider leapfrogging to emissions standards adopted by India or Taipei,China, or the even more stringent new EU standards which will become effective in 2006.

Particulate matter is currently not regulated for two and three wheelers. Once practical test methods have been developed for measuring PM levels in the emissions of two and three wheelers, standards should also be formulated for PM.

In recent years, 2-stroke engine technology for motorcycles has been substantially improved and at present the environmental performance of such new 2-stroke powered motorcycles is approaching parity with those of 4-stroke engines. Based on this, policymakers in Asia should avoid imposing bans on 2-stroke technology but instead regulate emissions from new two and three wheelers through setting tight emissions standards that have to be met by both 2- and 4-stroke powered motorcycles.

In–use standards

As new vehicle standards are tightened, in-use vehicle standards should also be tightened. These in-use standards should form the basis for routine vehicle emission inspections carried out as part of the inspection and maintenance (I/M) program or for roadside apprehension programs. Criteria pollutants which should be regulated for in-use vehicles are: for diesel-fuelled vehicles, PM, smoke and NO_x; for gasoline-fuelled vehicles, CO, HC and NO_x; and for two and three wheelers, CO, HC and smoke.

Considering that the average lifetime of vehicles in Asia is much longer than in Europe or the US, this will lead to a growing diversification of in-use standards in Asian countries as the emissions standards for new vehicles become more strict.

Not all Asian countries have regulated emissions of in-use vehicles. In cases where such regulations exist, there are differences in the pollutants that are regulated, in vehicle types and vehicle age. Not enough discussion has taken place on the appropriate emissions standards for different categories of in-use vehicles. As a consequence, different countries apply different standards for the same vehicle type of the same age (see Tables 4 and 5). As in the case of new emissions standards, it is also important that a medium-term strategy for in-use standards be developed in co-operation with the auto, transport and oil industry.

Apart from the emissions standards for in-use vehicles, it is also important to regulate the type of testing that will be used to assess whether the standards are being met. Currently the idle test is being used for gasoline-fuelled vehicles in the majority of countries and for diesel-fuelled vehicles, the free acceleration test is being used. The advantage of these tests is that they are easy to carry out and the equipment required is cheap. The main disadvantage is that the tests do not give a good idea of whether the more sophisticated pollution controls such as a catalytic converter, that more and more cars are equipped with, are operating properly. So-called loaded tests are more suitable for this purpose, but different and more expensive equipment is required for such tests. Policymakers will have to prepare themselves for legislating both tighter in-use emissions standards and more complex test procedures.

Considering that the average lifetime of vehicles in Asia is much longer than in Europe or the US this will lead to a growing diversification of in-use standards in Asian countries as the emissions standards for new vehicles become more strict

Emissions standards for in–use two and three wheelers is another area that will require considerably more attention from policymakers in Asia. In the majority of cases, only CO and HC are regulated and only idle tests are prescribed. As in the case of emissions standards for new motorcycles policymakers in Asia should take their lead in the formulation of in-use standards for two and three wheelers from Taipei,China and India. In phasing in tighter emissions standards for in-use motorcycles it could be considered to follow the example of the People's Republic of China, which has legislated initial stricter standards for Beijing than for the country in general (see Table 6).

Table 4
Emissions Standards for In-Use Gasoline Vehicles in Asia

Country	Effectivity	CO (%)	HC (ppm)	Test
Bangladesh	—	24.0 g/km	2.0 g/km	Dynamic
Cambodia	Current	4.5	10,000	Idle
Hong Kong, China	Current	0.5	—	Low idle or in accordance with manufacturers' specifications
		0.3		High idle, $\lambda = 1 \pm 0.03$ or in accordance with manufacturers' specifications
India	Current	3.0		Idle
Indonesia	Current	4.5	1200	Idle
Malaysia	Current	3.5-4.5	600-800	Idle
Nepal	Current	3.0	1000	—
Pakistan	Current	6.0		Idle
Philippines	Before 1997 January	4.5	800	Idle
Philippines	1997	3.5	600	Idle
Philippines	2003	0.5	100	Low idle At high idle CO limit = 0.3 ($\lambda = 1 \pm 0.03$) or in accordance with manufacturers' specifications
PRC[a]	Current	4.5	900	Idle
PRC[b]	Current	4.5	1200	Idle
Singapore	Current	3.6-6.0		Idle
Sri Lanka	Before 1998	4.5	1200	Low idling
Sri Lanka	After 1998	3.0	1200	Low idling
Thailand	Before 1993 November	4.5	600	Idle
Thailand	After 1993 November	1.5	200	Idle
Viet Nam[c]	Proposed 2002 December	6.0[d]	1500	Idle
Viet Nam[c]	Proposed 2005	4.5[e]	1200	Idle
Viet Nam[c]	Proposed 2008	3.0[f]	600	Idle

CO = carbon monoxide, g/km = gram per kilometer, HC = hydrocarbons, ppm = parts per million
[a] For light duty vehicles
[b] For heavy duty vehicles
[c] Applicable in Hanoi, Ho Chi Minh, Hai Phong, Da Nang
[d] Rest of country CO limit = 6.5%
[e] Rest of country CO limit = 6.0%
[f] Rest of country CO limit = 4.5%

Table 5
Emissions Standards for In-Use Diesel Vehicles in Asia

Country	Effectivity	Smoke (HSU)	Test
Bangladesh	—	65	—
Cambodia	Current	50	—
Hong Kong, China	Current	60	Free acceleration
		50	Loaded lug down test on a chassis dynamometer[a]
India	Current	65	Free acceleration
Indonesia	Current	50	Free acceleration
Malaysia	Current	50	—
Nepal[b]	Current	65	—
Pakistan	Current	40	Free acceleration
Philippines	Current	2.5 m^{-1}	Free acceleration[c]
Philippines	2003	1.2 m^{-1}	Free acceleration[d]
PRC	Current	4.5 Rb	Free acceleration
Singapore	Current	50	—
Sri Lanka	Current	65	Idle
Sri Lanka	Current	75	Free acceleration
Thailand	Current	45	Free acceleration
Thailand	Current	35%	Loaded
Thailand	Current	50	Filter test – free acceleration
Thailand	Current	40%	Filter test – loaded
Viet Nam[e]	Current	72	Idle
Viet Nam[f]	Current	85	Idle
Viet Nam[g]	2005	72	Idle

HSU = Hartridge smoke unit, m^{-1} = light absorption coefficient, Rb = Filter or Bosch smoke meter unit
[a] For vehicles apprehended under the Smoky Vehicle Control Program
[b] For vehicles manufactured in 1995 and beyond
[c] For naturally aspirated engines, limit is 2.5 m^{-1} for turbo-charged engine and 4.5 m^{-1} for a 1,000 m increase in elevation
[d] For naturally aspirated engines, limit is 2.2 m^{-1} for turbo-charged engine and 3.2 m^{-1} for a 1,000 m increase in elevation
[e] Applicable in Hanoi, Ho Chi Minh, Hai Phong, Da Nang
[f] Rest of country
[g] Limit is 50 HSU for newly registered vehicles starting 2005

Country	Effectivity	Vehicle Type	Standards CO (%)	Standards HC (ppm)	Remarks
Bangladesh	—	—	24 g/km	2 g/km	Under discussion
Cambodia	current	2- and 4-stroke	4.5	10,000	Idle test
India	current	2- and 4-stroke	4.5	9,000	Idle test
Indonesia	current	2-stroke	4.5	3,000	Idle test
	current	4-stroke	4.5	2,400	Idle test
Philippines	current	2- and 4-stroke	6	—	Idle test
PRC	before 2003 July	2-stroke	4.5	8,000	Idle test
	before 2003 July	4-stroke	4.5	2,200	Idle test
	after 2003 July	2-stroke	4.5	4,500	Idle test
	after 2003 July	4-stroke	4.5	1,200	Idle test
Beijing	before 2001 January	2-stroke	4.5	8,000	Idle test
	after 2001 January	2-stroke	2	3,500	Idle Test
	before 2001 January	4-stroke	4.5	2,200	Idle Test
	after 2001 January	4-stroke	2	500	Idle Test
Sri Lanka	current	2- and 4-stroke	6	—	Low-idling
Taipei,China	current	2- and 4-stroke	4.5	9,000	Idle warm test
	2004 January	2- and 4-stroke	3.5	2,000	Idle cold test
Thailand	current	2- and 4-stroke	4.5	10,000	Idle test for CO and HC; 30% white smoke limit; free acceleration for white smoke
Viet Nam	current	2-stroke	4.5	10,000	Idle test
	current	4-stroke	4.5	1,500	Idle test

Table 6
Emissions Standards for In-Use Motorcycles in Asia

CO = carbon monoxide, HC = hydrocarbons, g/km = gram per kilometer, ppm = parts per million

Vehicle technology

The type of engine technology (carburettor or fuel injection) used as well as possible additional vehicle emission control devices will greatly influence the likelihood that vehicles in Asia will be able to meet the current and future emissions standards set by governments. Now that lead has been removed in almost all countries in Asia, the use of catalytic converters for new gasoline-powered vehicles should become compulsory.

The gradual tightening of emissions standards for diesel vehicles will make it necessary for sulfur levels to be reduced. This will enable the use of advanced emission control devices in diesel vehicles such as diesel particulate filters. When low sulfur diesel fuel is introduced, strong consideration should be given to retrofitting existing vehicles with oxidation catalysts (500 ppm maximum sulfur) or diesel PM filters (50 ppm maximum) which can achieve significant and rapid PM reductions. To speed up the adoption of this technology, cost benefit studies should be conducted to help decision makers understand the potential benefits of this technology.

Simple oxidation catalytic converters have already been introduced for two and three wheelers in Taipei,China and India. The use of these relatively cheap devices can also be considered in other countries with large motorcycle populations.

Centralized I/M systems (sometimes called "test only" systems) where the inspection function is separated from the maintenance function have consistently been found to be much more effective than decentralized systems, where inspections and repairs are combined

Inspection and maintenance and other strategies to reduce emissions from in-use vehicles

Combustion-powered vehicles naturally tend to deteriorate with age and usage, and as a result emission levels can rise significantly. Good maintenance is required to keep emissions levels at or near design levels. Such maintenance is not always performed or performed properly. Targeted inspection and maintenance (I/M) programs, however, can identify problem vehicles and assure their repair, thereby contributing substantially to lower emissions and improved air quality.

So as not to overwhelm the service sector or create a strong political backlash, I/M stringency should be gradually phased in so that initially only the worst 15% to 20% of the vehicle fleet fails with periodic tightening of the in-use standards as the service industry and maintenance practices adapt.

Centralized I/M systems (sometimes called "test only" systems) where the inspection function is separated from the maintenance function have consistently been found to be much more effective than decentralized systems, where inspections and repairs are combined. It is very difficult to supervise and audit test and repair systems and to prevent corruption and poor quality control. Policymakers must resist adoption of programs that combine testing with repair and that are very unlikely to achieve significant emissions reductions.

The shift towards a "loaded test" rather than the "idle test" currently used in most I/M systems in Asia will require new, additional test equipment including chassis dynamometers. The costs of such equipment will make it difficult for small-scale workshops to take part in the implementation of an I/M program, which is another reason for considering a centralized system.

Experience from across the world has demonstrated that while governments should regulate I/M programs, the actual implementation of I/M programs is best carried out by the private sector, provided that there is competition in the market. Policymakers should assure an open and transparent bidding process. An adequate fee structure should be developed in which the affected vehicle owners pay the full costs of the I/M program including the costs of auditing and overseeing the private sector-run program by government or private auditors, and that will still allow private sector operators to make a sufficient profit to maintain, replace and upgrade equipment as required.

Where multiple ministries (e.g., Environment, Police, Transport) or different levels of government (e.g., national and local) are involved in the I/M program, special care must be taken to assure that there is a full dialogue with all appropriate ministries or departments at the early stages of program design and that full agreement is worked out regarding specific roles and responsibilities. I/M programs typically also include testing for roadworthiness and safety. Departments and organizations responsible for this part of the I/M program need to be fully involved in the discussions on design and functioning of the I/M program.

To strengthen the chances for success of I/M programs there must be a well-thought out public awareness program that explains the public health need for the program, the potential benefits and how the program works. A careful and thorough dialogue among all relevant stakeholders including providers, regulators, enforcers/police, vehicle manufacturers, the driving public and media must be facilitated at the earliest stages of program development and subsequently maintained throughout implementation. This needs to be coupled with an effective enforcement mechanism to assure motorist participation in the program. In countries where motor vehicle registration requirements are routinely and effectively enforced, registration-based I/M enforcement systems have been very effective.

Quality assurance including covert and overt auditing and quality control should be properly planned and implemented. This will help to prevent, root out and penalize any corruption that has negatively impacted several I/M systems in Asia.

Roadside testing can complement a more comprehensive Motor Vehicle Inspection System but not replace it. Policymakers should insure that roadside testing is designed as a complement to but not an alternative to testing in fixed stations. The roadside testing should primarily have the function of identifying gross polluting vehicles.

Roadside testing should primarily have the function of identifying gross polluting vehicles complementing the comprehensive Motor Vehicle Inspection System

Some cities and countries have started, or are considering, using remote sensing devices to identify gross polluting vehicles. So far the effectiveness of such equipment in the Asian context has not been well established. The quality and readability of number plates is often weak in Asian countries and only few countries in Asia have reliable computerized databases, which will make it possible to summon gross polluting vehicles.

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In the Philippines, an innovative program was started in which mobile phones are used to identify gross polluting vehicles. The initial experience has been that on average in the first two months 1,000 vehicles are reported on a daily basis. Experience has demonstrated that it is important to have the required capacity in place to follow-up on initiatives that actively involve the public.

While a great deal of attention has been paid to the "I" in I/M, it is the "M" that actually reduces emissions. Any I/M program needs to be accompanied by a program aimed at the maintenance and repair sector. I/M programs if operated properly will identify vehicles that do not comply with in-use emissions standards. Very often the quality of repairs is weak and needs attention. Careful attention must be paid to assuring that the service industry has sufficient lead time to properly equip itself to properly repair vehicles that are found to be not in compliance with tighter emissions standards. In addition, adequate training must be made available so that the mechanics and technicians are sufficiently skilled. As vehicles become more sophisticated the need for the service industry to retool and retrain becomes more important. Policymakers need to consider how to develop and implement effective programs for certification of workshops, technicians and spare parts. This will require an institutionalized dialogue with the auto and repair industry.

In certain cases it will be not be feasible to reduce pollution through the introduction of tighter emissions standards and the only solution will be to scrap the vehicle, ban its entry in heavily-polluted areas, or change the fuel type.

Box 2 **Reporting Gross Polluters by Mobile Phone in Metro Manila, Philippines**

To assist in the identification of gross polluters in Metro Manila, individuals can send an SMS or text message from their mobile phones to report sightings of smoke belching vehicles. The report becomes part of an automated database. As soon as the same vehicle has been reported 5 times by 5 different individuals the Land Transport Office takes action by sending summons to the owner of the vehicle to produce the vehicle for formal testing.

Cleaner fuels

Over the course of the past 30 years, pollution control experts around the world have come to realize that cleaner fuels must be a critical component of an effective clean air strategy. Fuel quality is now seen as not only necessary to reduce or eliminate certain pollutants (e.g., lead) directly but also a precondition for the introduction of many important pollution control technologies. The most important impediment to adopting state-of-the-art new vehicle emission technology (equivalent to Euro 3 and 4) in Asia is the fuel quality, especially the level of lead and sulfur in gasoline and the level of sulfur in diesel. These parameters should receive highest priority in the development of medium- and long-term strategies for fuel standards. The long-term vehicle emissions standards strategy is to adopt Euro 4 standards for light duty vehicles, and Euro 4 and 5 standards for light duty and heavy duty diesel vehicles, respectively. The European gasoline and diesel fuel standards, described in Table 1, should be adopted in the same time frame.

Setting fuel standards will require institutional mechanisms that actively include a variety of stakeholders (government, private sector, and civil society) and which allow for extensive consultation. In countries where such an institutional mechanism is not yet in place, it should be created. With respect to the involvement of the private sector, it is important that both the oil and the auto industry are fully involved in such discussions. Because the environment and public health concerns are the driving force behind improvements in fuel quality, the Environment Department should have a major role in setting fuel standards. In order to implement stricter fuel standards and increase the acceptability of the associated costs to consumers, countries should institute more and better awareness campaigns. Such campaigns must emphasize the public health consequences of not improving fuel quality.

All countries should develop a short- and medium-term strategy that identifies proposed standards to be adopted over the next several years so as to allow fuel providers and the vehicle industry sufficient time to adapt. In developing fuel standards, countries should attempt to work closely with other countries in the region and to harmonize standards where possible. This should not be used as an excuse for delaying or watering down requirements as harmonization does not mean that every country must follow the same time schedule. The harmonization of fuel standards should go hand in hand with the harmonization of emissions standards.

Fuel strategies should not only address government policy with respect to traditional fuels such as gasoline and diesel but also alternative fuels such as CNG and LPG. It is expected that such fuel strategies will not be single fuel-based but will have a place for different types of fuel. The relative weight of individual fuels will vary from place to place and be determined by the structure of the vehicle fleet, available fuels and possible alternative usages of fuel. Subsidies that favor fuels that result in high emissions should be eliminated and tax policies which encourage the use of the cleanest fuels should be adopted. An effective means of encouraging the rapid introduction of low-sulfur fuels beyond traditional command-and-control regulations is to adopt a tax policy that results in higher sulfur fuels costing more at the pump than lower sulfur fuels. Hong Kong, China has successfully implemented such a strategy.

Gasoline

The rapid phaseout of lead in gasoline over the last years in most of Asia is an example of how governments can act effectively to improve fuel quality and through this reduce air pollution. Where not fully implemented, the addition of lead to gasoline should be eliminated as rapidly as possible.

In order to maximize the performance of current catalyst technology, sulfur concentrations in gasoline should be reduced to a maximum of 500 parts per million (ppm) as soon as new vehicle standards (Euro 2 or equivalent) requiring catalysts are introduced.

Emerging advanced catalyst technologies that are capable of achieving very low emissions (as required under Euro 4) will require a maximum of 50 ppm or less and a plan for introducing such fuel quality should be adopted at the early stages of development of a long-term vehicle pollution control strategy. As reflected in Table 7, countries in Asia still have a long way to go in improving the quality of gasoline. Countries in Asia should consider leapfrogging to the long-term target of 50-ppm sulfur or less rather than proceeding through a series of intermediate steps, as this will reduce the costs of changing. To help convince decision makers to issue more stringent gasoline standards, additional studies have to be conducted on the costs of refinery modification as well as the benefits to be derived from improvements in air quality.[16]

Benzene content should be reduced to a maximum of 1 percent by volume. Aromatics should be reduced to 35%. Gasoline vapor pressure should be reduced to a maximum of 60 kilopascals.

Diesel

To introduce Euro 2 standards, the maximum sulfur content should be reduced to 500 ppm; for Euro 3 vehicles, the maximum should be no more than 350 ppm; for Euro 4 vehicles, 50 ppm or less is required. Maximum emissions reductions from Euro 4 or more advanced systems will be achieved with a maximum of 10-ppm sulfur. A plan for introducing such low-sulfur fuels should be adopted at the early stages of development of a long-term vehicle pollution control strategy. Currently, most of the Asian countries do not have such a strategy in place. While interim improvements in diesel fuel quality will be beneficial to air quality, it might be most efficient and cost effective for a refinery to go directly to the lowest desired sulfur level rather than to do so with several interim steps. As in the case for gasoline, additional studies are required to determine the costs of refinery upgrading across Asia.[17]

When low-sulfur diesel fuel is introduced, strong consideration should be given to retrofitting existing vehicles with oxidation

Table 7
Gasoline Specifications in Asia and Europe

Country	Lead	Sulfur ppm	Benzene % v/v, max	Aromatics %	Olefins %	Oxygen % m/m, max	RVP summer kPa, max
Linked to Euro 3 Vehicle Standards Effective 2000	Lead free	150	1.0	42	18	2.7	60
Linked to Euro 4 Vehicle Standards Effective 2005	Lead free	50	1.0	35	18	2.7	60
Bangladesh	Lead free	1000	—	—	—	—	0.7 kg/m^2
Cambodia	0.15 g/l	—	3.5	—	—	—	—
Hong Kong, China	Lead free	150	1	42	18	2.7	60
India	Lead free	1000[a]	5[b]	—	—	2.7	35-60
Indonesia	0.30 g/l	2000	—	—	—	2.0 (premix)	62
Japan	Lead free	100	1	—	—	—	78
Malaysia	Lead free	1500	5	40	18	—	70
Philippines	Lead free	—	2	35	—	—	—
PRC	Lead free	1000	2.5	40	35	—	74
Singapore	Lead free	—	—	—	—	—	—
Sri Lanka	Lead free	1000	4	45	—	2.7	35-60
Taipei,China	Lead free	180	1	—	—	2.0	8.9 psi
Thailand	Lead free	500	3%	35	—	1-2%	—
Viet Nam	Lead free	5000-10000	5	—	—	—	—

g/l = gram per liter, kg/m^2 = kilogram per square meter, kPa = kilopascal, ppm = parts per million, %m/m = percent by mass, %v/v = percent by volume, psi = pound per square inch, RVP = Reid vapor pressure
[a] In Delhi, Mumbai, Kolkata and Chennai sulfur levels are 500 ppm
[b] Benzene – 3% in metros and 1% in National Capital Region

catalysts (500 ppm maximum sulfur) or diesel PM filters (50 ppm maximum) which can achieve significant and rapid PM reductions.

While less critical, other diesel fuel properties such as cetane number, density, distillation and polyaromatic content can also have positive or negative impacts on emissions and should be carefully evaluated.

Several generic types of diesel fuel additives can have a significant effect on emissions. These include cetane enhancers,

Table 8
Current and Proposed Sulfur Levels in Diesel in Asia, European Union and United States

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Bangladesh							5000									
Cambodia					2000											
Hong Kong, China		500					50									
India	5000				2500					500					350	
Indonesia	5000															
Japan	500				100					50		10[a]				
Malaysia	5000		3000				500[b]									
Pakistan	10000						5000									
Philippines	5000					2000			500							
PRC	5000		2000													
Republic of Korea	500															
Singapore	3000		500													
Sri Lanka	10000							3000								
Taipei,China	3000			500			350					50				
Thailand	2500			500					350							
Viet Nam	10000							2000		500						
European Union					350					50				10		
United States	500														15	

> 500 ppm   51–500 ppm   < 50 ppm

[a] Under consideration
[b] Marketed

smoke suppressants and detergent additives. Cetane enhancers are used to enhance the self-ignition qualities of diesel fuel. These compounds appear to reduce the aromatic hydrocarbons' adverse impacts on HC and PM emissions, but effects are not significant.

Smoke suppressing additives are organic compounds of calcium, barium, or (sometimes) magnesium. Added to diesel fuel, these compounds inhibit soot formation during the combustion process, and thus greatly reduce emissions of visible smoke. However, they tend to significantly increase the number of very small ultrafine particles that are suspected of being even more hazardous to health. Particulate sulphate emissions are greatly increased with these additives, since all of them readily form stable solid metal sulphates, which are emitted in the exhaust. The overall effect of reducing soot and increasing metal sulphate emissions may be either an increase or decrease in the total particulate mass, depending on the soot emissions level at the beginning and the amount of additive used. Policymakers in Asia should be careful in promoting the use of smoke suppressing additives, as well as other additives in diesel, unless full test reports are available which also document their impact on other pollutants than smoke, especially ultrafine PM.

Alternative fuels

Alternative fuels include compressed natural gas (composed of methane); liquefied petroleum gas (composed of propane or butane); bio-diesel, methanol, ethanol, vegetable oils; synthetic liquid fuels derived from coal and various fuel blends, such as gasohol; electricity; and hydrogen.

Policymakers in Asia need to consider the environmental impact and costs as their main criteria in developing policies to encourage the use of alternative fuels. A medium-term perspective is required in which it is important to consider questions like: is there enough supply to meet demand if the alternative fuel promoted catches on in a big way; alternatively, what could be done to clean up the fuel to be replaced by the alternative fuel promoted?

Sufficient information is now available on the environmental benefits of CNG and LPG. Both fuels if substituting for diesel will have somewhat lower NO_x, and substantially lower PM emissions unless the diesel vehicle is burning ULSD and is equipped with a PM filter. Engines running on biodiesel instead of, or blended with, petroleum diesel tend to have lower black smoke and CO emissions, but can have higher NO_x and possibly higher emissions of particulate matter. These differences are not very large, however. Light duty methanol vehicles have emissions of NO_x and CO similar to gasoline vehicles. Emissions of VOCs are roughly half of gasoline vehicles. The environmental benefits of electricity and hydrogen have also been well established.

There are considerable differences in maturity of engine vehicle technologies between different types of alternative fuels. While some of these technologies are well proven and already used on a large scale, like CNG-powered light duty vehicles, others such as hydrogen-powered vehicles are still in a pilot or research and development stage.

The cost to produce and distribute the alternative fuel is, in most cases, high. LPG is, in this respect, a positive exception.

Decisions on whether and what alternative fuel to promote will be highly context- and location-specific. Based on the current stage of technology and costs it is recommended that policy makers focus on the possible use of CNG and LPG in their deliberations.

Policymakers in Asia need to consider environmental impact and costs as their main criteria in developing policies to encourage the use of alternative fuels

Where CNG is readily available in a given locality, and where very low sulfur diesel (50 ppm or less) is not readily and reliably available, strong consideration should be given to replacing diesel buses with CNG buses. Other centrally-fuelled fleets such as refuse trucks or local delivery trucks are also attractive candidates for replacement. However, where diesel with 50 ppm or less sulfur can be made available in the short- to medium-term, particulate filter retrofit should be considered as a possibly lower cost option instead of switching to CNG.

There are several obstacles to the widespread use of natural gas- and LPG-fuelled vehicles including the absence of transportation and storage infrastructure, additional cost (primarily of the fuel storage tanks), loss of cargo space, increased refuelling time, and lower driving range. Therefore, economic incentives in the form of lower taxes on fuels or other incentives should be considered as a means to stimulate the introduction and acceptance of these fuels.

Where LPG is readily available and a distribution system can be set up, and where ULSD is not readily and reliably available, consideration should be given to replacing diesel or gasoline taxicabs with LPG. Also, where compressed natural gas or LPG is readily available in a given locality, consideration should be given to replacing other high polluting vehicle types such as two-stroke engined autorickshaws with CNG or LPG. Conversions to both LPG and CNG have been well established as a viable technology. In terms of PM and HC emissions reductions, the most successful strategy for three wheelers is to replace the existing gasoline-fuelled, 2-stroke engine with a CNG- or LPG-fuelled 4-stroke engine.

An inherent advantage of gaseous fuels is the assurance that adulteration will not be a problem. They are also inherently low in PM. These factors should be carefully taken into account when considering whether or not to switch vehicles to these fuels.

Conversion of existing gasoline-fuelled vehicles to CNG or LPG is not very difficult and if done well can result in emissions reductions. If conversions are not carried out well, however, environmental benefits will be minimal. If such conversions are considered wherever such fuels are available in a given location quality control criteria should be established for conversions. The quality control criteria should be monitored on a regular basis to ensure that the conversions will achieve the envisaged emission reductions.

Conversion of existing diesel vehicles to natural gas is difficult and problematic and very often results in higher actual NO_x emissions. Therefore, for diesel vehicles, replacement should be considered rather than conversion. It is not recommended to ban the use of diesel vehicles in order to stimulate the use of CNG- or LPG-fuelled vehicles; instead it is recommended to adopt stricter emissions standards, which will help promote the use of cleaner alternative fuels or will lead to the adoption of cleaner conventional fuels.

Methanol has many desirable combustion and emissions characteristics, including lean combustion capability, low flame temperature (leading to low NO_x emissions) and low photochemical reactivity. It is also a liquid, which makes its storage and handling much simpler than with gaseous fuels. At current and foreseeable prices, the most economical feedstock for methanol production is natural gas, especially natural gas found in remote regions where it has no ready market. Light duty methanol vehicles have emissions of NO_x and CO similar to gasoline vehicles. The major barrier to widespread use of methanol is its high cost and price volatility. There is little prospect for it to become price-competitive with conventional fuels unless world oil prices increase greatly.

Ethanol is produced primarily by the fermentation of starch from grains (mostly corn) or sugar from sugar cane. It is most commonly used as an oxygenate in reformulated gasoline and in a gasoline blend called "gasohol." These fuels can be burned in gasoline engines. Specialized engines are necessary in order to burn pure ethanol. In engines burning reformulated gasoline using ethanol, VOCs and CO are reduced but NO_x tends to increase slightly. A gasohol-fuelled automobile costs no more than a comparable gasoline vehicle. Since ethanol is derived from grains and sugars, the production of ethanol for fuel is in direct competition with food production in most countries. This keeps ethanol prices relatively high, which has effectively ruled out its use as a motor fuel except in countries such as in Brazil and the US, where it is heavily subsidized. The high cost of producing ethanol (compared to hydrocarbon fuels) remains the primary barrier to widespread use.

Biodiesel is produced by reacting vegetable or animal fats with methanol or ethanol to produce a lower-viscosity fuel that is similar in physical characteristics to diesel, and which can be used neat or blended with petroleum diesel in a diesel engine. The general consensus is that blended or neat biodiesel has the potential to reduce diesel CO emissions (although these are already low), smoke opacity, and measured HC emissions. However, many studies show an increase in NO_x emissions for biodiesel fuel when compared to diesel fuel at normal engine conditions. Particulate emission data are mixed. Most studies show a reduction but some show increases under certain conditions. The high cost of biodiesel fuel is one of the principal barriers making it less attractive as a substitute for diesel fuel.

Traffic planning and demand management

Dealing with air pollution from mobile sources requires an integrated approach. Transport planning including Travel Demand Management (TDM) and Transport Systems Management (TSM) is a fundamental part of such an approach. Significant political will and technical capacity are required for successful implementation and vigorous efforts should be made to create and sustain both. An integrated approach requires combining: land use and transport planning; travel demand management; and transport systems management and regulation. These three elements should be supported by appropriate policies and actions on resource mobilization, taxation, pricing, subsidies; institutional and legal aspects; as well as promotion and awareness raising.

Land use and transport planning

For air quality management to be successfully integrated in land use and transport planning practices, there is a need for an effective and responsive urban management system. This requires the presence of an appropriate organizational structure, technical capacity and procedures at the local level. Action should be taken to lay the basis for effective comprehensive planning at a metropolitan scale and within this overall planning framework to pursue the planning for individual sites or locality-related initiatives. The emphasis should be placed on establishing a better-integrated transport system with public transport playing a much greater focal role. Social aspects should be taken into account in preparing urban plans with increased weight given to "bottom-up" planning including community consultation. Integrated planning models that are capable of addressing air pollution, transport and health issues can provide important decision-support for a comprehensive planning process. However many of such planning models require a large amount of data, which is often not available in many of the cities in Asia.

The formulation of air quality objectives to assist in the transport planning process is valuable. Better integration of transport planning and air quality planning is required by locally-empowered agencies. Ideally, transport plans should be mandated to meet specific air quality objectives. Policymakers in Asia should consider whether to make funding for implementation of transport plans in urban areas contingent on this occurring.

Travel demand management

As incomes rise in Asia continued increases in motorization are to be expected. Hong Kong, China and Singapore are the only cities in Asia that have been able to significantly moderate the demand for car ownership. They have done so through the adoption of appropriate policies to directly control ownership. Even so, both cities have found that car ownership restraints alone are insufficient to manage private vehicle use (measured in vehicle-kilometers). They have found that appropriate pricing, TDM and land use policies are also essential.

By its nature TDM involves a multitude of agencies within and outside the transport sector. It consists of many measures covering "hardware" (e.g., physical investments) and "software" (e.g., policies, pricing). It is, therefore, complex and a multi-agency activity that frequently causes problems in implementation in Asian cities. From a financial viewpoint TDM is attractive to Asia as it typically consists of low cost improvement measures that in combination can have far-reaching effects.

TDM measures when directed to air quality improvement should not be implemented in isolation but in conjunction with other transport planning, TSM, and transport pricing measures. Public transport should desirably be the dominant mode but this cannot be achieved without the implementation of sound and comprehensive TDM policies. Policies should restrain car ownership and reduce the demand for private car and motorcycle use and at the same time promote increases in public transport use.

Motorists in Asia, in most cases, do not pay the full costs for the infrastructure they are using or the environmental damage caused by them. Improvements to transport pricing should therefore be applied to send clear signals to private vehicle users on the true costs of their motoring on society. Fuel taxes and special levies on vehicle registrations, for example, should only be considered where they can be clearly linked to better road maintenance and air quality objectives.

Transport systems management and regulation

A key issue in many cities is the low average vehicle speeds arising from the interaction of a wide variety of vehicle types with different acceleration characteristics. This contributes to vehicle emissions and air pollution. There are numerous low cost, fast acting management measures that can be adopted to improve traffic flow and to increase traffic speed and there are many examples of segregated bus stops, bus and nonmotorized vehicle (NMV) lanes and other similar treatments in many cities. Low cost, quickly implemented schemes catering to the specific needs of each vehicle type including NMVs and pedestrians are needed. These interventions may also reduce emissions and improve air quality.

Enforcement of traffic laws and regulations can achieve significant improvements in traffic flow. Its potential safety benefits are also considerable. Proper enforcement is best implemented when the traffic code is clear and traffic management measures support desirable driving behavior. Education of motorists and road users will help to maximize the benefits of good traffic management works.

Public transport

The role of public transport varies widely in Asian cities. Although in some Asian cities public transport's mode share is very low (less than 5%), in most of Asia's cities public transport vehicles (usually buses, but also other indigenous modes) operating on fixed routes and powered by diesel engines carry the majority of public transport trips. These diesel-powered public transport vehicles are a major PM and NO_x emission source.

Policies for public transport to improve air quality can either consist of activities that clean the vehicles directly (e.g., engine upgrades, use of alternative fuels) or can consist of activities that seek to influence modal shift (i.e., increase switching to public transport). Improvements to public transport proposed to reduce emissions, or other service quality enhancements, should be implemented in an environment where the operations are efficient and financially sustainable.

Maintaining loyalty to public transport, or attracting car and motorcycle drivers to switch to public transport is not easy in view of the status and convenience private vehicle usage confers. But high quality, fast and accessible public transport services whether by rail or bus, and combined with other measures such as road pricing and parking restraints have proven to be quite successful in attracting car drivers especially when the road system is congested.

If public transport operators are not responsive to their patrons and outside influences then efforts to raise the importance of public transport are not likely to succeed. The efficiency of public transport is promoted by competition. Competition "for the market" backed up by appropriate regulation is usually better for air quality than competition "in the market" which is often associated with unruly operations through public transport vehicles competing with each other for passengers on the street.

Several Asian cities have recently introduced new urban rail systems but, in general, to date they have failed to attract their forecast patronage (often less than 25% of forecast in the first year of opening). Modern urban rail or light rail transit systems do have a role in the busiest corridors of Asia's largest cities i.e., where demand for public transport movement exceeds 20,000 passengers per hour per direction in the peak hour, which is about the limit for sustainable bus-way operations. To make urban rail systems more successful, more attention should be given to linking such rail systems with other "feeder" public transport services, good quality waiting and transfer facilities, common ticketing and information systems that support "seamless" connections between rail and bus-way systems and the overall public transport system. Singapore, Seoul, Taipei, China and Hong Kong, China have such integrated systems. Other cities in Asia are now following suit but often on a single mode basis such as for buses only, or for urban rail only.

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NMVs and pedestrians

NMVs like bicycles and pedestrians, do not pollute the air. In many of the developing countries in Asia, NMVs are a major mode and source of employment. However, with rising income the view often prevails that NMVs are an inferior mode and attempts are often made to ban or severely restrict NMV use. It is essential that major new transport investments provide overall community benefits and do not unfairly disadvantage NMVs, pedestrians or low-income groups.

In many cities in Asia with high NMV use there is still ample space to inexpensively segregate NMVs and provide integrated NMV networks thus achieving high environmental and economic returns. Low cost investments to enhance pedestrian movements are similarly very beneficial. Such efforts to promote the use of NMVs and walking combined with effective policies to expand the share of public transport have been able to reduce the dependency on private modes of travel.

Modern urban rail or light rail transit systems do have a role in the busiest corridors of Asia's largest cities i.e., where demand for public transport movement exceeds 20,000 passengers per hour per direction in the peak hour, which is about the limit for sustainable bus-way operations

Create an enabling environment for lasting successful solutions to pollution from vehicles

Managing vehicle emissions in the context of overall air quality management

These policy guidelines deal specifically with the reduction of pollution from vehicles. For efforts to reduce emissions from vehicles to be successfully implemented, it is important that they are part of an overall approach to improve air quality. Such an overall strategy needs to be based on ambient air quality standards that define maximum pollution levels and which determine whether air quality is harmful to health. Such ambient air quality standards can best be based on the World Health Organization Air Quality Guidelines.[18]

To be able to mitigate emissions from vehicles, it is important to have a realistic overview of what the overall pollution levels are. For this, it is important to have an effective ambient air quality monitoring system in place which records either on a continuous basis, or on a periodic basis, the ambient air quality. For policymakers to act in a timely and appropriate manner on the results of air quality monitoring, they need to receive information on a regular basis in a manner that explains the impact of air pollution as well as possible trends. To create support for air quality management measures, it is important to inform the general

For policy-makers to act in a timely and appropriate manner on the results of air quality monitoring, they need to receive information on a regular basis in a manner that explains the impact of air pollution as well as possible trends

public on the status of air quality and the reasons why the air quality is below the standards set.

In order to be able to plan a successful campaign to reduce pollution from vehicles, it is important to know the relative contribution of different types of vehicles to air pollution in different parts of the city. The next step is to carry out source apportionments to determine the relative contribution of mobile, stationary, and area sources of pollution to overall air quality. Periodic studies need to be carried out to develop and update source inventories, this also to determine the impact of measures taken to reduce pollution from mobile sources.

Legal and institutional framework

Legal framework

For measures to reduce pollution from vehicles to be successful it is important that they have a solid legal basis, to avoid a situation where control measures are successfully contested in court. The legal framework needs to specify different standards and a system of incentives and sanctions to promote compliance with the standards promulgated. Experience in Asia has demonstrated that suspension of registration of polluting vehicles is often more effective than the imposition of fines. However, for suspension of registrations to be an effective tool, it is required that vehicle registrations are computerized and updated on a regular basis.

Box 3 **Incentives for Cleaner Vehicles**

Incentives that have been used successfully in Asia are tax differentials for unleaded gasoline in several countries. The tax differential on low-sulfur diesel in Hong Kong, China led to a widespread early adoption of the lower sulfur levels in diesel.

The use of financial incentives in Taipei,China convinced many people to trade in their dirty 2-stroke scooter for a cleaner electrical one. Several countries in Europe have good experiences with lower taxes for cars which meet more stringent emissions standards than required.

Institutional mandates

Institutional mandates for activities related to management of mobile sources of pollution should be clearly spelled out. Important in this respect is being clear on who has the responsibility to:

- set ambient air quality standards and to monitor the ambient air quality;
- impose emergency measures such as limiting traffic, in case the health of the population is endangered;
- set vehicle emissions standards;
- oversee the implementation of emissions standards including periodic emission testing in I/M program and roadside testing;
- set fuel standards;
- monitor fuel quality;
- develop and implement traffic planning and demand management.

Responsibilities for air quality management in Asian countries are typically divided over several national government agencies and local government agencies. Often one department is assigned the responsibility to coordinate air quality management, usually the Department of Environment, while individual line departments are responsible for the main components of managing emissions from vehicles, often the Transport Department and the Department of Energy.

The role of local governments in managing vehicle emissions

Policymakers in Asia need to consider how to involve local governments more effectively in formulating strategies to reduce vehicular pollution. Currently the involvement of local governments has been limited in most parts of Asia. However, in those places where progress is being made in improving air quality, there usually is an active involvement of local government, especially in the implementation of standards and policies.

Air quality standards, emissions standards and fuel standards should be formulated at the national level, after consultation with local governments and other stakeholders. Flexibility should be given to local governments to impose stricter standards if required. Local governments can play an important role in monitoring air quality provided the equipment and procedures used are compatible with national systems. The implementation of new vehicle standards typically should be the responsibility of national government agencies although local governments can insist on tighter emissions standards provided cleaner fuel is available. Local governments can play a lead role in the implementation of in-use vehicle emissions standards as long as their approach is in line with the overall administrative and technical framework developed at the national level. Local governments do not need to have a major role in setting fuel standards. They can, however, advocate that cleaner fuels are introduced in a phased manner whereby highly-polluted cities are given priority. Local governments can also actively advocate and support the introduction of alternative fuels. Local governments need to have the lead role in developing and implementing transport policy and traffic management measures.

Strengthening coordination for management of vehicle emissions

For various reasons, effective coordination between departments often does not take place. Coordination, should extend beyond the responsible government departments and include affected private sector groups such as bus and taxi companies as well as the auto and the fuel industry. It should also include environmental groups from civil society. This will facilitate the participation of such groups in the setting of emissions standards and fuel standards.

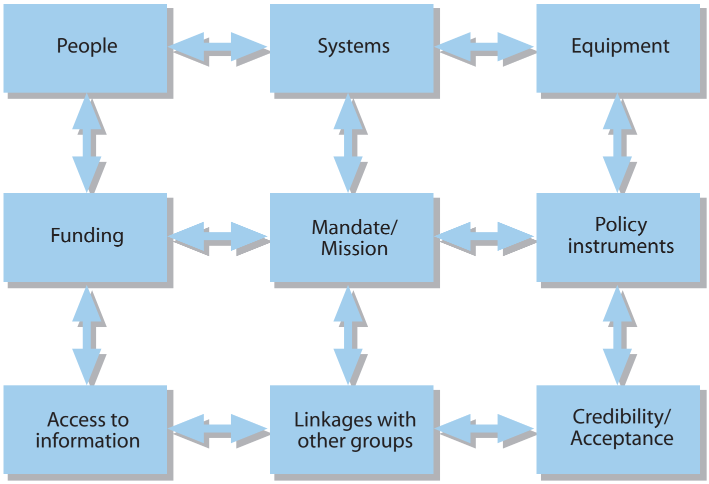
Coordination and cooperation between government and stakeholders from outside the government in the management of mobile sources of pollution will improve if there is:

- A legal basis which empowers stakeholders to be involved in planning and implementation of strategies to reduce vehicle pollution;
- Genuine commitment on the side of the lead government agencies to involve other stakeholders. Civil society is more likely to be willing to work with government if it feels it is seen as a serious partner. Private sector is a very strong potential partner for government provided that government is sincere in its efforts to involve the private sector in the setting of policy, taxation, and pricing related to vehicle emission control;
- Consistent and transparent enforcement of policies and regulations concerning vehicle emissions and fuel quality;
- Permanent structure for consultation rather than ad-hoc meetings, and if such a structure is perceived to be a joint structure rather than a government-driven forum. Ideally, such a structure should not be solely dependent on the lead government agency for funding, in order to ensure its reputation as a neutral platform;
- Access by all stakeholders to all relevant information;
- Sufficient (technical) capacities among all stakeholders to take part in, and contribute to the discussions;
- Specialized working or discussion groups such as oil-auto working groups to ensure the sound technical basis of recommendations.

Capacity building

Organizations responsible for the development and implementation of strategies to reduce vehicle emissions in the majority of countries in Asia suffer from severe capacity shortages. This is valid for national government agencies, local government agencies, and also for private sector and civil society organizations. This makes it difficult to efficiently and effectively carry out the specific mandate they have, which results in a situation that integrated

Figure 7
Elements of Effective Capacity Building



strategies are not developed or that important components of a vehicle reduction strategy are not implemented properly. The capacity shortage is in most cases qualitative; staff not having been trained properly. In a number of cases the number of people assigned to the task is simply not large enough.

Limited capacity in one or more organizations at the same time also makes it more difficult to move beyond ad-hoc measures to an integrated strategy.

For capacity building efforts to be successful, it is important that they do not simply focus on the recruitment of additional staff or on providing additional training. For an organization to substantially strengthen its capacity, all of the components in Figure 7 need to be accounted for. In the past, capacity building efforts have often not been successful because they focused only on some of the elements that together constitute capacity. Examples of this are the purchase of equipment without providing funds for operation and maintenance, strengthening mandates without providing additional staff, adopting policies without policy instruments to implement the policy. To overcome such problems, it is important to draw up a comprehensive capacity building strategy which is based on a careful analysis of the local situation. The strategy needs to focus on all organizations in government, private sector, and civil society that are involved in an integrated strategy to reduce vehicle emissions or in specific components of such a strategy like the introduction of cleaner fuels or the strengthening of an I/M program. Sustained funding and genuine political will be required to implement such strategies successfully.

Awareness

For efforts to reduce vehicle emissions to be successful, it is vital that there is a widespread awareness on the significance of the problem caused by air pollution from mobile sources. As long as there is no awareness that people are getting sick or dying and the costs associated with this, it will be difficult to successfully implement activities to reduce vehicle emissions. It is not sufficient, however, to raise a general sense of awareness. Different stakeholders need to develop different types of awareness and understanding, reflecting their involvement:

- Policymakers: awareness of the need to develop appropriate legislation (standards), sanctioning of economic instruments (tax incentives), and allocation of appropriate powers and budget;
- National government agencies and local government agencies: awareness of the need to develop an overall strategy on air quality management and reduction of vehicle emissions, awareness of the availability of approaches and instruments to manage air quality and reduce vehicle emissions and their effectiveness;
- Civil society groups: awareness of the need to act and knowledge of approaches that can be followed to reduce vehicle emissions. Also, once a strategy has been developed awareness is required on the strategy and its components in order to ensure cooperation from civil society groups in its implementation;

Box 4 **Partnership for Clean Air (PCA) in Manila, Philippines**

The PCA started as an ad-hoc initiative to support the phaseout of leaded gasoline. After that, it moved on to address other fuels as well.

Now it is a partnership with membership from national and local government agencies, private sector, civil society, and development agencies. The main objective of PCA is to promote awareness to support the implementation of the Clean Air Act of 1999.

PCA is disseminating information through http://www.savetheair.org , newsletters and workshops.

Increasingly, PCA is also used as a forum to discuss how the different aspects of the Clean Air Act of 1999 can be best implemented.

- Private sector: awareness of the financial costs of air pollution, the existence of technological alternatives that can reduce air pollution and operational costs, the provisions of the relevant laws and the willingness of government to enforce standards set in the law;
- General public: awareness of actual air quality levels and the health and environmental consequences associated with those levels, and awareness of the possibilities that require them to act in support of cleaner air.

Successful awareness raising strategies are often a combination of long-term objectives aimed at raising the general understanding of all concerned stakeholders on the harmful impact of vehicle pollution and specific short-term objectives in support of specific campaigns such as the introduction of catalytic converters. Adequate funding needs to be made available for the development and implementation of awareness raising campaigns. Investments in awareness raising have a very high potential return.

It can be done

Air pollution from mobile sources does cause substantial negative health impacts and economic costs to society in Asia. These negative impacts will increase in the years to come if no effective action is taken.

These guidelines contain a large number of suggestions to help policy-makers in Asia develop and implement effective policies to reduce emissions from vehicles. Although difficult, experience, both from inside Asia and outside Asia, has shown that it is possible to take effective measures to reduce vehicle emissions. The successful phaseout of leaded gasoline, the partial introduction of lower sulfur diesel, the adoption of stricter emissions standards for vehicles in several Asian countries and experiments with greater citizen involvement in managing mobile sources of pollution all show that it is possible to make a difference.

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It is hoped that these guidelines contribute to a better understanding of the problem of air pollution caused by vehicles. Actions are to be taken in an integrated manner, involving all the groups that are mentioned in these guidelines. It is the policy-makers of Asia that hold the key to the formulation and successful implementation of strategies to implement the actions called for in these policy guidelines. If they can display the political will and perseverance required, governmental organizations tasked with the formulation and implementation of vehicle emission reduction strategies will have a good chance to succeed because they will have the resources to do the job. Strong political leadership and perseverance will also send a clear signal to all who are now contributing to the pollution that the time has come to act and to change their behavior.

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[16] Recently, studies have commenced to assess the costs of refinery upgrading to compy with stricter fuel quality standards for gasoline. In line with the experience from Europe and the United States, actual costs are often lower than was originally projected. (e.g., Study on Improving Transport Fuel Quality in China: Implications for the Refining Sector (August 2002) by Trans-Energy Research Associates, et. al.; APEC Clean Transportation Fuels - Security Supply Study; Study on Motor Fuel Quality Improvements prepared for the Democratic Socialist Republic of Sri Lanka (December 2002) by Enstrat International Ltd.; A Study on Changes in Specifications For Gasoline and Diesel Fuels in Thailand (March 2002) by Daedalus LLC and ERC-Siam)

[17] In addition to the studies on costs of refinery upgrading mentioned in footnote 16, another study was undertaken on the Cost of Diesel Fuel Desulphurisation for Different Refinery Structures Typical of the Asian Refinery Industry (January 2003) by Enstrat International Ltd. for the Asian Development Bank.

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