Urban Road Transportation Externalities: Costs and Choice of Policy Instruments

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Urban transportation externalities are a key development challenge. Based on the existing literature, the authors illustrate the magnitudes of various external costs, review response policies, and measure and discuss their selection, particularly focusing on the context of developing countries. They find that regulatory policy instruments aimed at reducing local air pollution have been introduced in most countries in the world. On the other hand, fiscal policy instruments aimed at reducing congestion or greenhouse gas emissions are limited mainly to industrialized economies. Although traditional fiscal instruments, such as fuel taxes and subsidies, are normally introduced for other purposes, they can also help to reduce externalities. Land-use or urban planning, and infrastructure investment, could also contribute to reducing externalities; but they are expensive and play a small role in already developed megacities. The main factors that influence the choice of policy instruments include economic efficiency, equity, country or city specific priority, and institutional capacity for implementation. Multiple policy options need to be used simultaneously to reduce effectively the different externalities arising from urban road transportation because most policy options are not mutually exclusive. JEL codes: R40, R41, R48

There has been rapid growth in both vehicle production and registration worldwide. While 246 million motor vehicles were registered worldwide in 1970, that number had grown to 709 million in 1997 (Powers and Nicastri 2000). By 2007, over 72 million new vehicles were being produced annually, adding to the existing global vehicle stock (Ward's Automotive Group 2008). It is not only the industrialized countries where rapid growth in vehicle ownership is taking place. Consistent economic growth, rising incomes, and urbanization have led to rapid

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growth in vehicle ownership and usage in many developing countries as well. For example, in China the total number of registered motor vehicles has increased more than 11 times from 2 to 25 million between 1980 and 1995 (Gan 2003). In India, between 1981 and 2002, the size of the bus fleet quadrupled, the number of motorcycles increased 16-fold, the number of cars increased seven-fold, and the number of goods vehicles increased five-fold (Pucher and others 2005).

The transport sector is the primary contributor to a number of environmental externalities, such as greenhouse gas (GHG) emissions and local air pollution—particularly in urban centers—and traffic congestion. Globally the transport sector accounts for more than 60 percent of oil consumption and about one quarter of energy-related carbon dioxide (CO_2) emissions (IEA 2006).[1]

In most urban centers around the world, road transportation is the largest source of local air pollutants such as carbon monoxide (CO), sulfur dioxide (SO_2), oxides of nitrogen (NOx), volatile organic compounds (VOCs), and total suspended particulates (TSP). Vehicular emissions account for 40–80 percent of air quality problems in the megacities in developing countries (Ghose 2002). In rapidly urbanizing megacities, air pollution is a serious and alarming problem.[2] Air pollution levels in these cities exceed the air quality standards set by the World Health Organization (WHO) by a factor of three or more. Air pollution is causing approximately 2 million premature deaths worldwide every year (WHO 2008). Globally about 3 percent of mortality from cardiopulmonary disease, about 5 percent of mortality from cancer of the trachea, bronchus, and lung, and about 1 percent of mortality from acute respiratory infections in children under five years old are caused by air pollution (Cohen and others 2005).

Various policy instruments have been implemented or are planned to address the negative externalities from urban road transportation. These include fiscal instruments, such as congestion charges, vehicle taxes, fuel taxes, and subsidies for clean fuels and vehicles. Besides regulatory instruments, such as fuel economy standards, local air pollution standards have also been implemented. However, considering the rapid increase in urban transportation externalities, particularly congestion and emissions, the limited implementation of policies and measures is inadequate. The expansion of existing instruments and the introduction of new ones is therefore essential, but such policies and measures are associated with several issues that require further investigation before they can be recommended for broader implementation. Some of the pertinent issues include: Which policy instrument or measure would be the most effective and under what conditions? Are these policies and measures mutually exclusive? If not, what combination of these instruments would produce the best results? Answering these questions is crucial as hundreds of cities across the globe, mostly in developing countries, are suffering severely from the negative externalities arising from urban road

transportation and are currently seeking appropriate instruments to correct them. This study reviews existing policy instruments and the factors affecting their selection.

Some existing studies (Acutt and Dodgson 1997; Parry, Walls, and Harrington 2007) have reviewed alternative policy instruments used to reduce urban transportation externalities. These studies, however, focus only on theoretical aspects of the instruments and do not provide any quantitative information on the impacts to the economy, environment, or society as a whole.

In the rest of the paper we present estimations of external costs; introduce different types of policies and measures to control transport sector externalities; discuss factors influencing policy choices; summarize our key conclusions.

External Costs of Urban Transportation

A large number of studies (for example ADB 2002; World Bank 2002; Deng 2006; Jakob, Craig, and Fisher 2006; ADB and ASEAN 2007) have estimated the cost of different externalities arising from urban transportation for different regions in the world. These estimates vary significantly from country to country, not only because of varying levels of externalities, but also due to the difference in methods and underlying assumptions. Since it is not feasible to discuss all available studies, we briefly present estimates of external costs, particularly in developing countries, for the purpose of illustration.[3]

One of the major environmental concerns regarding vehicular transport is its costs to society in terms of local and global pollution. Table 1 presents the magnitude of the costs of one local air pollutant, a particulate matter of size 10 micrograms (PM^{10}), in selected cities in East Asia. As can be seen from the table, the cost of a single air pollutant could range from approximately 1 to 3 percent of national gross domestic product (GDP).

Note that the costs vary significantly, depending on several factors, such as the components of costs considered and the methodology used to estimate the costs. For example, the cost in Indonesia also includes costs of restricted activity days, hospital admission, and emergency room visits, whereas these costs were not included in the case of the Philippines. The cost estimated for Beijing using the willingness-to-pay method is more than four times as high as that estimated using the human capital approach. The magnitude of local air pollution costs is relatively smaller in industrialized countries as compared to developing countries because of the pollution control policies already in place. For example, Jakob, Craig, and Fisher (2006) estimate the cost of local air pollution from road transportation in Auckland, New Zealand at NZ$58.4 million (or 0.2 percent of the region's GDP) in 2001.

Table 1. Costs of Local Air Pollution in Selected Cities in East Asia

Country (city)	*Year*	*Economic loss (US$ millions)*	*% of national GDP*	*Source*
Philippines (Metro Manila, Davao, Cebu, Baguio)	2001	432.0	0.6	World Bank (2002)
Indonesia (Jakarta)	1998	181.4	1.0	ADB (2002)
Thailand (Bangkok, Chiang Mai, Nakhon Sawan, Khon Kaen, Nakhon Ratchasima, Songkla)	1996–99	825.3	1.6	World Bank (2002)
China (Beijing)	2000	974.0[1]	3.3	Deng (2006)
		209.0[2]	0.7	

[1] based on willingness-to-pay methodology.

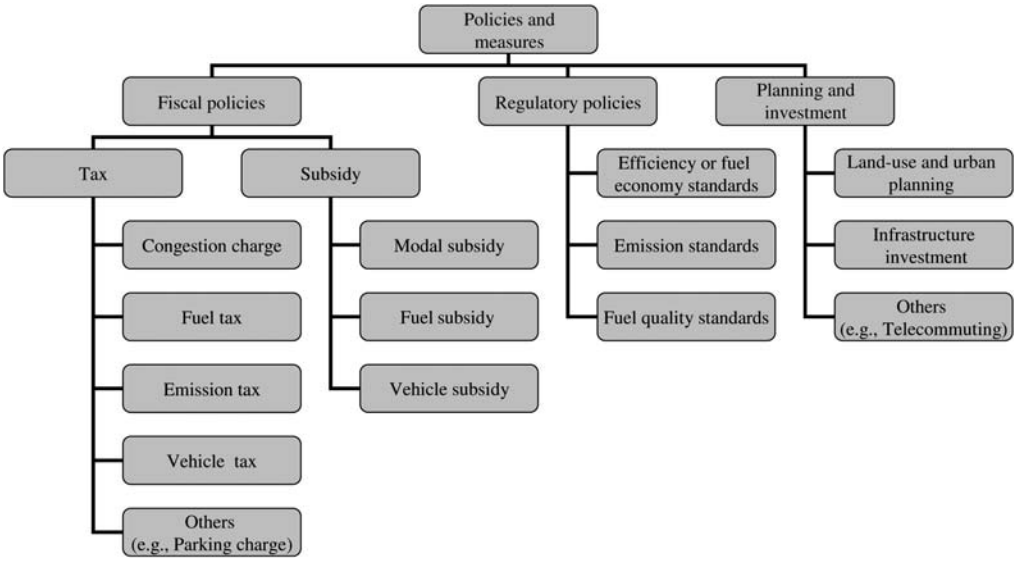
[2] based on human capital methodology.

Notes: Only one pollutant, PM^{10}, was considered in all these studies, except Jakarta, where NO_2 was also considered. The costs in the Philippines include those of premature death, chronic bronchitis, and respiratory symptoms. The costs in Jakarta include those of premature mortality, restricted activity days, hospital admission, emergency room visits, asthma attacks, lower respiratory illness (children), respiratory symptoms, and chronic bronchitis. The costs in Thailand do not include those of excess deaths and chronic bronchitis.

Traffic congestion is another key source of urban transportation externalities. ESCAP (2007) estimates the costs of traffic congestion in Bangkok, Kuala Lumpur, Jakarta, and Manila to be 2.1, 1.8, 0.9, and 0.7 percent of GDP, respectively, in 1996. Zergas (1998) estimates a congestion cost of US$286 million (0.59 percent of national GDP) for Santiago, Chile in 1994 without including the marginal increase in fuel consumption and air pollution caused by congestion. Schrank and Lomax (2005) estimate that total congestion costs in the 68 major urban regions in the United States amounts to $78 billion (0.84 percent of national GDP) in 1999. These estimates illustrate that the relative economic loss due to traffic congestion in many cities in the developing countries is even higher than that in cities in industrialized countries.

Traffic accidents cause hundreds of thousands of deaths and millions of injuries each year, as well as billions in financial losses. The costs vary across countries depending upon the cost assigned to medical expenses, lost productivity, and loss of life. ADB and ASEAN (2007) estimate that costs of traffic accidents amounted to 2 to 3 percent of national GDP in South East Asian countries during the 2001–03 period, with the exception of Singapore and Brunei, where the costs are much lower (0.5 to 1.2 percent of GDP). Mohan (2002) finds that accident costs are higher in high income countries and lower in low income countries. For example, while accident costs accounted for 4.6 percent of GDP in the United States in 1994, it accounted for only 0.3 percent of GDP in Vietnam in 1998. The higher accident cost in developed countries is mainly due to the higher value attached to productivity and higher health care

Figure 1. Classification of Policies and Measures to Reduce Urban Road Transportation Externalities



Notes: *Congestion charges* are tolls on vehicle mileage to help reduce the number and duration of trips, to alter routes, and to decrease speed variation; *fuel taxes* are levies on the consumption of fuels in proportion to their pretax prices; *emission taxes* refer to levies charged directly on effluents, or on fuels in proportion to the content of emission-causing elements in the fuels; *vehicle taxes* are nonrecurrent payments in connection with purchase and registration of vehicles; *modal subsidies* are for public transportation (for example bus, railway, and water); *fuel subsidies* are for clean fuels (for example ethanol and biodiesel); and *vehicle subsidies* are for clean vehicles (for example fuel cell and hydrogen cars, CNG bus). *Fuel economy standards* specify mileage traveled per unit of fuel consumption; *emission standards* refer to caps or limitations imposed on the amount of exhaust coming from vehicle tailpipes; *fuel quality standards* are designed to limit the content of elements in fuels that cause pollution, such as lead in gasoline and sulfur in diesel; *land-use and urban planning* refers to urban or planning activities aimed at reducing travel demand, fuel consumption, traffic congestion, and emissions.

costs. Because the cost of life lost in an accident is higher than the value of time lost to traffic congestion, the external costs of accidents tend to be higher than the external costs of congestion. In 2006, accident costs accounted for $164.2 billion compared to $67.6 billion for congestion in the United States (Cambridge Systematics 2008).

Policy Instruments to Reduce External Costs

Urban road transportation externalities may be addressed through a variety of policies and measures. Figure 1 presents a classification of these policies and measures.

Fiscal Policy Instruments

Fiscal policy instruments are price-based instruments. They include fuel taxes (for example an excise tax on fuel or a BTU tax), vehicle taxes (for example an ownership, licensing or registration fee), emission and/or pollution taxes or charges (for example a carbon tax, a sulfur tax), congestion charges or toll taxes, and subsidies (for example for clean fuels, efficient vehicles, and public transportation).

Fuel Tax. Traditionally the fuel tax has been a common instrument to raise government revenues with low administrative costs; it is also used to generate revenue to finance road maintenance. In many countries, fuel taxes are principal sources of government revenue. For example in developing countries like Niger, Nicaragua, South Korea, and Côte d'Ivoire, fuel taxation accounts for more than 20 percent of total state revenue. In industrialized countries, too, fuel taxes are primary sources of government revenue. For example, in 2004, fuel taxes accounted for 10 percent of state revenue in the Netherlands, 12 percent in France, 17 percent in Spain, 17 percent in Japan, and 12 percent in the United States (Metschies 2005).

Although the fuel tax is introduced mainly to generate government revenues, it could have a significant impact on the reduction of emissions and traffic congestion. For example, Eltony (1993) finds that a 10 percent increase in fuel price would cause 75 percent of households to reduce their vehicle mileage within a year. As a result, 15 percent of households would switch to smaller vehicles and 10 percent to more efficient ones. Hirota, Poot, and Minato (2003) show that a 1 percent increase in the fuel tax would reduce vehicle-miles traveled (VMT) by 0.042 percent. According to Sterner (2006), had the other Organisation for Economic Co-operation and Development (OECD) countries introduced a gasoline tax at the level of EU countries such as Italy, the United Kingdom, and the Netherlands, gasoline consumption in OECD countries would have been reduced by 44 percent. Conversely, if all OECD countries had a low gasoline tax like the United States, total OECD gasoline consumption would have been 31 percent higher.

Vehicle Tax. While fuel taxes are expected to reduce vehicle utilization, vehicle taxes are expected to discourage vehicle ownership. Various factors are considered while designing vehicle taxes. These taxes are based on fuel economy in Denmark, on emission standards in Germany, on vehicle gross weight and fuel type in Sweden and the Netherlands, and on CO_2 emissions in France and the United Kingdom (Kunert and Kuhfeld 2007). Engine model and engine capacity are also considered in some countries, such as Thailand, the Philippines, and Malaysia (Hirota, Poot, and Minato 2003).

In some countries, such as Singapore, vehicle taxes have been used as the primary measure for discouraging private transportation, thereby reducing air pollution and congestion. Vehicle ownership taxes, including the Additional Registration Fee, Excise Duty, annual Road Tax, and the Vehicle Quota System (VQS), have significantly discouraged private vehicle ownership in the country since the 1970s (Willoughby 2000). During 1990–2002, the VQS succeeded in bringing down the average annual motor vehicle population growth rate to 2.8 from 4.2 percent (Santos, Li, and Koh 2004). Similarly, strong growth in the vehicle fleet, especially private cars and motorcycles, was successfully curbed through a registration tax and an annual license fee in Hong Kong (Khan 2001).

Car-related taxes play an important role in reducing overall VMT and CO_2 emissions. Using data from 68 large cities, 49 OECD countries, and 19 non-OECD Asian countries, Hirota, Poot, and Minato (2003) show that for every 1 percent increase in ownership taxes, VMT decreases by 0.22 percent, and for every 1 percent increase in acquisition taxes, VMT decreases by 0.45 percent. Similarly a 1 percent increase in acquisition and ownership taxes was found to decrease CO_2 emissions by 0.19 percent.

Emission Taxes. Three types of emission taxes are normally proposed, and in some cases introduced, in order to reduce emissions from urban road transportation. These are: (i) taxes on local air pollutants such as suspended particulate matters (SPMs) and VOCs; (ii) taxes on local as well as regional air pollutants, such as NOx and SOx(for example a "sulfur tax"); and (iii) taxes on GHG emissions (for example a "carbon tax"). The first type of taxes is not common. The second type has been introduced in a number of cities, such as Tokyo. A reduction in the sulfur content of fuel is important not only to reduce SO_2 emissions, but also to improve the effectiveness of catalysts used to reduce NOx. The carbon tax is the most widely discussed policy instrument in the literature due to overwhelming interest from researchers on climate change. Since a carbon tax can be introduced uniformly to all types of energy consumers (for example households, industry, government), literature on carbon taxes that focuses specifically on emissions from transportation is not common.

Congestion Charges. Congestion charges have been extensively discussed in the literature since the concept was pioneered by Arthur Cecil Pigou in 1920. It has been applied in various parts of the world with varying degrees of success. The area licensing scheme (ALS), introduced in Singapore in 1975, is probably the first example of congestion pricing. After 23 years in operation, the ALS was replaced by an electronic version called the Electronic Road Pricing System in 1998. In 2003, the city of London introduced a congestion charge scheme in which vehicles entering a 22 square kilometer zone comprising core shopping,

government, entertainment, and business districts were required to pay a congestion charge of £5 between 7 a.m. and 6.30 p.m. on weekdays. The charge has been increased to £8 since July of 2005.

Congestion charges not only help to correct transportation externalities but can also generate a significant amount of revenue. For example, annual revenues generated through congestion charges are much higher than the annual operating costs in Singapore and Norway. Congestion charges are thus designed differently depending on the goals. In Singapore, the United States, and the United Kingdom, the primary objective behind road pricing is congestion relief; whereas in Norway it was initially designed to generate revenue and is currently aimed at raising environmental quality and safety. In Singapore and the United Kingdom, motorists pay charges on a daily basis, unlike the United States and Norway where motorists pay a toll per passage. In Singapore, charges vary, depending on peak and off-peak periods.[4]

The primary objective of a congestion charge is to reduce traffic congestion. The congestion tax system introduced in London, for example, led to a reduction in city-center traffic of 12 percent, of which 50–60 percent shifted to public transport (Transport for London 2004). It is estimated that daily inbound traffic would be reduced by 5 percent in New York if a toll (set at the level of current tolls on the two parallel Metropolitan Transportation Authority (MTA) tunnels) or a variable charge (with MTA tolls modified to match it) were introduced on the East River Bridge. A London-type congestion charge would reduce daily traffic volume in the city by 9 percent; if full variable pricing were introduced, the reduction could reach 13 percent (Zupan and Perrotta 2003).

A congestion charge can also help reduce vehicle emissions. Evans (2007) shows that the distance vehicles traveled across London was reduced by approximately 211 million kilometers per year with a £5 charge, and 237 million kilometers per year with an £8 charge. The value of CO_2 emissions saved was £2.3 million and £2.5 million with the £5 and £8 charges, respectively. Rich and Nielson (2007) estimate that proposed road-user charging schemes in Copenhagen could reduce CO_2 emissions by anywhere from 11.5 million tons to 154 million tons annually, depending upon the type of congestion charge, such as a distance charge, a large toll ring, or a small toll ring. Daniel and Bekka (2000) find that vehicle emissions in Delaware could be reduced by as much as 10 percent on aggregate and by 30 percent in highly congested areas through the use of a congestion charge.

Subsidies. Three types of subsidies are common in the transport sector. These are subsidies to: public transportation (for example bus, railway, and water); clean fuels (for example ethanol and biodiesel); and clean vehicles (for example fuel cell and hydrogen cars, compressed natural gas (CNG) buses). While subsidies for

public transportation could reduce both emissions and congestion, subsidies for cleaner fuels and vehicles do not necessarily help reduce congestion.

Subsidies for public transportation could be the main fiscal instrument for modal shifting from private transportation (for example car) to public transportation (for example rail or bus). Public transportation is already subsidized in many countries around the world for several reasons. In developing countries, public transport subsidies are necessary mainly because low-income households can neither afford to own private vehicles nor pay the actual fare if public transportation is not subsidized. Public transportation is highly subsidized in industrialized countries as well. For example, only 25 percent of the total capital and operating expenses in the United States and 50 percent in Europe are covered by fares for public transit (Brueckner 1987).

Public transportation subsidies can be interpreted as environmental policy instruments from two angles. First, existing subsidies could have contributed to both reducing emissions and congestion because some users of public transportation could have used private transportation and thus increased emissions or worsened congestion in the absence of such subsidies. For example, Cropper and Bhattacharya (2007) find that removal of the bus subsidy (that is a 30 percent increase in fares) would reduce bus commuters by 10–11 percent in Mumbai, India. Second, additional subsidies on purely environmental grounds could help reduce emissions and congestion by encouraging travelers to switch to public from private transportation.

Subsidies are a key fiscal policy instrument for the promotion of clean fuels, particularly the use of biofuels. Subsidies for biofuels are common practice in countries where their production is significant (for example in Brazil, the United States, and Germany). In Brazil, sales taxes on hydrous ethanol (containing water) and E25 (25 percent ethanol) are smaller than that for gasoline (Coyle 2007). In the European Union, 21 countries grant a tax exemption (full or partial) for each liter of biodiesel supplied to the market, and 20 countries grant tax exemptions for ethanol (Kutas, Lindberg, and Steenblik 2007). Biofuel subsidies are often justified on the basis of their alleged positive effects on climate, energy, and agricultural policy goals.

Several major subsidies and incentives have been introduced by the federal and state governments in the United States. The federal incentives include: the Biodiesel Blenders' Tax Credit, the Small Producer Tax Credit, the Federal Biobased Products Preferred Procurement Program, the United States Department of Agriculture (USDA) Energy Systems and Energy Efficiency Improvements Program, and the USDA Value-Added Producer Grant Program. It is argued that without the existing federal and state subsidies, which average about $0.80 per gallon, ethanol production in the United States would not be economically viable (Saitone, Sexton, and Sexton 2007).

There exists a consensus among existing studies that subsidies are necessary to promote clean vehicles. Rubin and Leiby (2002) argue that, without subsidies, no substantial hybrid penetration is possible; they estimate that a permanent subsidy of $1,600 per vehicle would ensure a market share of hybrid vehicles at about 45 percent, while a $4,000 subsidy could increase the share to 90 percent in the United States. Ichinohe and Endo (2006) show that in order to achieve an 8 percent energy-related CO_2 emissions reduction in Japan by 2030 from the 1990 level, the share of hybrid passenger cars in 2030 would need to be 62 percent, which would require a subsidy of $1.23 billion a year. Haan, Peters, and Scholz (2007) find that tax rebate incentives in Swiss cantons could lead to significant increases in sales of such cars in those areas. Similarly Potoglou and Kanaroglou (2007) find that reduced monetary costs, purchase tax relief, and low emission rates are the factors that would encourage households to buy cleaner vehicles within the metropolitan area of Hamilton, Canada. The total cost of the electric vehicle (EV) is at least 50 percent more than that of gasoline-powered cars; thus its air pollution mitigation benefits alone would not be enough to give the EV a clear advantage against all conventional cars (Funk and Rabl 1999).

In many developing countries, EVs and vehicles run on alternate fuels are subsidized by the government. For example, in major Chinese cities, such as Beijing, Shanghai Tianjin, Shenzhen, Xi'an, Chongqing, and Changchun, local governments provide financial support to encourage the use of CNG and Liquid Petroleum Gas in transport (Zhao 2006). In Malaysia, monogas vehicles receive a 50 percent discount and bifuel or dual fuel vehicles receive a 25 percent discount off the road tax (Hirota, Poot, and Minato 2003).

Other Fiscal Instruments. Other fiscal instruments mainly include parking charges, which can reduce transport sector externalities by discouraging driving through an increase in the costs of car use. Parking charges could instigate a switch over to public transportation from private transportation (Acutt and Dodgson 1997). For example, a reduction in the parking subsidy from 100 to 30 percent of the cost of parking for all employees in government offices in Ottawa, Canada led to a 20 percent reduction in single car trips and also caused a modal shift through a 17 percent increase in public transit use within a year (Wilson and Shoup, 1990). Through simulation studies of five British cities, Dasgupta and others (1994) demonstrate that doubling parking charges reduces the share of central area trips by car by 13 percent.

Regulatory Policy Instruments

Regulatory instruments are legal instruments that alter the behavior of individuals, firms, or both by enforcing technical standards or mandates. They include

standards for fuel economy, emissions, and fuel quality. They reduce transport-sector negative externalities by imposing technological innovations (for example efficient and less polluting vehicles), mandating cleaner fuels (for example unleaded gasoline and low sulfur diesel), and compelling the retirement of old and polluting vehicle stock.

Fuel Economy Standards. Fuel economy standards have been introduced, mainly in developed countries (for example the United States, Canada, Japan, and European countries), for a number of reasons, such as energy security, local air pollution, and climate change. In the United States, although the Corporate Average Fuel Economy (CAFE) standard is lauded as the main policy instrument to reduce transport sector emissions, it was initially introduced from an energy security perspective in the early 1970s and was aimed at cars and light trucks (light vehicles). Currently vehicles with a gross vehicle weight rating of 8,500 pounds or less are legally obliged to comply with CAFE standards. The 2007 Energy Bill included a provision to achieve 35 mpg by 2020. The CAFE standards resulted in a remarkable improvement in the average on-road fuel economy of new cars and light trucks from an average of 14 mpg in the mid-1970s to 21 mpg in the mid-1990s (Zachariadis 2006). Besides the United States, Australia, Canada, Japan, China, and South Korea have specified fuel economy standards for their vehicles.[5]

In Japan, the government has established a set of fuel economy standards for gasoline and diesel powered light-duty passenger and commercial vehicles. These targets are to be met by 2005 for diesel and by 2010 for gasoline. The average fuel economy of gasoline vehicles is expected to increase by 23 percent from the 1995 level by 2010. Regulations for diesel vehicles are structured slightly differently, including a fixed average regulated emission limit value, which is used for certification and for production control (Bauner, Laestadius, and Iida 2008).

In Europe, fuel economy standards are expressed in terms of CO_2 emissions to reflect E.U. concerns on climate change. The E.U. automobile industry is committed to a CO_2 emission target of 140 grams per kilometer by 2008/2009, 25 percent lower than the 1995 level of 186 grams per kilometer, with a further reduction to 120 grams per kilometer by 2012. The Japanese and Korean auto-manufacturers also signed similar agreements with the European Commission (EC) in 1999; however, they agreed to meet the target of 140 grams per kilometer in 2009 instead of 2008 (Dieselnet 2005).

A number of studies have assessed the impacts of fuel economy standards on fuel consumption and emission reduction (see, for example, DeCicco 1995; Greene, 1998; Parry, Walls, and Harrington 2007). Improvement of fuel economy at the rate of 6 percent a year would result in savings of 2.9 million barrels of gasoline a day and 147 million metric tons of carbon emissions a year (DeCicco 1995). CAFE standards have led to about a 50 percent increase in on-road fuel

economy for light-duty vehicles during the period 1975–95 so that consumers, in the late 1990s, spent over $50 billion a year less on fuel than what they otherwise would have spent at 1975 mpg levels (Greene 1998).

Emission Standards. The implementation of emission standards is the most direct way of reducing local air pollution (such as CO, VOC, SPM). These emissions require substantial reduction to meet local ambient air quality standards, and they cannot be effectively reduced through fiscal or other regulatory instruments. Emission standards have been introduced in practice in many countries since the 1970s. However, levels of emission standards, vehicle coverage, monitoring, and enforcement differ across countries.

In the United States, emissions standards for CO, VOC, and NOx have been in place since 1975 (USEPA 1999). Among the states, California, which began to regulate vehicle emissions before the federal government, leads in imposing stringent environmental regulations.

In Canada, the federal government introduced the On-Road Vehicle and Engine Emission Regulations in 1999 for vehicles and engines manufactured or imported into Canada on or after January 1, 2004. The regulations are similar to established emission standards and test procedures for on-road vehicles in the United States (CONCAWE 2006).

In Europe, emission regulations have been implemented since the late 1970s and early 1980s (CONCAWE 2006). The European Union adopted Euro I, Euro III, and Euro IV standards in 1996, 2000, and 2005, respectively. Euro V regulations, which new models were obliged to meet starting October 1, 2008, and new registrations of vehicle models certified earlier are supposed to meet starting October 1, 2009, are even more stringent (Bauner, Laestadius, and Iida 2008). In Japan, the emission standards are on a par with standards adopted in Europe and the United States.

In response to rapidly deteriorating urban air pollution, developing countries have also initiated adoption and enforcement of emission standards. Stringency of the standard, however, varies across countries and cities depending upon the level of air pollution and other factors. Emission standards in these countries are softer compared to those in developed countries. However, some developing countries, such as China, aim to introduce Euro IV standards starting from 2010 (Liu and others 2008). Countries such as Bangladesh, India, Indonesia, Sri Lanka, Nepal, Singapore, South Africa, Argentina, Brazil, and Chile have introduced Euro standards, whereas Malaysia, the Philippines, South Korea, and Saudi Arabia have implemented U.S. emission regulations. Some countries like Colombia, Ecuador, and Mexico have provided flexibility by adopting both the U.S. equivalents and E.U. standards.

Fuel Quality Standards. Realizing the public health danger of pollutants such as lead and oxides of sulfur, many countries started reducing the level of these elements in fuels in the early 1990s. Starting in January, 1995, leaded gasoline sales were banned in the United States. Similarly leaded gasoline was banned in the European Union, effectively from January 1, 2000, although some countries like Greece, Italy, and Spain were granted a grace period of some extra years to phase out lead. Use of leaded gasoline has been banned in many developing countries as well. For example, it was banned in sub-Saharan Africa on January 1, 2006.

The sulfur content of fuels has also been cut substantially in several countries. In the United States, the gasoline sulfur content standard has been set at less than 5 milligrams per kilogram since 2007 through a sulfur control program introduced in 2004. EU Directive 2003/17/EC introduced a new phase-in requirement for both gasoline and diesel, restricting the maximum sulfur content to 10 milligrams per kilogram from January 1, 2009 (CONCAWE 2006).

Fuel quality regulations and specifications have been introduced in many developing countries. The standards, however, vary significantly across countries. In countries like Argentina, Kenya, and Bolivia, the maximum allowable limit for sulfur in fuels is 500 milligrams per kilogram, which is one fourth of that in Pakistan, one third of that in Guatemala, El Salvador, Honduras, Malaysia, and Tanzania, and half of that in Bangladesh, India, the Philippines, Thailand, Columbia, Paraguay, Nicaragua, and Panama (CONCAWE 2006).

China is taking aggressive steps toward containing hazardous components in fuel. Leaded gasoline was successfully phased out by the local government in Beijing by 1998. At present, sulfur content ranges from 300 to 500 ppm for gasoline and from 500 to 800 ppm for diesel fuel in Beijing (Hao, Hu, and Fu 2006).

Other Laws and Regulations. Although fuel economy standards, emission standards, and fuel quality standards are the most frequently used regulatory instruments, several others have been experimented with, to varying degree of success. Italy has adopted a policy which bans private cars from entering city centers. In Swiss cities such as Bern and Zurich, the restrictive measures taken by the government has made driving so difficult that many Swiss prefer riding public transport to reach the city centers (Bonnel 1995). Mexico City instituted the so called "No-Driving Day" program in 1989, which mandated not driving one day during the week (Monday to Friday) and two days during serious pollution episodes. During the weekends, odd and even license plate numbers are used, which forces one half of all cars to be parked.

Planning and Investment

Planning and investment includes urban or regional planning activities that may lower the level of externalities from transportation by reducing travel demand,

fuel consumption, traffic congestion, and emissions. This includes the expansion of existing, and the construction of new, infrastructure, such as bus rapid transit (BRT), surface train, subways and metros.

Land Use and Urban Planning. Transport sector externalities can be reduced through land use and urban planning that leads to less urban sprawl and lower dependence on vehicular transportation. Several studies have shown that there exists a statistically significant relationship between the intensity of land use and the frequency and duration of vehicle travel (Frank and Pivo 1995; Mindali, Raveh, and Salomon 2004). A number of studies, such as Newman and Kenworthy (1989) and Bagley and Mokhtarian (1998), suggest that higher density reduces transport energy consumption (and thereby associated emissions) by lowering the vehicle miles traveled.

Using data from 84 cities around the world, Lyons and others (2003) empirically demonstrate that minimizing the outward growth of cities and providing support for compact city planning principles directly benefits the environmental quality of cities. Through a comparative study of two Nashville, Tennessee neighborhoods, NDRC (2003) finds that the neighborhood that was 68 percent denser had 25 percent fewer vehicle miles traveled and 7 percent less toxic emissions per capita per day. Holden and Norland (2005) show, based on the results of a survey conducted in eight residential areas in Oslo, Norway, that increased densities lead to low energy use for both housing and everyday travel. Litman (2005) finds that people living in city centers in Davis, California typically drive 20–40 percent less, and walk, cycle, and use public transit two to four times more than their suburban counterparts. In the greater Toronto area, average commuter distance increases by 0.25 kilometer for every one kilometer away from the city's central business district, and the average commuter distance increases by 0.38 kilometer for every one kilometer away from the major suburban employment center (Miller and Ibrahim 1998). Based on ex post evaluation of 30 years of compact urban development in the Netherlands, Geurs and van Wee (2006) conclude that urban sprawl, car use, emissions, and noise levels would have been much higher than their current levels had there been no compact urban development policies.

Infrastructure Investment. Investments in public transport infrastructure, particularly bus rapid transit (BRT) and railways (for example metro, surface, and elevated rails), help reduce all types of externalities (that is congestion, emissions, and accidents). For example, commuter rail produces almost half as much CO_2 emissions as an average car trip per passenger kilometer of travel in the United States (ABA 2007). Similarly BRT is considered to be one of the more environmentally friendly modes of urban transportation as it leads to reduced travel duration, improved air quality, increased pedestrian space and bike use, and less private

vehicle use (Molina and Molina 2004). The TransMilenio BRT project in Bogota, Colombia is estimated to have reduced: the emission of CO_2 by 14.6 million metric tonsduring the first 30 years of its operation; 93 percent of traffic fatalities; 40 percent of local air pollutants; and 32 percent of travel time as compared to the transportation that would have been implemented otherwise (Lee 2003). The BRT system in Mexico City is expected not only to reduce CO_2 emissions by 0.28 metric tons but also to produce US$3 million in health benefits each year from reduced local air pollutants (Vergara and Haeussling 2007).

Over the last two decades, BRT has been promoted to address transport sector externalities in both industrialized and developing countries. Several cities in industrialized countries have expanded existing coverage or constructed new BRT systems, including Pittsburgh, Los Angeles, and Honolulu in the United States; Ottawa in Canada; Brisbane and Adelaide in Australia; Leeds, London, Reading, and Ipswich in the United Kingdom; Nantes in France; Eindhoven in the Netherlands; and Nagoya in Japan. Similarly many developing countries have also constructed BRT systems, such as China (Beijing), Thailand (Bangkok), India (Delhi and Hyderabad), Bangladesh (Dhaka), Ghana (Accra), South Africa (Cape Town), Senegal (Dakar), Tanzania (Dar es Salaam), Guatemala (Guatemala City), Peru (Lima), and Chile (Santiago).

Other infrastructure investments, such as metro, light rail, and electric bus systems, have been tried with mixed success. Mackett and Edwards (1998) observe reductions in private vehicle use and congestion as a result of metro systems in Atlanta and Baltimore, and metro and light rail systems in Memphis and Miami in the United States, but find no evidence of such reductions in other cities such as Adelaide (Australia), Manchester (United Kingdom), and San Jose (United States), although air pollution is seen to be mitigated in Sacramento (United States). Using a unique panel dataset for five major cities—Boston, Atlanta, Chicago, Portland, and Washington DC—that upgraded their rail transit systems in the 1980s, Baum-Snow and Kahn (2000) show that investment in rail reduces private car use, reduces congestion, and improves the environment. The Trolleybus System in Quito, Ecuador has been successful in substituting private with public transportation. The 11.2 kilometer trolley bus line is estimated to reduce the emission of contaminants by 400 tons annually; it has also reduced travel time by 50 percent (Rogat 2003).

Telecommuting. Telecommuting refers to working from a distance (for example home or neighborhood business centers) instead of commuting to an office to work. The increased penetration of cellphones and internet access could make telecommuting a viable alternative in both industrialized and developing countries. Until now, telecommuting has been practiced primarily in industrialized countries. The database of the Statistical Indicators Benchmarking the Information Society

indicates that the teleworking labor force accounts for 25 percent of the total labor force in the United States and 5 percent (Spain) to 26 percent (the Netherlands) of the total labor force in European countries in 2002 (Gareis, Hüsing, and Mentrup 2004).[6]

A number of studies have been carried out to assess the impacts of telecommuting, particularly on congestion and air pollution. Koenig, Henderson, and Mokhtarian (1996) show that home-based telecommuting reduces personal vehicle trips by 27 percent, VMT by 77 percent, total organic gas emissions (TOC) by 48 percent, CO emissions by 64 percent, NOx emissions by 69 percent, and particulate matters (PM) emissions by 78 percent as compared to nontelecommuting days. Center-based telecommuting reduces VMT by 53 percent, TOC by 15 percent, CO emissions by 21 percent, NOx emissions by 35 percent, and PM emissions by 51 percent again as compared to nontelecommuting days (Mokhtarian and Varma 1998).

The reduction potential of telecommuting on transport sector externalities has also been observed in developing countries. Dissanayake and Morikawa (2003) investigated the role of telecommuting in reducing transport sector externalities in Bangkok. Their findings show a significant reduction if telecommuting is integrated with other policy instruments such as road pricing and fuel taxes. Mamdoohi, Kermansha, and Poorzahed (2006) find that in Tehran jobs such as working with a PC, talking on the telephone, teamwork, and participating in meetings are suitable for telecommuting.

The Choice of Policy Instruments

One of the crucial questions most developing countries are currently facing concerns the type of instruments to introduce to reduce externalities from urban road transportation. The answer is not straightforward. The principal factor that affects the choice of a policy instrument is the economic factor. The economics, however, includes indirect as well as direct costs and benefits, including the value of avoided externalities damage. Technical factors, such as the physical characteristics of the externalities, and institutional factors, such as institutional capacity, could also play a role.

Efficiency

Economic efficiency compares policy instruments using a broader common denominator, such as welfare cost. While a large volume of literature estimating the welfare impacts of some policy instruments, such as fuel taxes, congestion tolls, and fuel economy standards, is available, this is not the case for other instruments.

The magnitude as well as the direction of the welfare impact of a policy instrument depends on a number of factors, such as the valuation of avoided externality damages and the ways in which the revenue generated through the instruments (for example toll revenue, fuel tax revenue) is recycled back into the economy. Economic intuition suggests that a fuel tax or congestion toll will cause aggregate welfare loss unless the avoided externality damages are accounted for in welfare impacts (see for example Parry and Bento 2002; Nelson, Gillingham, and Safirova 2003).[7] Revenue recycling schemes significantly influence welfare impacts. Proost and van Dender (2002) find that if the revenue generated through gasoline taxes is recycled to cut labor taxes, it would even improve welfare.

Several studies have measured the welfare effects of fuel economy regulations. The results of the studies, however, differ widely not only in magnitude but also in the direction of the welfare effect. Kleit (2004) demonstrates that a long-run increase in the CAFE standard not only causes huge welfare loss but also that it is an inefficient instrument for fuel conservation. However, this result could change if the value of avoided externalities were considered. Parry, Walls, and Harrington (2007) find that, contingent upon how consumers value fuel economy technologies and their opportunity costs, higher fuel economy standards can produce anything from significant welfare gains, to very little or no effect, to significant welfare losses. If the values of reducing oil dependency and climate change are accounted for, fuel economy standards could be welfare-improving.

Studies of the welfare impacts of other policy instruments, such as emission standards, subsidies, and infrastructure investment, are not available, and therefore it is difficult to confirm if these instruments would generate net benefits to society. Nevertheless, emission standards are likely to produce net social benefits because they do not necessarily lead to a cut in fuel consumption and therefore do not cause welfare loss. Moreover, the value of avoided externalities (for example the reduction of pollution related mortality and morbidity) would outweigh the implementation costs. Similarly infrastructure investment would create economic spillover through interindustry linkages and job creation and therefore could increase overall benefits to society.

While literature comparing costs of all the policy instruments considered here are not available, some studies compare tax and efficiency instruments to control GHG emissions. Crandall (1992) finds the carbon tax to be much more efficient than a petroleum tax, which is more efficient than CAFE standards, in reducing GHG emissions. The CAFE would cost the economy at least 8.5 times as much as a carbon tax with equivalent effects on carbon emissions. Inefficiency on the part of the CAFE is mainly due to its failure to equate the marginal costs of reducing fuel consumption across all uses, including usage of older vehicles and nonvehicular consumption. Several studies (for example Austin and Dinan 2005; West and Williams 2005; Fischer 2008) empirically demonstrate that a gasoline tax

would be cheaper than fuel economy standards in reducing gasoline consumption and associated emissions. Nivola and Crandall (1995) argue that the United States would have saved at least as much oil by reducing the number of miles driven in all types and vintages of vehicles, at about a third of the economic cost, if a fee of just 25 cents a gallon had been added to the cost of gasoline nine years ago. Dowlatabadi, Lave, and Russell (1996) demonstrate that enhanced CAFE standards might have little or no effect on urban air pollution and might generate a less than proportional reduction in GHG emissions. They also show that the CAFE is not the most cost effective way of lowering NO, VOC, and GHG emissions. Portney and others (2003) argue that by reducing the number of gallons consumed per mile, the CAFE standards make driving cheaper, which might lead to an overall increase in pollution (that is a rebound effect). However, Greening, Greene, and Difiglio (2000) find that such a rebound effect is very small. Gallagher and others (2007) argue that, although the CAFE standards are politically attractive and induce innovation among other things, it might not be the right policy instrument when it comes to ensuring energy security through reduced fuel consumption.

Equity

The distributional effects of a policy instrument also influence its choice. For example, if fuel used for public transportation (for example diesel) is taxed, it increases the cost of public transportation—the mode mostly used by low income households—and thus discourages the substitution of high emission private transportation with low emission public transportation. Moreover, taxation on fuels used for freight transportation increases the costs of transporting goods. Therefore fuel taxation should be discriminatory and aimed at encouraging the use of public transportation, resulting in a lower burden on low income households. For this reason, many developing countries tax gasoline higher as compared to diesel; sometimes the latter is even subsidized.

The scheme of recycling tax revenue also has important equity implications. Wiese, Rose, and Schluter (1995) show that both the absolute and relative burden of the fuel tax on the lowest income households would increase if fuel tax revenue is allocated by the government for general spending instead of it being rebated to households. Richardson (1974) and Arnott, de Palma, and Lindsey (1994) argue that congestion charges could benefit higher income groups that value the time gained, and that people with small economic margins could be worse off. As congestion charges disproportionately impact on the travel choice of lower income households, revenue redistribution is the key to the acceptability of congestion charging schemes. According to Evans (1992), low-income groups can benefit from congestion charges if the revenue generated is invested in public

transportation as these groups use this transportation more often than higher income groups. Further strengthening this argument, Eliasson and Mattsson (2006) demonstrate that women and low-income groups benefit the most when the revenue from fuel or congestion taxes is used for improving public transport. The distribution impacts of congestion pricing depend upon where different population groups live and work, their mode of transportation for commuting, and the ways in which revenues collected are allocated. Parry and Bento (2002) show that the net effect of a revenue-neutral tax on congestion can stimulate labor force participation at the margin.

Implementability

Most studies comparing the economics of policy instruments (for example fuel tax, fuel economy standards, emission standards) ignore the costs of implementation. While this does not affect the total costs of some instruments, such as fuel or emission tax, it would have significant effects on the total costs of other instruments, such as emission standards. The implementation of emission standards requires a system or institution to monitor and enforce the standards, and this is costly. Existing studies (for example Faiz and others 1990; Mage and Walsh 1992) argue that without a rigorous inspection and maintenance (I/M) program, smoke and particulate emissions from vehicles cannot be controlled in developing countries.

Many countries have introduced emission inspection programs for automobiles (CONCAWE 2006), but the lack of institutional capacity (for example lack of training of personnel, poor quality test equipment) curtails the effective implementation of policy instruments, particularly emission standards. In India, for example, more than 15 percent of drivers do not take I/M tests, and those who take it pass without truly controlling their emissions (USAID 2004). In Nepal, between 16 and 32 percent of vehicles failed the emissions test between 2000 and 2002 (Faiz, Ale, and Nagarkoti 2006). In Chongqing, China only 10 percent of vehicles brought in by drivers failed the emissions test, as against 40 percent that failed when flagged down by roadside inspectors (USAID 2004).

In low-income countries with limited institutional capacities, an instrument with smaller or no monitoring costs (for example fuel tax, emission tax) would be more effective than those requiring large monitoring or administrative and compliance costs.

Balancing the Criteria in Choosing Instruments

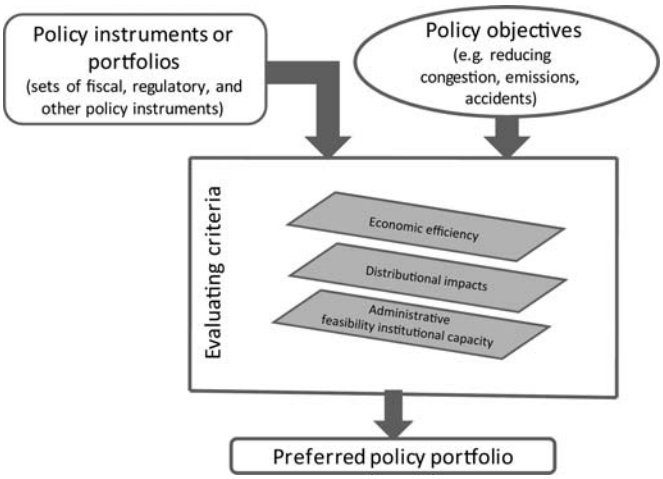
Developing a policy framework and balancing various factors within the framework is a key challenge for reducing negative externalities from the transport sector. The sections below briefly highlight this issue.

Framework for Choice. As discussed above, selection of policy instruments depends on several factors. It is always challenging to compare these factors because some are quantifiable while others are not. Those such as economic efficiency and distributional effects can be quantified.[8] However, other factors like institutional capacity, implementation, or administrative hurdles cannot readily be quantified. Quantitative valuation of factors, notably differences in distributional impacts, is also elusive. Some policy instruments differ as they have differing objectives, even if their impacts can be quantified using numerical models (for example reduction of congestion vs emissions). Therefore an analytical framework consisting of both quantitative and qualitative assessments are needed to balance various criteria for selecting a policy instrument or a portfolio of instruments for reducing transport sector externalities. Acutt and Dodgson (1997) developed a matrix of both quantitative and qualitative indicators (for example costs and benefits to the government, consumer welfare, distributional effects, administrative complexity for implementation) for various policy instruments. Eskeland and Jimenez (1992) also discuss various criteria for choosing policy instruments for pollution control in developing countries.

A simplified representation of a framework for selecting among portfolios of policy instruments is presented in figure 2. The first step is to define the objectives of the policy intervention. In order to accomplish the objectives, various combinations of policy instruments then need to be evaluated against various criteria, including economic efficiency, distributional effects, and administrative feasibility or institutional capacity. Consideration of multiple criteria would be necessary because some policy instruments are superior to others with respect to one criterion, while the reverse is the case in terms of other criteria.

Country Criteria. Many cities, particularly in developing countries, are facing severe local air pollution problems. The costs of pollution damage, including costs of mortality and morbidity due to local air pollution, are significantly higher than the costs of other emissions such as GHG. Note that most developing countries with the exception of big emitters, such as China, India, Brazil, Indonesia, and South Africa, contribute very little to the global concentration of GHG emissions that cause climate change. Thus they do not consider reducing GHG emissions a priority. Instead these countries give higher priority to policy instruments that substantially reduce local air pollution. Obviously emission standards would be the most effective instruments for reducing local air pollution. Traffic congestion is emerging as a key problem in many cities in developing countries, causing huge costs to the economy. Congestion charges could be the most efficient option for resolving this problem. Anas, Timilsina, and Zheng (2009) and Parry and Timilsina (2009), for example, find that a congestion toll would be the most

Figure 2. A Framework for Selection of Policy Instruments and Portfolios to Reduce Externalities.



efficient policy instrument for reducing congestion externalities in Beijing and Mexico City.

On the other hand, developed countries, which are historically responsible for the atmospheric concentration of GHGs, could impose fuel or emission taxes as these instruments are more efficient and administratively less complex. Existing studies, such as Acutt and Dodgson (1997) and Sterner (2006), argue that fuel and emission taxes tend to be the most effective policy instruments when it comes to reducing CO_2 emissions.

Land-use or urban planning and infrastructure investment could help reduce transport externalities, but these options are highly expensive in megacities where space is not available for the expansion of surface transportation. In the city core, dismantling existing infrastructure to expand roads or surface railways is highly expensive. In growing parts of a city (or peripheral areas), on the other hand, low energy urban or transport planning would help significantly reduce future emissions and congestion. Thus while land-use or urban planning could be useful in new or growing cities, it may not be helpful in already developed cities. Moreover some studies show that land-use planning aimed at increasing residential density has very limited effects in reducing transport externalities. Sharpe (1982) shows that a tripling of the density of Melbourne would yield only an 11 percent transport energy saving. Schimek (1996) finds that a 10 percent increase in residential density leads to a meager reduction of 0.7 percent in household automobile travel in the United States. Cox (2000) demonstrates that in dense European and Asian cities, where traffic intensity is higher and traffic speeds are lower, air pollution is greater than in lower-density U.S. and Australian cities.

Telecommuting could help in reducing transport externalities in cities where the service sectors (for example banking and government services) are the main providers of employment. On the other hand, it does not help much in industrial cities where the physical presence of the labor force is needed in manufacturing facilities.

Some developing countries that import petroleum products find it hard to maintain the required fuel quality standards due to the lack of their own refineries. This is because such countries without their own refineries may not be in a position to enforce regulations related to fuel standards. Nepal, for example, without its own refinery, depends on imported products and is experiencing severe air pollution problems related to the high levels of benzene in imported gasoline (Kiuru 2002).

A policy instrument that works in one country may not necessarily work in others with different socioeconomic and cultural settings. For example, policy instruments like the ALS, which was viewed as very successful in Singapore, might not work in countries like India or Indonesia, due to the different socioeconomic and political settings (Chin 1996).

Multiple Instruments. The existing literature (for example Molina and Molina 2004) suggests that externalities from urban transportation cannot be solved through one specific policy instrument; instead it requires a portfolio of policy measures that best suit each city's specific circumstances. For example, local air pollutants (such as SPM, CO, VOCs, and lead) require substantial reduction to avoid their effects on human health. However, policy instruments such as fuel taxes or fuel economy standards to cut these emissions to the required level would not be feasible technically and economically. Therefore emission standards with strong monitoring and enforcement mechanisms are required for this purpose. On the other hand, taxes and fuel economy standards would be more efficient options for reducing fuel consumption and CO_2 emissions, and a congestion toll would be more effective in reducing traffic congestion. Hence a city suffering from local air pollution and congestion, and emitting significant amounts of CO_2, might benefit from emissions standards, fuel taxes, and congestion charges.

Imposing vehicle ownership taxes may discourage car ownership but not its use by motorists. In order to discourage both ownership and usage, it may be necessary to implement car ownership taxes and other charges related to vehicle use concurrently (Faiz and others 1990). Thus a well-designed tax on vehicle ownership and use would be more effective than the introduction of these instruments in isolation.

Although urban planning can be an effective means of reducing travel demand, preventing fragmentation, and providing opportunities to choose more

environmentally friendly modes of transport, it alone is not capable of reducing all the negative externalities associated with the transport sector. The scale of urban transportation externalities can be reduced significantly only when the land-use or urban planning approach is combined with an appropriate set of infrastructure, management, and pricing measures.

Conclusions

In this study we have illustrated the magnitude of the external costs of urban transportation in developing countries and discussed the choices of policy instruments to reduce these externalities. The costs of these externalities to society amount to billions of dollars every year in many countries. The existing literature indicates that the relative magnitudes of local air pollution and congestion costs (that is in terms of percentage of GDP) are even higher in developing countries as compared to those in industrialized ones. The costs, however, also vary significantly due to methodological differences, coverage of externality components, and underlying assumptions.

There exist three types of policies and measures to control the externalities: (i) fiscal policies, such as fuel and emission taxes, congestion charges and subsidies for clean fuel and vehicles, and public transportation; (ii) regulatory policies, such as standards for fuel economy, emissions, and fuel quality; and (iii) planning and investment measures, such as land-use or urban planning and infrastructure investment. These policies and measures are not mutually exclusive. Instead there exists a general consensus in the literature that a portfolio approach or proper integration of various policies and measures is necessary to reduce effectively externalities from urban road transportation.

Local air pollution is the priority concern for many developing countries; therefore emission standards would be the most appropriate in those countries which have not already introduced standards to reduce local air pollution. Other policy instruments, such as fuel economy standards, congestion or fuel taxes, urban planning, and investments, may help but would not be sufficient to reduce local air pollution to the level required to maintain ambient air quality standards as specified by the World Health Organization. Developing countries which have already introduced emissions standards could further strengthen standards and enforcement mechanisms, depending upon their required local air quality standards.

Despite the rich theoretical literature, congestion charges are limited in practice to a few cities in industrialized countries, such as Singapore, London, and Stockholm. Since it is the most efficient instrument for reducing traffic congestion, megacities in developing countries which are suffering heavy economic

losses due to congestion should consider congestion taxes. Although infrastructure investments, such as expansion of roads, could help reduce congestion, this might not reduce fuel consumption and emissions. Moreover the expansion of roads is often constrained by space in city cores, which suffer the most from congestion.

Fuel taxes are common around the world, but they have been aimed primarily at raising government revenues. Still, they are interpreted as policy instruments for reducing transport sector externalities because the level of these externalities would be higher in the absence of such taxes. However, a fuel tax should be discriminatory; while fuel used for private vehicles should be taxed, fuels used for public transportation should not. Otherwise substitution of high emission private transportation with low emission public transportation would not occur. Fuel taxes on private transportation are more likely to produce the desired results in those cities where good public transportation systems exist. Taxing fuel used in private vehicles, along with investment in public transportation, such as BRT, could produce better results as compared to policy instruments implemented in isolation.

Subsidies are provided to public transportation, clean fuels, and clean vehicles. Public transportation subsidies, common in both industrialized and developing countries, are not originally intended to reduce emissions. However, they contribute to the reduction of transport sector externalities as the level of these externalities would be higher in the absence of such subsidies. Subsidies also accelerate the deployment of cleaner vehicles, such as electric vehicles, hybrid vehicles, and CNG buses. Recycling revenues generated from fuel or congestion taxes for subsidizing clean vehicles is an example of complementing a subsidy policy with a tax instrument.

Various factors affect the selection of policy instruments for reducing urban transportation externalities. These include the relative damages of externalities; economic efficiency and distributional impacts of control measures and policies; and institutional capacity or administrative feasibility. An analytical framework that accounts for both quantitative and qualitative assessments of all influencing factors is necessary for selecting an appropriate portfolio of policy instruments for reducing negative externalities from urban transportation.

Notes

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1. As of year 2006.

2. Beijing, Cairo, Dhaka, Jakarta, Mexico City, and Shanghai rank in the top ten cities in the world in terms of emissions of TSP, SO_2, and NO_2 (Gurjar and others 2008).

3. See VTPI (2009) for the literature on estimating the external costs of transportation.

4. "Congestion charge" and "road pricing" are used interchangeably in some literature. In this paper we have distinguished between the two and focus only on congestion charges, as the purpose of road pricing could be different from reducing traffic congestion (for example revenue generation).

5. The programs in Australia and Canada were started in the late 1970s. While the Australian program is a voluntary one, the Canadian program has been mandatory since 1982 and resembles the U.S. CAFE standards.

6. Note that the number of teleworkers or telecommuters alone does not say much about their role in reducing congestion and emissions; a more important factor is how frequently (how many days in a year) they telecommute.

7. Depending upon revenue recycling schemes, some households might experience an increase in welfare (see for example Evans 1992; Proost and van Dender 2002; Eliasson and Mattsson 2006).

8. Existing studies, such as Parry and Bento (2002) and Parry and Timilsina (2009), developed analytical models to measure economic efficiency of various fiscal policy instruments. Wiese, Rose, and Schluter (1995) developed an applied general equilibrium model to measure distributional effects of a fiscal policy instrument. Studies such as West and Williams (2005) and Austin and Dinan (2005) developed analytical models to quantify economic efficiency of regulatory policy instruments. Anas, Timilsina, and Zheng (2009) developed a multilogit model to compare fiscal and regulatory policy instruments.

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