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A Review of Regulatory Instruments to Control Environmental Externalities from the Transport Sector

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Abstract

This study reviews regulatory instruments designed to reduce environmental externalities from the transport sector. The study finds that the main regulatory instruments used in practice are fuel economy standards, vehicle emission standards, and fuel quality standards. Although industrialized countries have introduced all three standards with strong enforcement mechanisms, most developing countries have yet to introduce fuel economy standards. The emission standards introduced by many developing countries to control local air pollutants follow either the European Union or United States standards. Fuel quality standards, particularly for gasoline and diesel, have been introduced in many countries mandating 2 to 10 percent blending of biofuels, 10 to 50 times reduction of sulfur from 1996 levels, and banning lead contents. Although inspection and maintenance programs are in place in both industrialized and developing countries to enforce regulatory standards, these programs have faced several challenges in developing countries due to a lack of resources. The study also highlights several factors affecting the selection of regulatory instruments, such as countries' environmental priorities and institutional capacities.

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A Review of Regulatory Instruments to Control Environmental Externalities from the Transport Sector[†]

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1. Introduction

Regulatory instruments are legal, enforceable, "command and control" type instruments aimed at reaching the desired, prescribed environmental quality targets or performance standards by regulating behavior of individuals and/or firms (Seik, 1996). In the transport sector, regulatory instruments induce adjustment of market participants' behavior (e.g., purchasing more fuel efficient vehicles, lowering operator speeds, optimizing logistics in freight transport, changing the modal split) by establishing suitable incentives (Ahrens, 2008). Examples of these instruments include the following: Corporate Average Fuel Economy (CAFE) standards established in the United States in line with the 1975 Energy Policy Conservation Act; On-Road Vehicle and Engine Emission Regulations established under the 1999 Canadian Environmental Protection Act; and European Union Emission Standards for Light Commercial Vehicles (i.e., Euro 2, Euro 3, and Euro 4 standards). Depending upon the primary objective, existing regulatory instruments target any of the following: (i) direct control of vehicular emissions or exhaust (e.g., emission standards in European Union, the United States, and many developing countries), (ii) reduction of fuel consumption (e.g., CAFE standards in the United States), (iii) cutting vehicle mileage (e.g., authorized mileage rates in the United Kingdom), (iv) lowering traffic congestion (e.g., the odd-and-even license plate rule in Mexico city). Some of these instruments can spur technological innovations. For example, higher CAFE standards can force vehicle manufacturers to produce more fuel-efficient vehicles; emission or exhaust standards mandate vehicles to be fitted with less polluting engines and emission control systems.

The key advantages of regulatory instruments are the directness and relative certainty of outcomes due to compliance measures. They boost economic competitiveness and environmental sustainability (Seik, 1996; Hricko 2004; Bartle and Vass, 2007). Strong regulatory programs and other regulatory efforts have had a significant effect on the control of air pollution in many countries (Ringquist, 1993). Regulatory measures alone, however, might not be sufficient to reduce vehicular emissions to the desired level. Therefore, effective pricing or fiscal policies, sound land use planning and the provision of environmentally sound public transportation systems can reinforce such regulatory measures (Faiz et. al, 1995).

Despite well-established theoretical foundations and wide implementation in the industrialized nations, regulatory policy instruments still present several issues that require further investigation before their widespread introduction in the developing world. The most important issues confronting policy makers in the developing world include, but are not limited to, the following: Which regulatory policy instrument would be the most effective in their context? How to design the implementation mechanisms? Keeping this broad objective in the background, this study presents an in-depth review of various types of regulatory policy instruments, such as fuel economy standards; emissions and exhaust standards; fuel specification standards and inspection and maintenance programs.

The paper is organized as follows: Section 2 briefly introduces various types of regulatory instruments followed by a detailed discussion of fuel economy standards in Section 3. In Section 4, we review vehicle emission standards. Section 5 and Section 6 present, respectively, fuel quality standards and inspection and maintenance programs. Section 7 discusses other laws and regulatory measures to control transport sector emissions. This is followed by discussions on key factors influencing the selection of regulatory instruments in Section 8. Finally, we conclude the paper in Section 9.

2. Types of Regulatory Instruments

Regulatory instruments to control environmental externalities from the transport sector can be classified into different categories using different criteria. For example, Carbajo and Faiz (1994) classified the instruments into three categories based on targets of the instruments. These instruments are those targeting: (i) vehicle engines (e.g., fuel economy standards, emission standards and inspection and maintenance programs); (ii) fuel quality, such as contents of lead and sulfur and mandatory blending of biofuels; and (iii) transport demand (e.g., traffic management through vehicle bans and designating lanes for high occupancy vehicles). In this paper we classify the instruments based on purpose of the instruments. Our classification is as follows: (i) fuel economy standards, which aim reducing fuel consumption and associated emissions, particularly, CO_2; (ii) emission standards which are directly aimed to the reduction of specific emissions released after fuel consumption; (iii) fuel quality standards to reduce or eliminate emission causing elements before the combustion of fuel and (iv) other regulatory measures either discouraging vehicle utilization (e.g., full or partial bans) or encouraging high occupancy of the vehicles (e.g., HOV lanes).

Fuel economy standards refer to standards on vehicle mileage per unit of fuel consumption (i.e., km per liter or miles per gallon). These are common ways to control emissions from the transport sector (Faiz et al., 1995). The CAFE standards introduced in the United States are good examples of fuel economy standards. Fuel economy standards help increase energy efficiency of vehicles, thereby cutting fuel demand and associated emissions. While these standards could be effective in reducing fuel demand and emissions, they do not help in reducing congestion. Fuel economy standards also reduce emissions indirectly by cutting fuel consumption in the supply chain, such as crude oil drilling and production, pipeline and oil refinery. For example, Potter (2003) showed that, in the United Kingdom, out of total emissions from an average car, 76 percent were from fuel usage, 9 percent from manufacturing of the vehicle, and the remaining 15 percent was from losses in the fuel supply system.

Emission standards are aimed at directly reducing emissions, the exhaust coming out of the tail pipes of vehicles. These standards are different from fuel economy standards because they directly control emissions from vehicles, whereas the latter reduce emissions by reducing fuel demand. Fuel economy standards are aimed mainly at reducing fuel consumption and greenhouse gas (GHG) emissions; however, emission standards control local air pollutants, such as suspended particulate matters (SPM), carbon monoxide (CO), volatile organic compounds (VOCs) or non-metallic organic compounds (NMOC), oxides of nitrogen (NOx), etc. While fuel economy standards reduce local air pollution, emission standards do not necessarily reduce fuel consumption as emissions of local air pollutants can be reduced without curtailing fuel consumption by fitting emission controlling devices in vehicles.

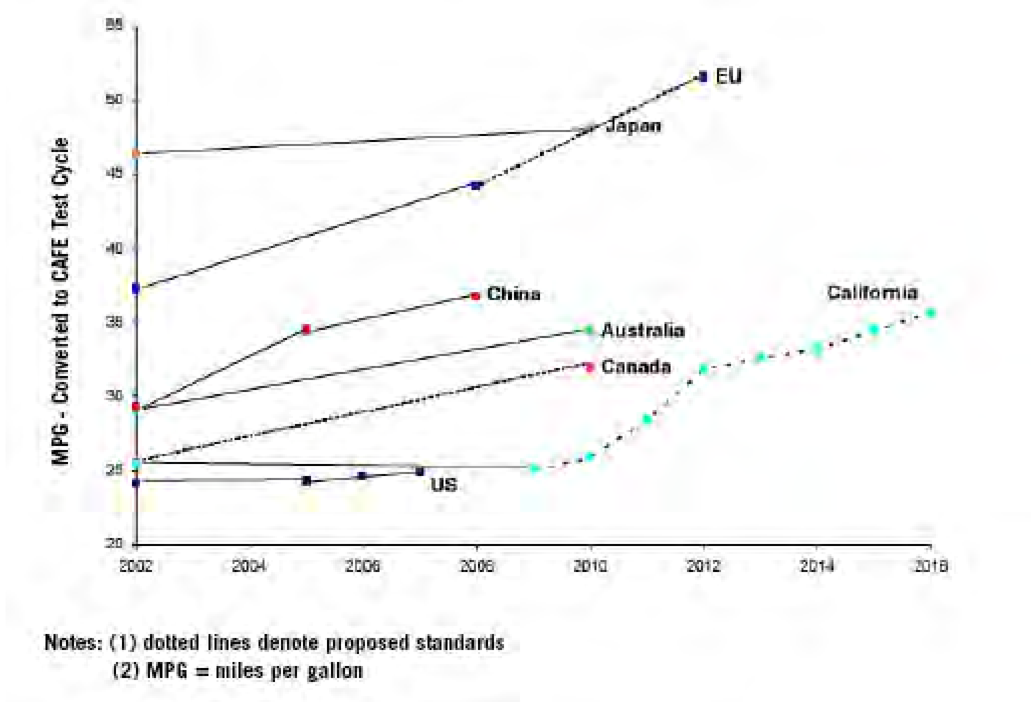
Fuel quality standards refer to the limit on the content of substances that cause environmental pollution, such as sulfur and lead, in fuel. In order to control emissions of lead and sulfur from vehicular sources, the best approach is to remove these elements from fuels before burning. Regardless of the age or state of repair, lead emissions from all gasoline-fueled vehicles can be eliminated by discontinuing the addition of lead to gasoline. Likewise, emissions of oxides of sulfur (SO_x) can be abated by reducing the sulfur contents of fuels.

3. Fuel Economy Standards[1]

The primary purpose of fuel economy standards is to reduce transport sector fuel demand through vehicle fuel efficiency improvements. A number of countries have introduced fuel economy standards, which help to reduce some types of emissions, such as CO_2, that are directly linked to fuel consumption. An and Sauer (2004) compared fuel economy standards, either already introduced or proposed, in nine countries or regions. The comparison showed that the European Union (EU) and Japan had the most stringent fuel economy standards in the world while the United States and Canada had the lowest standards. China has more stringent standards than those of Australia, Canada and the United States.

[1] For some countries/regions (e.g., EU) fuel economy standards are defined in terms of CO_2/GHG emissions per kilometer/miles traveled. Although these standards can be classified as emission standards; we have included them in fuel standards because these standards are implemented through equivalent fuel economy standards.

Figure 1: Fuel Economy Standards in Selected Countries/Region



Note: EU specifies its standards in terms of CO_2 emission release per kilometer. Similarly, California specifies the standards in terms of GHG release per mile. An and Sauer (2004) convert those standards to equivalent fuel economy standards for the purpose of comparison.
Source: An and Sauer (2004)

3.1 Corporate Average Fuel Economy Standards in the United States

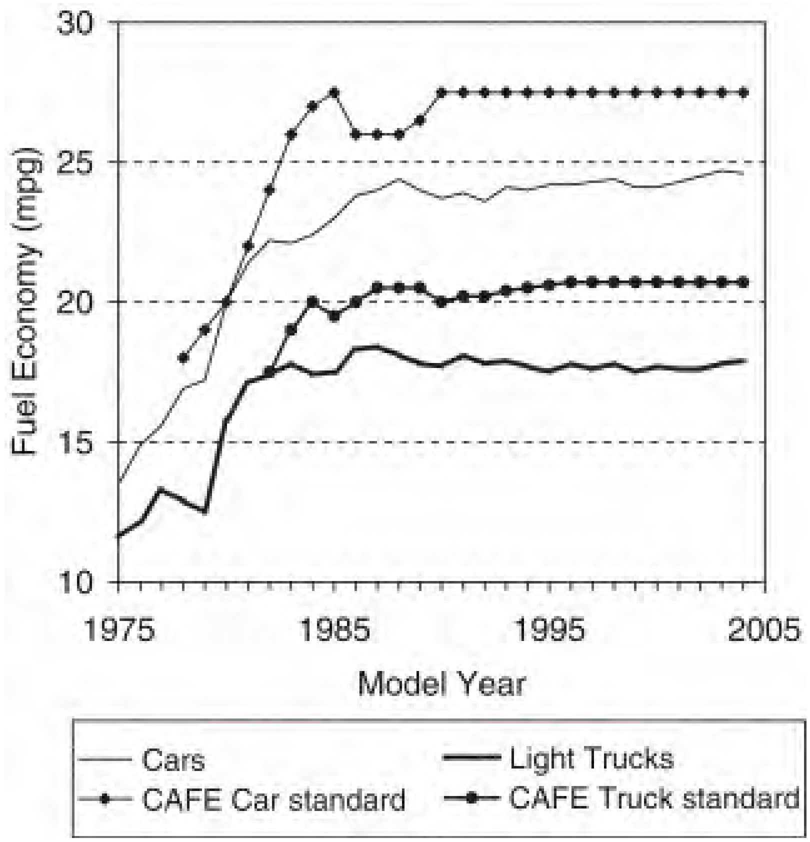
The CAFE standards require automobile manufacturers to meet stipulated standards for the sales-weighted fuel economy of light duty passenger vehicles sold and to maintain a distinct standard for passenger cars and light trucks (An and Sauer, 2004). Although CAFE is lauded as the main policy instrument to reduce transport sector emissions in the United States, it was, in fact, introduced from an energy security perspective in the mid-1970s. The impetus for CAFE was the oil crisis of 1973 (Proost and Van Dender, 2001). Title V of the Energy Policy and Conservation Act (EPCA), passed by the U.S. Congress in 1975, set automobile fuel efficiency standards for the first time in the United States. CAFE was one of the outcomes of this Act (Faiz et al., 1996; Kirby, 1995).

CAFE standards were initially set for cars and light trucks (light vehicles) (DeCicco, 1995). Currently, vehicles with a gross vehicle weight rating (GVWR) of 1,000 or less are legally obliged to comply with CAFE standards (Komiyama, 2008). Consumers have responded to CAFE standard by switching from large cars to light trucks, a less-regulated class of vehicles (Godek, 1997).

Minimum acceptable standards introduced by the EPCA began in 1978 at 18 mpg for passenger cars. By 1985, the fuel economy standard had increased to 27.5 mpg. Under intense pressure from lobbyists representing auto manufacturers, it was rolled back to 26.5 mpg in 1986. Fuel efficiency standard returned to its previous level of 27.5 mpg in 1989, where it has remained ever since (Kirby, 1995). The United States Congress, in 2007, passed a comprehensive energy bill, The Energy Independence and Security Act of 2007, which includes a provision to achieve fuel economy of 35 miles per gallon (MPG) for new automobiles by 2020 (Komiyama, 2008).

The evolution of U.S. CAFE standards presented in Figure 2 illustrates a remarkable improvement in the average on-road fuel economy of new cars and light trucks in the country. Although CAFE regulations do not directly affect vehicles in use, they tend to have a direct impact on the fuel efficiency of each vehicle covered by the standards. Over time, the U.S. CAFE regulations are seen to be successful in increasing average automotive fuel efficiency (Kirby, 1995). It increased from an average 14 mpg in the mid-1970s to 21 mpg in the mid-1990s (Zachariadis, 2006).

Figure 2: Evolution of CAFE standards and sales-weighted average fuel economy of newly registered cars and light trucks in the United States (1975–2004).



Source: Zachariadis (2006)

The drag that older vehicles impose on fuel efficiency appears to be quite substantial. The increase in the median age of registered automobiles (5.9 years in 1970 to 7.5 years in 1990 and 9.0 years in 2001), less stringent regulation of light pickup trucks, vans, and sport/utility vehicles has depressed the growth in fuel efficiency (Crandall, 1992; de Palma and Kilani, 2008). For example, fuel efficiency of all vehicles on the road has increased by only 34 percent even though the fuel efficiency of new cars increased by 76 percent (Crandall, 1992).

3.2 Fuel Economy Standards in Other Countries

Besides the United States, Australia, Canada, Japan, the European Union, China and South Korea have also specified fuel economy standards for their vehicles.

Australia: The Federal Chamber of Automotive Industries (FCAI) first established voluntary fuel economy standards for new passenger cars sold in Australia in1978 and lasted until 1987. However, those codes failed to achieve the desired targets (CONCAWE, 2006). In 1996, the Ministers for Transport and Primary Industries and Energy endorsed a second voluntary code of practice, which remained in force until July 2001. FCAI members, under the second voluntary code, agreed to reduce the passenger car National Average Fuel Consumption (NAFC) to 8.2 L/100-km (approximately 29 mpg) by the year 2000. In order to maintain the rate of improvement in NAFC achieved for the period up to the year 2000, a third voluntary fuel consumption agreement was reached between the FCAI and the government in 2003, which calls for reduction in fleet average fuel consumption for passenger cars by 18 percent by 2010.

Canada: The federal government introduced a voluntary Company Average Fuel Consumption (CAFC) standard in 1976 for the new passenger vehicle fleet. In 1982, the fuel economy standards were made mandatory. These regulations are comparable to the U.S. CAFE standards.

Japan: The Japanese government has established a set of fuel economy standards for gasoline and diesel powered light duty passenger and commercial vehicles. The targets to meet the standards are 2005 for diesel and 2010 for gasoline. The standards are based on average vehicle fuel economy by weight class. For gasoline vehicles, it varies from 15 MPG for vehicles weighing more than 2,266 kg to 49.6 MPG for vehicles weighing less than 702 kg (An and Sauer, 2004). By 2010, the average fuel economy of gasoline vehicles is expected to increase by 23 percent from the 1995 level. Regulations for both light duty and heavy-duty diesel vehicles are structured differently. An average regulated emission limit value is used for certification and for production control. This limit is complemented by a slightly higher maximum permissible limit value that must be passed for each vehicle unit (Bauner et al., 2008). Assuming no change in the vehicle mix, the targets for diesel vehicles call for a 14 percent fuel economy improvement compared to the 1995 fleet (11.6 km/l versus 10 km/l).

European Union (EU): After an agreement between the European Commission (EC) and the European Automobile Manufacturers Association (ACEA) in 1998 and similar agreements with the Japanese and Korean manufacturers (JAMA and KAMA) in 1999, the EU automobile industry committed to a target by 2008/2009. The major provisions of the ACEA Agreement, signed in March 1998, include a CO_2 emission target of 140 g CO_2/km, representing a 25 percent reduction from the 1995 level of 186 g CO_2/km, to be reached by 2008 with the possibility of an extension of the agreement to 120 g CO_2/km by 2012 (Dieselnet, 2005). The difference between the agreements signed by the European Commission (EC) with the European Automobile Manufacturers Association (ACEA) in 1998 and with the Japanese and Korean manufacturers in 1999 is that the target of 140 g CO_2/km is delayed by one year, to 2009, for, JAMA and KAMA (Dieselnet, 2005).

3.3 Impacts of Fuel Economy Standards on Fuel Consumption and Emissions

The impacts of fuel economy standards on fuel consumption (Geller et al., 1992; Goldberg, 1998; Greene, 1998) and emission reduction (Decicco, 1995) are helpful in assessing the performance of these standards and their suitability for replication in developing countries. Parry et al. (2004) used the Arizona I/M program data collected in 1995 and 2002 on car and truck emissions of volatile organic compounds (VOC), nitrogen oxides (NO*x*), and carbon monoxide (CO) to study the effects of fuel economy standards on emission rates in the United States. They found emission rates were significantly affected by fuel economy standards in 1995 but not so in 2002. This is mainly because the projected CO, hydrocarbon (HC) and NO*x* emissions per mile for cars and trucks with certified fuel economy of 20 and 30 mpg are virtually indistinguishable over vehicle lifetimes. Based on their findings, they proposed that lifetime emission rates are equivalent for different cars and for different light trucks. Using a vehicle stock turnover model, Decicco (1995) estimated the effect of enhanced fuel economy standards on gasoline consumption, GHG emissions, and hydrocarbon emissions for light duty vehicles in the United States. The author found that an improvement of 6 percent per year in fuel economy would result in savings of 2.9 million barrel of gasoline per day and 147 million metric tons of annual carbon emission avoidance. Likewise, using in-use emission data collected by remote sensing, Harrington (1997) demonstrated a strong association between better fuel economy and lower emissions of carbon monoxide (CO) and hydrocarbon (HC), which gets even stronger as vehicles age.

Despite the considerable amount of research done on the effects of CAFE on fuel consumption and other related factors, there is no universal consensus on the effects of the CAFE program on the fuel economy of the U.S. vehicle fleet, the overall safety of passenger vehicles, the health of the domestic automobile industry, employment in that industry, and the well-being of consumers (NSC, 2002). Greene (1998) estimated that CAFE standards have led to about a 50 percent increase in on-road fuel economy for light duty vehicles during the period 1975-1995. Improvement in fuel economy forced by the CAFE standards has resulted in an overall decrease in motor fuel expenditure. This means that consumers, in the late1990s, spent over $50 billion per year less on fuel than what they actually would have spent at 1975 mpg levels. By contributing to increased fuel economy, the CAFE program has reduced dependence on imported oil, improved the nation's terms of trade, and reduced CO_2 emissions relative to what otherwise would have been (NSC, 2002).

Although the overall goal of CAFE regulation has shifted from reducing fuel consumption in a period of high oil prices to reducing harmful emissions, positive environmental gains resulting from CAFE standard has drawn flak from various quarters (Goldberg, 1998). Dowlatabadi et al. (1996) demonstrated that enhanced CAFE standards might have little or no effect on urban air pollution and a less than proportional reduction in GHG emissions. They argued that CAFE is not the most cost effective way of lowering nitric oxide (NO), volatile organic compounds (VOC) and GHG emissions. Portney et al. (2003) asserted that by reducing gallons/mile, the CAFE standards make driving cheaper, which might lead to an overall increase in pollution.

Crandall (1992) ranked the effectiveness of a carbon tax, a petroleum tax, and CAFE standards in terms of their ability to reduce greenhouse gases. He considered a carbon tax to be much more efficient than a petroleum tax. CAFE, according to Crandall, would cost the economy at least 8.5 times as much as a carbon tax with equivalent effects on carbon emissions. The inefficiency of the CAFE is mainly because of its failure to equate the marginal costs of reducing fuel consumption across all uses, including usage of older vehicles and non-vehicular consumption. Using an empirically rich simulation model and cost estimates for anticipated fuel economy technologies, Austin and Dinan (2005), compared the cost of the higher CAFE standards against the cost of a gasoline tax that would save the same amount of gasoline. Their findings suggested that a gasoline tax would produce greater immediate savings by encouraging people to drive less and, eventually, to choose more-fuel-efficient vehicles. Fischer (2008) and West and Williams (2005) concurred with Austin and Dinan’s assertion that gasoline taxes are a more efficient means to reduce fuel consumption than mandating fuel economy increases.

Increased vehicle miles traveled due to enhanced fuel economy is another aspect that some studies, such as Dowlatabadi et al. (1996), Bamberger (2002) and Portney et al. (2003), found to be problematic. An increase in VMT also means an increase in congestion and crash costs (CBO, 2003), and an increase in the overall cost of driving (Bamberger, 2002). Nivola and Crandall (1995) argued against the effectiveness of CAFE in reducing vehicle miles traveled and labeled CAFE as a problematic experiment. They argued that the United States would have saved at least as much oil, by reducing miles driven in all types and vintages of vehicles, at about a third the economic cost, if a fee of just 25 cents a gallon had been added to the cost of gasoline nine years ago. Wang (1994) proposed a marketable permit scheme for light duty vehicle manufacturers as a more efficient alternative to the existing CAFE standards. For CAFE to be more effective, Portney et al. (2003) suggested the adoption of tradable fuel economy (FE) permits among manufacturers, revision of the criterion for distinction between cars and light trucks, and removal of distinctions between domestic and imported vehicle fleets.

Several studies (Greene, 1991; NRC 2002; Greene and Hopson, 2003) have measured the welfare effects of fuel economy regulations by estimating lifetime fuel saving benefits and subtracting the added vehicle costs from it. Welfare studies widely differ not only in magnitude but also in the direction of the welfare effect. Kleit (2004) demonstrated that a long-run MPG increase in the CAFE standard not only causes a huge welfare loss but that it is also an inefficient instrument for conserving fuel. He found that a long-run 3.0 MPG increase in the CAFE standard leads to $4 billion of welfare loss per year and 5.2 billion gallons of gasoline savings per year. He shows that the same amount of fuel can be conserved with an increase in the gasoline tax of 11 cents per gallon. The overall welfare loss resulting from such an increase would be $290 million per year or about one-fourteenth of the cost imposed in the former case. Dowlatabadi et al. (1996) argued against further increasing CAFE standards. They maintain that fuel savings from increasing CAFE are subjected to diminishing returns. West and Williams (2005) showed that an interaction with the tax-distorted labor market causes the cost advantage of the gas tax over the CAFE standard to be higher than anticipated. In such a context, increasing the gas tax would very likely lead to welfare gain, whereas welfare loss is almost certain if the CAFE standard is tightened.

Table 1 presents the impacts of CAFE standards on fuel savings and job losses. The CAFE standards might be considered successful in enhancing fuel economy but the gains achieved through CAFE standards have been undermined by the growth in vehicle fleet: The policy has not been able to reduce overall fuel demand due to the rapid growth of the vehicle fleet. Gallagher et al. (2007) pointed out the ineffectiveness of CAFE in terms of ensuring energy security. He argued that, although 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. Total motor vehicle fuel consumption in the United States has increased by 60 percent since the enactment of the CAFE program. Enhanced fuel economy standards may have propelled more driving – the so-called “rebound” effect – increasing the total vehicle miles traveled. Greening et al. (2000), however, argued that the increase in travel resulting from the decrease in cost per mile and reduced fuel intensity arising from the CAFE standards is minimal.

Table 1. Macroeconomic and Welfare Impacts of Fuel Economy Standards of US CAFE Standards

Study	Approach	Estimated Impacts
Dacy et al. (1980)	INFORUM input–output model	A net increase in employment of 140,000 jobs by 1985 due to CAFÉ standards; job losses in steel, petroleum and gas, and wholesale and retail trade sector are offset by new jobs created in various service industries, plastics, metal stampings, and other sectors.
Motor Vehicles Manufacturers Association (1990)		The loss of between 159,000 and 315,000 jobs in the motor vehicle industry
Geller et al. (1992)	Input–output model	Fuel savings of $54 billion (1990 dollar) Increasing the fuel efficiency of passenger cars from 28 mpg in 1990 to 40mpg in 2000 and 50 mpg in 2010 would create 244,000 by 2010
Goldberg (1998)		Reduced fuel consumption by 19 million gallons per year; the gasoline tax would have to increase by 780 percent, or 80 cents per gallon, to achieve the same fuel savings as the CAFE standards.

Source: Bezdek and Wendling (2005)

Goldberg (1998) and Parry et al. (2004) argued that welfare gains depend upon myriad factors such as ability of the CAFE to function as a set of internal taxes on fuel inefficient vehicles, subsidies on fuel-efficient vehicles, local pollution, nationwide congestion, traffic accidents, and how consumers value fuel economy technologies and their opportunity costs. CAFE, according to Goldberg (1998), may not fare that badly from a welfare point of view because of its ability to function as a set of internal taxes (on fuel inefficient) and subsidies (on fuel-efficient vehicles) within each firm. Based on the estimates of CAFE's impact on local pollution, nationwide congestion, and traffic accidents, Parry et al.(2004) found 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. Using marginal oil dependency and carbon externalities value of $0.16 and $0.12 per gallon respectively, they demonstrated that the reduction in fuel demand induced by improved fuel economy is welfare improving only when the marginal external costs of carbon emissions and oil dependency exceed the product of the existing fuel tax and the marginal social value of fuel tax revenues.

4. Vehicle Emission Standards

The implementation of emission standards is the most direct way of reducing emissions per VMT (Walsh, 1992).Without introducing emission standards, policies aimed at reducing fuel consumption and enhancement of fuel economy may not be sufficient to contain local air pollutant from the transport sector (ADB, 2003). Olsson (1994) argued that stringent emission standards lower emissions by forcing the auto industry to derive new vehicle technologies. Emission standards have been introduced in practice in many countries since 1970s. However, levels of emission standards, vehicle coverage, and monitoring and enforcement differ across countries. Here, we briefly discuss a few examples of emission standards introduced in selected countries/states.

4.1 Emission Standards in the United States

In the United States, Congress passed the Clean Air Act in 1970, calling for the first tailpipe emissions standards to control specifically carbon monoxide (CO), volatile organic compounds (VOC), and oxides of nitrogen (NOx). In 1975, the new standards were put into effect with a NOx standard for cars and light duty trucks of 3.1 grams per mile (gpm). In order to make the Act more effective, Congress amended the Act and further tightened emission standards in 1977. The NOx standard, between 1977 and 1979, was reduced from 3.1 gpm to 2.0 gpm for cars. In order to meet the Clean Air Act requirements, the Environmental Protection Agency (EPA) set the first tailpipe standards for light duty trucks at 1.7 gpm in 1979 and for heavier trucks at 2.3 gpm in 1988. Effective in 1988, the standards for light duty trucks were lowered to 1.2 gpm (USEPA, 1999).

Tier 1 Emission Standards in the United States

In 1990, Congress amended the Clean Air Act. Emission standards were further tightened to counter the additional pollution resulting from the increase in vehicle stock. Published as a final rule on June 5, 1991, Tier 1 standards were implemented between 1994 and 1997. Effective in 1994, the NOx standard was set at 0.6 gpm for cars (USEPA, 1999). The Tier 1 vehicle emission standards (0.25 grams per mile non-methane hydrocarbons (NMHC) for light duty vehicles, which were introduced progressively from 1994 onwards in the United States, became obsolete after the 2003 model year with a phase-in implementation of Tier 2 standard schedule from 2004 to 2009 (Gwilliam et al., 2004).

Tier 2 Emission Standards in the United States

The EPA proposed Tier 2 tailpipe emissions standards in 1999 that were to be implemented in 2004. For the first time, both cars and light duty trucks were subject to the same national pollution control system. The same emissions standards apply to all vehicle weight categories. For example, cars, minivans, light-duty trucks, and SUVs have the same emission limit. Tier 2 set the new standard at 0.07 gpm for NOx, a 77 to 86 percent reduction for cars. In order to take full advantage of vehicle emission control technologies, the EPA also proposed a reduction in average sulfur levels to 30 parts per million (ppm) (USEPA, 1999) from the then average of more than 300 ppm. As a comprehensive national control program meant to regulate vehicles and their fuel as a single system, the Tier 2 Emission Standards pursue significant emission reductions (Gwilliam et al., 2004). Tier 2 regulations are more stringent than Tier 1 requirements, and they further extend the application of the standards to include some of the heavier vehicle categories that were not included in Tier 1 standards (Dieselnet, 2005).

In order to understand how the Tier 2 program works, it is necessary to understand the EPA’s classification of light duty vehicles and trucks. Vehicles and trucks under 8500 lb gross vehicle weight rating (GVWR) are classified as light duty vehicles.

Table 2. Tier 2 Light Duty Full Useful Life Exhaust Emission Standards

[Emission Limits (g/mile)]

Bin no	NO_x	NMOG	CO	HCHO	PM	Notes
11	0.9	0.28	7.3	0.032	0.12	(1)
10	0.6	0.156 (0.230)	4.2 (6.4)	0.018 (0.027)	0.08	(2,3,4)
9	0.3	0.090 (0.180)	4.2	0.018	0.06	(3,5)
8	0.2	0.125 (0.156)	4.2	0.018	0.02	(2,6)
7	0.15	0.09	4.2	0.018	0.02	
6	0.1	0.09	4.2	0.018	0.01	
5	0.07	0.09	4.2	0.018	0.01	
4	0.04	0.07	2.1	0.011	0.01	
3	0.03	0.055	2.1	0.011	0.01	
2	0.02	0.01	2.1	0.004	0.01	
1	0	0	0	0	0	

(1) Bin 11 is only for MDVPs and is available up to and including the model year
(2) Bin deleted at the end of 2006 model year (2008 for HLDTs)
(3) The higher temporary NMOG, CO, and HCHO values apply only to HDLTs and expire after 2008.
(4) Optional temporary NMOG standard of 0.280 g/mile applies for qualifying LDT4s and MDVPs only.
(5) Optional Temporary NMOG standard of 0.130 g/mile applies for LDT2s only.
(6) Higher temporary NMOG standard is deleted at the of 2008 model year.
Source: CONCAWE, 2006

Under the Tier 2 program, manufacturers select a set of full useful life standards from the same row also called “emission bin” or “bin” for a given test group of light duty vehicles (LDVs) and light duty trucks (LDTs). The way it works is that, under the “emission bin” approach, manufacturers select a set of emission standards (a bin) to comply with, as a result of which test groups are obliged to meet all standards within that particular bin. For example: If a manufacturer aims for Bin 5 for its light duty diesel vehicles and cannot meet the target, the higher bins in that case allow a safety factor. It is the manufacturer’s responsibility now to offset the higher bin models with similar volumes of lower bin vehicles (CONCAWE, 2006). In addition, the Tier 2 vehicles are obliged to meet the requirements of one of the available “emission bin” and a full life NO_x standard of 0.07 g/miles (CONCAWE, 2006).

California Emission Standards

Among the states in the U.S., California tends to be the leader in imposing increasingly stringent environmental regulations. In 1989, the California Air Resources Board (CARB), in response to severe air pollution problems in Los Angeles and other major cities in California, established stringent, technology-forcing vehicle emission standards to be phased in between the period of 1994 and 2003 (Faiz et. al., 1996). As California began to regulate vehicle emissions earlier than the Federal government, it is treated differently than the other states when it comes to providing a free hand to adopt its own unique vehicle emissions control program. Under the Clean Air Act in 1970, California is allowed to set its own emissions standards (ECMT, 2000). The LEV II regulations, which were formally adopted on 5 August 1998 and came into operation on 27 November 1999, are the current standards for California (See table 3 & 4) (CONCAWE, 2006).

Table 3. LEV II Exhaust Emissions Standards-Light and Medium Duty Vehicles

[All Private cars & Light Duty Trucks < 8500 lb GVW]

Category	**50,000 miles**				
	NMOG	**CO**	**NOx**	**PM**	**HCHO**
LEV	0.075	3.4	0.05	-	0.015
ULEV	0.04	1.7	0.05	-	0.008
SULEV	-	-	-	-	-
	120,000 miles				
	NMOG	**CO**	**NOx**	**PM**	**HCHO**
LEV	0.090	4.2	0.07	0.01	0.018
ULEV	0.055	2.1	0.07	0.01	0.011
SULEV	0.010	1.0	0.02	0.01	0.004

*Limits are for intermediate life of 5 yrs or 50,000 or full useful life of 10, 0000 miles or 10 years
Source: CONCAWE, 2006

Table 4. LEV II Exhaust Emissions Standards- Medium Duty Vehicles (MDVs)

Type (Weight (GVWR), lbs.)	Durability Mileage	Emission category	NMOG	CO	NOx	PM	HCHO
8,500 - 10,000	12,000	LEV	0.195	6.4	0.2	0.12	0.032
		ULEV	0.143	6.4	0.2	0.06	0.016
		SULEV	0.1	3.2	0.1	0.06	0.008
10,001 - 14,000							
	12,000	LEV	0.23	7.3	0.4	0.12	0.04
		ULEV	0.167	7.3	0.4	0.06	0.021
		SULEV	0.117	3.7	0.2	0.06	0.01

Note: Light duty trucks up to 8,500 lbs GVWR, and medium-duty vehicles that are up to 14,000 lbs GVWR fall under the CA LEV-II standards adopted by California. LEV, ULEV and SULEV stand for, respectively, low-emission vehicles, ultra low- emission vehicles and super ultra-low emission vehicles. The LEV II standards indicate the maximum exhaust emission limits for the intermediate and full useful life of LEVs, ULEVs, and SULEVs. It also includes fuel-flexible, bi-fuel, and duel fuel vehicles when operating on the gaseous or alcohol fuels.

Source: CONCAWE, 2006

4.2 Emission Standards in Canada

The Canadian government, on 12 December 2002, under the Canadian Environmental Protection Act of 1999, published its new On-Road Vehicle and Engine Emission Regulations, which is being applied to vehicles and engines that are 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).

4.3 Vehicle Emission Regulations in Europe

In Europe, it was the United Nations Economic Commission for Europe (UN-ECE) that formulated emission regulations in the 1970s and early 1980s (CONCAWE, 2006). The motor vehicle emission regulations developed by the ECE were then adopted by individual member states (Faiz et al.1996). Although in the early years the European Union (EU) adopted regulations that were almost identical with the ECE equivalents, EU has since become proactive in formulating vehicle emission standards. Under the provisions of the Treaty of Rome, EU member states are legally obliged to follow EU regulations (CONCAWE, 2006). In order to make the existing regulations for light duty vehicles more stringent, the EU council of Ministers, in March 1994, adopted EU Directives 94/12/EC. The new emission limits were applied starting 1 January 1996 for new models and 1 January 1997 for existing models. Unlike previous regulations, it set separate standards for gasoline and diesel-fueled vehicles (CONCAWE, 2006). Tables 5 and 6 below display the EU's commitment to reducing the transport sector emissions: The EU has, over time, adopted tougher standards for all vehicular pollutants.

Table 5. EU Emission Standards for Passenger Cars (Category M_1*), g/km

Tier	Date	CO	HC	HC+NOx	NOx	PM
Diesel						
Euro 1†	1992.07	2.72 (3.16)	-	0.97 (1.13)	-	0.14 (0.18)
Euro 2, IDI	1996.01	1	-	0.7	-	0.08
Euro 2, DI	1996.01[a]	1	-	0.9	-	0.1
Euro 3	2000.01	0.64	-	0.56	0.5	0.05
Euro 4	2005.01	0.5	-	0.3	0.25	0.025
Euro 5	2009.09[b]	0.5	-	0.23	0.18	0.005[e]
Euro 6	2014.09	0.5	-	0.17	0.08	0.005[e]
Petrol (Gasoline)						
Euro 1†	1992.07	2.72 (3.16)	-	0.97 (1.13)	-	-
Euro 2	1996.01	2.2	-	0.5	-	-
Euro 3	2000.01	2.3	0.2	-	0.15	-
Euro 4	2005.01	1	0.1	-	0.08	-
Euro 5	2009.09[b]	1	0.10[c]	-	0.06	0.005[d,e]
Euro 6	2014.09	1	0.10[c]	-	0.06	0.005[d,e]

* At the Euro 1..4 stages, passenger vehicles > 2,500 kg were type approved as Category N1 vehicles
† Values in brackets are conformity of production (COP) limits
a - until 1999.09.30 (after that date DI engines must meet the IDI limits)
b - 2011.01 for all models
c - and NMHC = 0.068 g/km
d - applicable only to vehicles using DI engines
e - proposed to be changed to 0.003 g/km using the PMP measurement procedure
Source: Dieselnet (undated)

Table 6. EU Emission Standards for Light Commercial Vehicles, g/km

Category	Tier	Date	CO	HC	$HC+NO_x$	NO_x	PM
Diesel							
N_1, Class I ≤1305 kg	Euro 4	2005.01	0.5	-	0.3	0.25	0.025
	Euro 5	2009.09[b]	0.5	-	0.23	0.18	0.005[e]
	Euro 6	2014.09	0.5	-	0.17	0.08	0.005[e]
N_1, Class II (1305-1760 kg)	Euro 4	2006.01	0.63	-	0.39	0.33	0.04
	Euro 5	2010.09[c]	0.63	-	0.295	0.235	0.005[e]
	Euro 6	2015.09	0.63	-	0.195	0.105	0.005[e]
N_1, Class III	Euro 4	2006.01	0.74	0.46	0.46	0.39	0.06
>1760 kg	Euro 5	2010.09[c]	0.74	0.35	0.35	0.28	0.005[e]
	Euro 6	2015.09	0.74	0.215	0.215	0.125	0.005[e]
Petrol (Gasoline)							
N_1, Class I ≤1305 kg	Euro 4	2005.01	1	0.1	-	0.08	
	Euro 5	2009.09[b]	1	0.10[f]	-	0.06	0.005d[,e]
	Euro 6	2014.09	1	0.10[f]	-	0.06	0.005d[,e]
N_1, Class II (1305-1760 kg)	Euro 4	2006.01	1.81	0.13	-	0.1	
	Euro 5	2010.09[c]	1.81	0.13[g]	-	0.075	0.005d[,e]
	Euro 6	2015.09	1.81	0.13[g]	-	0.075	0.005d[,e]
N_1, Class III >1760 kg	Euro 4	2006.01	2.27	0.16	-	0.11	
	Euro 5	2010.09[c]	2.27	0.16[h]	-	0.082	0.005d[,e]
	Euro 6	2015.09	2.27	0.16[h]	-	0.082	0.005d[,e]

† For Euro 1/2 the Category N_1 reference mass classes were Class I ≤ 1250 kg, Class II 1250-1700 kg, Class III > 1700 kg.
a - until 1999.09.30 (after that date DI engines must meet the IDI limits)
b - 2011.01 for all models
c - 2012.01 for all models
d - applicable only to vehicles using DI engines
e - proposed to be changed to 0.003 g/km using the PMP measurement procedure
f - and NMHC = 0.068 g/km
g - and NMHC = 0.090 g/km
h - and NMHC = 0.108 g/km
Source: CONCAWE, 2006

The European emissions standards have become stricter with the adoption of newer Euro limit values. It has gradually tightened catalyst-forcing standards for new gasoline-fueled cars (also called Euro 1 standards) since its adoption in the early 1990s. It adopted Euro 2, Euro 3, and Euro 4 in 1996, 2000, and 2005 respectively. It also adopted similar requirements for diesel cars and light and heavy commercial vehicles (ADB, 2003). In response to the ongoing planned and probable control measures across the European Union (EU), by the year 2010, vehicular emission in Europe are expected to fall markedly (Reis et al., 2000). The maximum permissible limits set by Euro 3 called for 30 percent reduction of carbon monoxide (CO), hydrocarbons (HC) and nitrogen oxides (NOx) and 80 percent reduction of particulate matter (PM) emissions. Euro 5 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. NOx emission limits are further reduced, by 60 percent compared to Euro 3 (Bauner et al., 2008). Because of the voluntary agreement between the European Automobile Manufacturers Association (ACEA) and the European Commission, the former are obliged to reduce the fuel consumption and average unit emissions of CO_2 of new private cars, both gasoline and diesel, by 21 percent from the period of 1995 to 2008 (Joumard, 2005).

Emission standards alone will not be able to constrain car usage and associated emissions. With an increase in living standards, consumer preferences do shift considerably. In the EU, while Gross Domestic Product (GDP) witnessed 2.5 percent growth in between 1970 and 1997, annual passenger and freight transport averages increased by an average of 2.8 and 2.6 percent (Walsh, 2000). A gradual shift in consumers' preference towards new low emission car purchases might be able to slow down the rise in emissions level but more cars on roads also means more congestion and emissions. In addition to the enforcement of stringent emission standard, the following measures should be implemented to improve the effectiveness of emissions control policies: (i) measures such as the use of renewable or non-fossil based fuels and alternative technologies such as fuel cells and gasoline-electric hybrid engine; (ii) shift to less energy intensive modes and reductions in travel, (iii) technological improvements in fuel economy; and, (iv), an increase in load factors (Scholl et. al., 1996; Dargay and Gately, 1997; Kosugia et. al., 2005).

4.4 Vehicle Emissions Standards in Latin America

Like other developing countries, Latin American countries have witnessed rapid growth in transport sector emissions. Urban air quality has deteriorated with an increase in the number of vehicles on urban roadways. In Buenos Aires, for example, the transport sector accounts for over 99 percent of CO emissions and 46 percent of the NOx emissions (Venegas and Mazzeo, 2006). The situation in Brazil is quite similar. In 2004, transport sector emissions accounted for 46 percent of total HC and 98 percent of total CO in the Saõ Paulo Metropolitan Area (SPMA) (Vivancoa and Andradeb, 2006). In Santiago, Chile, older cars and diesel-powered vehicles are the main contributors to CO and NOx concentrations. Between 1990 and 2000, they accounted for 65 percent of total urban air emissions (Jorquera, 2002). In Mexico City, the transport sector accounted for 98 percent of total CO emissions, 40 percent of total HC emissions, 81 percent of total NOx emissions (Molina and Molina, 2002).

In response to rapidly deteriorating urban air quality, Latin American countries have initiated or adopted emission standards. The stringency of the standards, however, varies across countries/cities depending upon the level of air pollution and other factors. As outlined in Table 7, many Latin American countries have imposed complete or partial bans on used vehicles imports. Despite a huge market for used vehicles, countries such as Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Paraguay, Uruguay, and Venezuela have completely banned used vehicle imports (Pelletiere and Reinert, 2002).

Table 7. Latin America Vehicle Standards

Country	Vehicle Standards	
	Imported	Locally Manufactured
Argentina	Only new vehicles, equipped with emission control technologies according to Euro 3 standards	As of 2006, new light duty vehicles must comply with Euro 3, Euro 4 as of 2009, likewise for new diesel trucks and buses.
Brazil	No importation of used vehicles; imported new vehicles must meet Euro 4 standards	Vehicle emissions standards set by IBAMA, based on Euro standards: Euro 2 implemented in 1993, Euro 4 planned for 2008 equivalent to PROCONVE IV standard), and Euro 4 in 2009. All new trucks and buses must be Euro 4 in 2009.
Chile	Importation of used vehicles is banned.	Emissions testing programs started in 1994 (annual and roadside inspections). Euro 3 standards introduced in 2004, Euro 4 to start in 2009 for passenger cars. Euro 4 for diesel light vehicles required from 2005.
Colombia	Importation of used vehicles is banned.	Light duty petrol vehicles must meet USEPA 1987 standards. New vehicles must comply with Euro 1; heavy duty diesel vehicles must comply with equivalent of USEPA 1994 standards for buses and 1991 standards for other vehicles. New buses must comply with Euro 2, other new heavy duty vehicles with Euro 1.
Ecuador	Importation of used vehicles is banned. Model 2000 and newer cars must possess catalytic converters	New light duty petrol vehicles must meet USEPA 1987 standards or Euro 1; new heavy duty diesel vehicles must comply with USEPA 1994 standards or Euro 2.
Mexico	Vehicle maxium 10 years, must have a gasoline engine, and must be equipped with a catalytic converter	Since 1993, heavy duty diesel vehicles must meet one of these standards: US 1998, US 2004, Euro 3, or Euro 4. All light duty and passenger vehicles must meet US Tier 1, except on NOx (levels vary) and PM (applies only to diesel).
Paraguay	Importation of used vehicles is banned.	
Venezuela	Importation of used vehicles is banned.	Emissions testing in certain areas, with fines for violators.

Source: UNEP (2008)

Table 8 shows the emission standards adopted by selected countries in Latin America. Argentina, Brazil, and Chile have chosen to adopt EU standards, whereas Colombia, Ecuador, and Mexico have provided flexibility by adopting both the U.S. equivalents and EU standards. As compared to Argentina and Brazil, Chile, and Mexico have introduced more stringent emission standard.

Table 8. Emission Standards in selected Latin American countries

Country	Vehicle type	Effective Date	CO (g/km)	HC (g/Km)	NO_x (g/km)	PM (g/km)[1]
Argentina	New Vehicles	1/1/1995	12	1.2	1.4	0.373
	All imports	1/1/1997[2]	2	0.3	0.6	0.124
	All new regular	1/1/1998	6.2	0.5	1.43	0.16[3]
Brazil	Cars	1/1/1992	24	2.1	2	-
	Light Duty	01/01/1995				
Chile	Passenger cars	1/1/1995	2.11	0.25	0.62	0.125
	Light & Medium Duty (gvw < 3860 kg)	1/2/1995	6.2	0.5	1..43	0.16
Costa Rica	Gasoline passenger cars and light duty vehicles					
	< 1800 kg	1/1/1995	5.7	0.25	0.63	-
	1800-2800 kg	1/1/1995	6.2	0.5	1.1	-
	2800-6400 kg	1/1/1995	19.2	1.2	10.6	-
	>6400 kg	1/1/1995	49.8	2.3	10.6	-
Mexico	Cars	1/1/1993	3.4	0.41	1	-
	light duty vehicles gvw < 6012 lb	1/1/1994	14	1	2.3	-
	light duty vehicles gvw 6013-6614 lb	1/1/1994	14	1	2.3	-

(1) Diesel Vehicles only
(2) 01/01/99 for all new registrations
(3) PM 0.31 g/km for vehicles < 1700 kg
Source: CONCAWE (2006)

The introduction of emission standards for both new and old cars, along with travel demand management programs, and regulatory measures such as vehicle inspection and maintenance programs (I/M), fuel specification, etc., have reduced vehicular emissions in Latin American countries. For example in Mexico City, the total daily CO and NOx emissions from light and medium gasoline vehicle in 2000, were 48 percent and 26 percent lower, respectively, from 1998 levels (Schifter et. al., 2005).

4.5 Vehicle Emissions Standards in Asia

Emission standards have been widely implemented in Asia. Some Asian countries (e.g., Singapore, Hong Kong) have introduced and strictly enforced stringent emission standards (Seik, 1996); others are yet to get there. Besides lower standards, strict enforcement is a major challenge in Asia. For example, China's current limit (Euro II), as compared to the United States, is 26 percent higher for carbon monoxide and double for hydrocarbons. However, the proposed Euro II standards have not been met due to weak enforcement (Zhao, 2004).

Table 9 illustrates exhaust emissions regulations in selected Asian countries. Countries such as Bangladesh, India, Indonesia, Sri Lanka, Nepal, and Singapore have introduced Euro standards, whereas Malaysia, Philippines, South Korea, Taiwan, and Saudi Arabia have implemented U.S. emissions regulations.

In order to combat deteriorating urban air quality, China has adopted aggressive vehicle emissions standards. It imposed emissions standards equivalent to Euro 1 in 2000 and aims at meeting current European emissions standards, with a lag of about 4–6 years. (Bauner et al., 2008). The existing vehicle emissions standards adopted in Beijing are similar to Euro 2 standards (Deng, 2006). Euro 4 standards will kick in starting 2010 (Liu et al., 2008).

Like mainland China, Taiwan, too, has taken some bold steps towards containing transport sector emissions. The first stage emission standards for gasoline cars were introduced on 1 July 1987. In Taiwan, all passenger cars must pass emission standard tests for CO and HC during the idle phase at 0.5% and 100 ppm, respectively, for new cars and 1.2% and 220 ppm for in-use cars. Vehicle regulation requires all new passenger vehicles to have exhaust catalyst. It also requires all vehicles to undergo annual I/M tests to pass the emission standards (Chiang et al., 2008)

Table 9. Exhaust Emission Regulations in Selected Countries

Country	Vehicle type	Fuel	Effective date	Equivalent Emission Limits
Bangladesh	Light & Heavy Duty	Gasoline	2006	Euro II
	Light & Heavy Duty	Diesel	2006	Euro I
China[(1)]	Light Duty (<3.5t)[(2)]- National	Gasoline & Diesel	1993	ECE 15.03 with higher limits
	Passenger Cars & Light Duty (Beijing & Sanghai)		July, 1999	Euro I
Hong Kong	Light Duty[(3)]		01/01/2006	Euro IV
India	Light Duty- National		2000	91/441/EEC[(4)]
	Light Duty-Delhi region		04/00	Euro II
Indonesia	Gasoline engines		2005	Euro II
	Diesel engines		2005	Euro II
Malaysia	Light Duty	Gasoline	01/01/00	94/12/EEC
		Diesel	01/01/00	94/12/EEC
Nepal	Light Duty-Imported		01/02	Euro I
Philippines	Light Duty		01/01/97	ECE R 15-04[(5)]
	Medium & heavy duty		01/01/97	ECE R 49-01
Singapore	Light Duty	Gasoline	01/2001	Euro II
		Diesel	10/2006	Euro IV
South Korea	Gasoline			US procedures
	Diesel			ECE R 49
Sri Lanka	Gasoline		01/01/2003	Euro II
	Diesel			
Taiwan	Passenger Cars[(6)]	Gasoline	07/90	US 1984 Limits
	Light duty[(6)]	Diesel		US 1984 LDT
Thailand	Light Duty	All[(7)]	25/08/2001	96/69/EC
Saudi Arabia				ECE R 15.03 equivalent

(1) The Chinese State Environment Protection Agency (SEPA) proposed the adoption of EU Directives 91/441/EEC in 2001.
(2) A government notice, posted on 27 June 2001, required the immediate cessation of production of carbureted vehicles. Production was halted immediately and sales were banned from 1 September 2001.
(3) Euro 3 or equivalent standards will apply to certain class of vehicles under3.5 tones on or after 1 January 2002. From 1 January 2006, LD diesel must comply with Califorrnia regulations. Euro 4 introduced from 01/01/2006 for vehicles up to 2.5 tones, extending to 3.5 tones from 01/01/2007.
(4) Employs a modified Indian Driving cycle similar to the ECE15+EUDC cycle, except that the maximum speed is limited to 90 km/h.
(5) Evaporative emission for spark ignition engines shall not exceed 2.0 grams per test. Crankcase emissions should be eliminated.
(6) Evaporative emission for spark ignition engines shall not exceed 2.0 grams per test.
(7) Proposed to the National Environment Board for implementation as follows: RM =<1305 kg from January 2003; RM>1305 Kg from 1 January 2004. Implementation of Row B of 98 /69/EC (Euro 4) is under discussion.

Source: CONCAWE (2006)

Japan is another Asian country that has taken strong measures towards vehicular emission control. In addition to various fiscal instruments, Japan has put in place tough regulatory standards. Its emission standards are clearly on par with standards adopted in Europe and the United States. There are two sets of standards: the first one aimed at reducing pollution from vehicles below 1250 Kg and the second for vehicles weighing more than 1250 Kg. Table 10 illustrates the differences in these two sets of standards. Japan's Central Environmental Council (CEC) published its third report on "Future policy for motor vehicle exhaust emission reduction" in December of 1998. It called for a further strengthening of NO_x and PM limits for diesel engines in two stages and led to 25-30 percent reduction in NO_x emission and 28-35 percent reduction in PM emission from 2002-2004, depending on vehicle category. It required 70 percent reduction in HC and CO emissions (CONCAWE, 2006).

Table 10: Japanese Emission Standards for Diesel Passenger Cars, g/km

Vehicle Weight	Date	Test	CO	HC	NOx	PM
< 1250 kg*	2005[b]	JC08[c]	0.63	0.024[d]	0.14	0.013
	2009		0.63	0.024[d]	0.08	0.005
	2002[a]		0.63	0.12	0.3	0.056
> 1250 kg*	2005[b]	JC08[c]	0.63	0.024[d]	0.15	0.014
	2009		0.63	0.024[d]	0.08	0.005

* - equivalent inertia weight (EIW); vehicle weight of 1265 kg
a - 2002.10 for domestic cars, 2004.09 for imports
b - full implementation by the end of 2005
c - full phase-in by 2011
d - non-methane hydrocarbons
Source: CONCAWE, (2006), Diesenet (undated)

5. Fuel Quality Standards

Fuel quality standards play a crucial role in protecting public health and the environment from transport sector emissions. It is often viewed as an important component of an overall plan to improve air quality. Cleaner fuels have an immediate impact on both new and existing vehicle fleets. There is a close relationship between fuel quality and emission control technologies, and it is also important for the successful adoption of stringent vehicle emission standards. The reduction of sulfur to near-zero levels is prerequisite for any air pollution reduction strategy to bear fruits (Hao et al., 2006; Blumberg et al., 2003).

Realizing the importance of cleaner fuel, countries started reducing the level of lead and sulfur in fuel in early the 1990s. Starting January 1995, leaded gasoline sales were banned in the United States. The maximum amount of lead permitted in unleaded gasoline in the United States is 0.013 grams/liter (CONCAWE, 2006). The Alliance of Auto Manufacturers, which represents the auto industry, supported a gasoline sulfur control program in 2004 and agreed to reduce sulfur content to “near-zero” levels (less than 5 mg/kg) by 2007 (CONCAWE, 2006). Similarly, leaded gasoline was banned in the EU effective from 1 January 2000, although some countries like Greece, Italy, and Spain had to be granted a grace period (Gwilliam et al., 2004). EU Directives 2003/17/EC introduced a new sulfur requirement for both gasoline and diesel with a maximum 10 mg/kg. It also called for the complete penetration of gasoline and diesel fuels with a maximum 10 mg/kg sulfur contents from 1 January 2009 (CONCAWE, 2006).

Table 11 illustrates specifications for unleaded gasoline in selected developing countries. Fuel quality regulations and specifications vary from one country to another. In countries like Mexico, the maximum allowable limit of sulfur in fuel is far lower than in countries such as Pakistan, India, Guatemala, El Salvador, Honduras, Malaysia, and Tanzania. In sub-Saharan Africa, lead was banned on 1 January 2006; the maximum allowable limit is 13 mg/l (CONCAWE, 2006). Sulfur limits, especially in diesel, tend to be very high in Pakistan, Malaysia, India, Bangladesh, Thailand, El Salvador, Guatemala, Honduras, and Nicaragua.

Table 11 Gasoline Specification-Selected Developing Countries

Country	Property RON (Value Min.)			Property Sulfur (mg/kg or ppm, Max)		
	Reg.	**Prem.**	**Supreme**	**Reg.**	**Prem.**	**Supreme**
Bangladesh	80	95		1000	1000	
India	88	93		1000	1000	
Malaysia	92	97		1500	1500	
Philippines	-	93		1000	-	
Pakistan	80	87	97	2000	2000	2000
Thailand	87	95		1000	1000	1000
Kenya	83	93		500	500	
Tanzania	87	95		1500	1500	
Argentina	83	-		500	-	
Bolivia	85	95		500	500	
Colombia	81	87		1000	1000	
El Salvador	87	95		1500	1500	
Guatemala	87	95		1500	1500	
Honduras	87	95		1500	1500	
Mexico	-	95		250-300	250-300	
Nicaragua	87	95		1000	1000	
Panama	87	91		1000	1000	
Paraguay	85	97		1000	1000	

Source: CONCAWE (2006)

China is taking aggressive steps towards containing hazardous components in fuel. By 1998, the local government in Beijing successfully phased out leaded gasoline. At present, sulfur content ranges from 300 ppm to 500 ppm for gasoline and from 500 ppm to 800 ppm for diesel fuel in Beijing (Hao et. al., 2006). Since eliminating lead as an octane booster in gasoline is a relatively low cost measure with high returns in terms of public health, Gwalliam et al. (2004) suggested that it should be a high priority for all countries that have not yet eliminated lead from gasoline.

The emissions of sulfur dioxide from diesel used in heavy vehicles are one of the main environmental concerns in most countries around the world. Hence, these countries have imposed standards on the sulfur content of diesel. Table 12 presents existing or planned standards for the sulfur content of diesel in selected countries. As can be seen from the table, sulfur standards for diesel have been rapidly stiffened in many countries over the last decade. For example, the standards in the United States, Japan and European Union have been reduced to 50 ppm in 2005 from 500 ppm in 1996. In Australia, the standards have been reduced to 50 ppm in 2006 from 2000 ppm in 1996. The standards stiffened further to 10 ppm in Japan and European Union. In some developing countries, such as, India, Philippines, Vietnam, the standards for diesel sulfur content were reduced by 10 times during the 1996-2005 period.

Although the costs and benefits associated with sulfur reduction vary from region to region, depending on the state of existing refineries, fuel quality, and emissions standards, the cost of sulfur reduction is affordable (Blumberg et. al., 2003). Some countries that import petroleum products might find it hard to maintain the required quality due to the lack of their own refineries. Consequently, developing countries without their own refineries may not be in a position to enforce fuel standard related regulations. Nepal, for example, lacking its own refinery, is dependent on imported petroleum products and is experiencing severe air pollution problems related to the high levels of benzene in imported gasoline (Kiuru, 2002).

Another important standard imposed on fuels in many countries is the minimum blending requirement of gasoline and diesel with ethanol and bio-diesel, respectively. Although energy security could be the primary purpose of such blending, reducing environmental externalities, particularly CO_2 emissions, is an equally important benefit. Table 13 presents examples of biofuels blending regulations in selected industrialized and developing countries. Most of these regulations were enacted quite recently, and they typically call for the blending of 10–15 percent ethanol with gasoline or the blending of 2–5 percent biodiesel with diesel. The provinces of British Columbia and Quebec in Canada have also announced that they would mandate ethanol blending but exact blending percentages are yet to be stipulated. Brazil has mandated the blending of biofuels for 30 years through its “ProAlcool” program; while the blending shares for ethanol were adjusted occasionally, they have remained in the 20-25 percent range.

Table 12: Existing and Planned Standards for Diesel Sulfur Contents in Selected Countries
Unit: PPM (milligram of sulfur per kilogram of diesel)

Country	1996	1998	1999	2000	2002	2003	2004	2005	2006	2007	2009	2010
USA	500								15			
EU	500			350				50			10	
Japan	500							50		10		
Australia	2,000				500				50			
Bangladesh	>5000				5,000							
Cambodia	>5000			2,000								
China	5,000	2,000										
India	5,000			2,500				500				350
Indonesia	5,000											
South Korea	2,000	500										
Malaysia	5,000	3,000			500							
Pakistan	10,000				5,000							
Philippines	5,000			2,000			500					
Singapore	5,000	500										
Sri Lanka	5,000					3,000						
Thailand	2,500		500									
Vietnam	10,000					2,000		500				

Source: Krylov et al. (2005)

Table 13: Biofuels Blending Mandates

Country	Ethanol	Biodiesel
Australia	E2 in New South Wales, increasing to E10 by 2011; E5 in Queensland by 2010	
Argentina	E5 by 2010	B5 by 2010
Bolivia		B2.5 by 2007 and B20 by 2015
Brazil	E22-E25	B2 by 2008 and B5 by 2013
Canada	E5 by 2010; E7.5 in Saskatchewan and Manitoba; E5 by 2007 in Ontario	B2 by 2012
China	E10 in 9 provinces	
Colombia	E10	B5 by 2008
Dominican Republic	E15 by 2015	B2 by 2015
Germany	E2 by 2007	B4.4 by 2007; B5.75 by 2010
India	E10 in 13 states/territories	
Italy	E1	B1
Malaysia		B5 by 2008
Paraguay		B1 by 2007, B3 by 2008, and B5 by 2009
Peru	E7.8 by 2010 nationally; starting regionally by 2006	B5 by 2010 nationally; starting regionally by 2008
Philippines	E5 by 2008; E10 by 2011	B1 by 2008; B2 by 2011
South Africa	E8-E10 (proposed)	B2-B5 (proposed)
Thailand	E10 by 2007	3 percent share by 2011
United Kingdom	E2.5 by 2008; E5 by 2010	B2.5 by 2008; B5 by 2010
United States	E10 in Iowa, Hawaii, Missouri, and Montana; E20 in Minnesota; E2 in Louisiana and Washington State	B5 in New Mexico; B2 in Louisiana and Washington State
Uruguay	E5 by 2014	B2 (2008-2011) and B5 by 2012

Note: Targets with no dates are already in place except in some U.S. states where the targets are expected to be effective in future years. There are other countries with future indicative targets that are not shown here

Source: Worldwatch Institute (2008).

6. Vehicle Inspection and Maintenance Programs

Inspection and maintenance (I/M) programs are largely devised to identify primary “gross polluters” and ensure that they are retrofitted or retired. Be it developed or developing countries, vehicles that are not properly maintained are responsible for a large fraction of total transport sector emissions. Based on a cross country study of CO and HC emissions from over 200,000 vehicles in the USA, Canada, Mexico, the UK, and Sweden, Guenther et al. (1994) found that less than 10 percent of the fleet, which are referred to as “gross polluters,” are responsible for half of the total emissions. Likewise, around 10–12 percent of the existing vehicle fleet accounted for about 50 percent of transport sector CO emissions in Nepal from 2001-2002 (Faiz et al., 2006). Therefore, the problem of a small percentage of ill-maintained vehicles diluting the gains made through higher fuel, emissions, and fuel economy standards is not a developed or developing countries’ problem; it is a global problem that calls for innovative ways to discourage “gross polluters” from getting on the roadways.

Although I/M programs have been widely implemented in both the developed and developing word, there is no universal consensus on the use of I/M programs to regulate vehicle emissions. Faiz et al. (1990) and Mage and Walsh (1992) emphasized the importance of I/M programs. According to Faiz et al. (1990), without a rigorous I/M program, smoke and particulate emissions from often overloaded and poorly maintained diesel-powered vehicles cannot be controlled in developing countries. Mage and Walsh (1992) argued that I/M programs are critical for controlling emissions from both new car and in-use vehicles. Gwalliam (2004) and Kebin and Chang (1999), based on experiences from Mexico City and China, considered I/M programs a success. The I/M system introduced in Mexico city with high volume, centralized test centers is an example of a successful program on a large scale (Gwalliam, 2004). In Beijing, according to Kebin and Chang, (1999), emissions decreased a total of 28 to 40 percent, and in Shanghai, CO and HC emission concentrations decreased on average by 39 percent. Like in Beijing, the I/M program introduced in 1992 in the Lower Fraser Valley of the Canadian province of British Columbia, led to reduction in HC emissions by 20 percent, CO by 20 percent, and NO_x by 1 percent (Faiz et al., 1996). Contrary to the aforementioned studies, Hubbard (1997) argued that the existing I/M programs in the United States have generated, at most, small environmental benefits.

Despite some criticisms, I/M programs have been widely implemented. In the United States, California was the first the state that implemented a wide-ranging test and repair

I/M program in 1984. It required gasoline-powered automobiles to pass inspections every two years (Faiz et al., 1996). In other states, depending upon the state's performance standards, motorists have to satisfy I/M requirements (Harrington et al., 2000).

Within the European Union, the member states have implemented the requirements of the Roadworthiness Framework Directive. It requires vehicle owners to go for a compulsory vehicle inspection and is enforced to ensure the necessary maintenance and upkeep of vehicles (CCAP, 2004). EU Directive 96/96/EC regulates I/M programs and safety inspections. The directive also provides some leeway to the member states in terms of: (i) setting a higher frequency of tests; (ii) making the testing of optional equipment compulsory; (iii) expanding test requirements to other classes of vehicles; and, (iv) prescribing additional or more stringent tests (USAID, 2004).

In Australia, a pilot I/M scheme was introduced in July 1998 in the greater Sydney area. Its main aim was to include all light duty vehicle by the year 2000. The main goal of the National In-service Emissions (NISE2) study was to establish a primary phase and a main phase testing that would aid in the establishment of the current emissions performance of light duty petrol vehicles (CONCAWE, 2006). The primary phase was designed to develop and validate reliable emission tests for light duty gasoline vehicles that are based on "real world" driving patterns. It was intended to provide the basic tools for use in the main phase for generating a more accurate and representative measure of the actual amount of pollutants emitted from the light duty gasoline fleet (CONCAWE, 2006).

China's I/M programs require regular inspections, which include yearly inspections, first-class maintenance, second class maintenance, and vehicle overhaul. In big cities such as Beijing, Shanghai, and Guangzhou, I/M programs have been effective, to a large degree, in lowering vehicle emissions (Kebin and Chang, 1999).

Despite their emission reduction potential, I/M programs have certain limitations, which are primarily on two fronts: (i) inefficient use of resources and inconvenience to motorists; and, (ii) infectiveness in identifying gross polluting vehicles (Calvert et al., 1993; Bishop et al., 1997). Lack of proper enforcement, and corruption, prevents the realization of the full potential of any I/M program. Moreover, the lack of capacity, such as the lack of training of personnel, and poor quality test equipment, can hinder the success of the program. India is a classic example of how the lack of a well-conceived program defeats the overall objectives of the program [USAID, 2004][2]. In Nepal, between 16–32 percent of vehicles failed the emissions test from 2000–2002 (Faiz et al., 2006). In Chongqing, China, only 10 percent of vehicles brought in by drivers failed the emissions test, but 40 percent of vehicles flagged down by roadside inspectors did not pass the emission test (USAID, 2004).

7. Other Laws and Regulations

Although policies such as fuel economy standards, emission standards, fuel quality standards, and I/M programs are most frequently utilized, they are by no means the only regulatory instruments introduced to discourage travel demand and reduce emissions from the transport sector. Several other regulatory measures have been experimented with, to varying degrees of success. For example, access bans, or partial and total vehicle bans, have been widely used in European countries such as Italy, Greece, The Netherlands, Spain, and Germany (Goddard, 1997). Italy has adopted a policy that bans private cars from entering the city centers. Italy aims to protect its historical city centers by not allowing non-residents to drive into the city center. In Swiss cities such as Bern and Zurich, the restrictive measures taken by the government (e.g., limited parking, road capacity reduction and diversion of through traffic) has made driving so difficult that many Swiss prefer using public transport (Bonnel, 1995).

The "No- Driving Day" (NDD) (or *Hoy No Circula*) policy introduced in Mexico City in 1989 is one of the much-discussed regulatory measures to control traffic congestion and vehicular emissions. It would not only help reduce environmental externalities through travel management but also reduce traffic congestion (Molina and Molina, 2004). The

[2] Indian I/M programs are plagued by poor quality personnel and test equipment, low compliance rates, and corruption. I/M tests are not taken by more than 15 percent of drivers and those who take it pass without truly controlling their emissions (USAID, 2004).

program mandates not driving one day during the week (except the weekends) and two days during serious pollution episodes. During the weekends, odd and even license plate numbers are used, which forced one-half of the fleet to be parked. By removing 20 percent of the vehicles from the streets in its first few months of operation, it did contribute towards the betterment of ambient air quality (Goddard, 1997). The gains made, however, were temporary. The program did not yield the desired level of success for several reasons. First, the city lacked sufficient public transport systems to meet the travel demand resulting from the ban on personal vehicles. Second, the driving public intelligently subverted the existing regulation. For example, many drivers adjusted to the restriction by purchasing additional autos in order to have at least one vehicle available on any given day. Many of the second vehicles were older and released more emissions. Some studies (e.g., Eskeland, 1994; Eskeland and Feyzioglu, 1995; Goddard, 1997) even argued that the program actually may have led to an increase in the number of vehicles and total emissions from road transport.

In addition to Mexico City, the traffic restriction (restricción vehicular) policy has been implemented in three different Latin American cities: Santiago (Chile), São Paulo (Brazil), and Bogotá (Colombia), with varying degree of success. The traffic restriction policy in Santiago implemented to reduce congestion and air pollution has limited the circulation of 20% of buses, taxis, and cars. In order to combat free rider problem, the schedule for the restriction is changed every few months. In São Paulo, the effects of the traffic ban have been undermined by growing car ownership. In order to meet air quality targets, Mexico City authorities are planning modifications to the existing scheme to ensure stricter enforcement with fewer exemptions (Mahendra, 2007).

Many Latin American countries have imposed complete or partial bans on used vehicles imports. Despite a huge market for used vehicles, countries such as Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Paraguay, Uruguay, and Venezuela have completely banned used vehicle imports (Pelletiere and Reinert, 2002).

The Supreme Court of India has played a proactive role in controlling vehicular pollution in New Delhi. Its directives include: (i) the phasing out of commercial/transport vehicles older than 15 years; (ii) the replacement of all pre-1990 autos and taxis with new vehicles using clean fuel; and, (iii) the conversion of the entire city bus fleet, both public and private, to use compressed natural gas (CNG) (DOT, 2009). The Supreme Court order for the conversion of the entire diesel-powered bus fleet in Delhi and its successful implementation clearly shows that the reluctance on the part of the government in developing countries in maintaining air quality can be overcome through the judicial system.

In many large U.S. cities, regulation such as high-occupancy vehicle (HOV) lanes and high-occupancy toll (HOT) lanes are introduced. These regulations help reduce emissions in two ways: (i) encouraging an increased vehicle occupancy and (ii) encouraging the use of clean vehicles (hybrids) and vehicles with higher fuel efficiency (motor cycles) as such vehicles are allowed in HOV and HOT lanes. Until recently, ten US States have considered allowing single occupant hybrid vehicles (SOHV) into HOV lanes (Chu et al., 2007). Although well intentioned, allowing hybrid vehicles in HOV lanes have started to produce negative externality in the form of increased congestion in HOV lanes. For example in Virginia, USA, where motorcycles and hybrid vehicles are allowed to ply on HOV facilities statewide, traffic congestion problem has been increasing experienced by the commuters. In a survey conducted in 2002, vanpoolers cited Congestion in HOV lanes as their second greatest concern, which has been increased in recent years by the influx of hybrid vehicles into the Virginia HOV lanes (Poole and Balaker, 2005). Increased congestion also means increase in pollution.

8. Which Regulatory Instruments and Where?

The literature on the design of regulatory policies to reduce transport sector externalities mainly focus on two central questions: (i) the desired level of protection of public health and environmental quality that a country or region is aiming to achieve and (ii) the cost and institutional capacity to implement the policies. Based on intent of the program(s), easing congestion or controlling pollution, the appropriateness of the regulatory instrument(s) under consideration may vary considerably. Factors that influence the effectiveness of the instrument should be used to gauge the appropriateness of the regulatory measure (Ghose, 2002; Satyanarayana, 2007). The selection of an instrument does not guarantee its effectiveness. The success of the selected instrument relies on factors such as: (i) the overall costs of emission control; (ii) the comprehensiveness of the law/regulations with regard to the level of development of the society; (iii) the ability of the industry in question to bear the control cost burden; and, (iv) the punitive measures in place and the chances of detection of violation (Priyadarshini and Gupta, 2003).

The choice of control options is based on the country's priorities, the characteristics of the air pollution problem and the resources of the regulating agency (Cohen and Kamieniecki, 1991; Faiz and Larderel, 1993). Take countries or cities facing severe local air pollution problems, for example. Most developing countries normally introduce emissions standards, whereas developed countries, which are equally concerned with local air pollution, adopt a myriad of regulatory measures, such as fuel economy and fuel standards, in addition to emission standards. Regulatory standards vary considerably from one country to another depending upon the level of motorization, dependency on private vehicles, and environmental consciousness. Fuel economy standards across European countries and between the United States and the EU vary significantly. Most developing countries are found to be reluctant to introduce stringent regulatory standards because of their limited resources to enforce the stringent standards (Cohen and Kamienicki, 1991; Priyadarshini and Gupta, 2003; Delfin, 2004).

Note here that regulatory standards are not mutually exclusive to each other in that introduction of an instrument does not require others. For example, emission standards are necessary to control local air pollutants such as CO, HC, NOx, and fine particulate matter. Control devices reducing these emissions do not necessarily reduce fuel consumption and CO_2 emissions and, hence, emission standards do not replace fuel economy standards. Similarly, emission standards may not replace fuel quality standards.

As the level of air pollution varies from one city to another, depending upon the level of motorization, compactness of the city, and maintenance level of the existing vehicle stock, most developing countries are struggling to make the selection of appropriate regulatory instruments that can effectively reduce emissions from the transport sector. One of the major questions, whose answer seems elusive for most, is what is the starting point in terms of framing effective policy instruments in reducing transport sector emissions? There seems to be no clear-cut answer to this question. There are, however, several worthy suggestions (Gwalliam, 2004; Mage and Walsh, 1992; ADB, 2003; Blumberg et al., 2003).

Understanding the factors affecting the total inventory of motor vehicle emissions is necessary to design effective programs. The ADB (2003) suggested that countries with a serious air pollution problem strongly consider leapfrogging to the most stringent standards possible, such as the Euro 2, Euro 3 or Euro 4, after making sure that the appropriate fuel is available. Blumberg et al. (2003) argued that jumping to near-zero sulfur diesel in a single step is more cost-effective and advantageous. The suggestions, although genuine, may not be always feasible due to the lack of resources, trained labor, and the required infrastructure. For example, one of the major difficulties associated with vehicle emission control programs is that it imposes significant economic and social costs (Gwalliam, 2004) and the actual beneficiaries are hard to identify (Faiz et al., 1999).

Motor vehicle pollution control programs should be based on a realistic assessment of costs and benefits and must be compared with the technical and administrative feasibility of proposed countermeasures. In order to make services affordable to the poor, transport policy must be designed to be both environmentally sensitive and consistent with public and private affordability.

9. Conclusions

This study reviews the main regulatory policy instruments to control transport sector externalities. The instruments considered include fuel economy standards, emission standards, fuel quality standards and other laws and regulations. We also highlight factors affecting the selection of regulatory instruments.

Fuel economy standards have generally been introduced in developed countries, which are not only concerned about local air pollutions but also other factors such as traffic congestion, climate change, and energy security. In the United States, fuel economy standards were first introduced in the early 1970s in an effort to lessen the impacts of the first oil crisis. Currently, the policy also serves to reduce GHG emissions. The fuel economy standard in the U.S. has not improved, however, since the 1985 level of 27.5 MPG, although the 2007 Energy Bill mandates an improvement to 35 MPG by 2020. In contrast to United States, the EU has defined fuel economy in terms of GHG emissions due to the increasing contribution of urban transportation to global GHG emissions. Implementation of the EU fuel economy standards will result in the reduction of vehicular CO_2 emission from 186 g/km in 1995 to 140 g/km in 2008 and further to 120 g/km by 2012.

Although the fuel economy standard is one of the key regulatory instruments employed in industrialized countries to reduce transport sector externalities, its success has been contested. Some existing literature argue that equivalent fiscal policy instruments, such as fuel or emission taxes, could have produced better results than fuel economy standards while reducing the same amount of fuel consumption and emissions. While the fuel economy standards help reduce fuel consumption and associated emissions, particularly CO_2 emissions, they do not necessarily reduce local and regional air pollutants, such as CO, VOC, NOx, and SPM to the level necessary to meet local air quality standards in many cities around the world.

Emission standards have been introduced in both industrialized and developing countries to control local air pollution. In response to the increase in local pollution level, vehicle emission standards have consistently been tightened over the years. Starting in 2004, tailpipe emissions standard for NOx has been set at 0.07 grams per mile in the U.S. (compare to 3.1 grams per mile in 1975). In the EU, there have been quick revisions in the emission standards towards advance standards. The Euro 1 standards introduced in the early 1990s were modified to Euro 2 in 1996, to Euro 3 in 2000 and finally to Euro 4 in 2005. Following the footsteps of the industrialized countries, developing countries, too, have made commendable progress in terms of adopting emission standards. Several countries in Latin America and Asia have adopted either Euro or U.S. emission standards to control their local air pollution.

In order to control some pollutants, such as lead and oxides of sulfur, the element causing these pollutants needs to be limited through fuel quality standards. Most countries around the world have phased out leaded gasoline and controlled lead content in unleaded gasoline. Similarly, many countries, both industrialized and developing, have introduced fuel quality standards to limit sulfur content, thereby reducing oxides of sulfur and particulate matter. Moreover, several countries have introduced mandates for blending ethanol and biodiesel into respectively, gasoline and diesel. This would certainly help reduce CO_2 and some local air pollutants.

Setting vehicular standards does not necessarily control emissions unless an effective enforcement mechanism is in place, however. Inspection and maintenance (I/M) programs are the most common initiatives countries have undertaken to enforce the standards. The programs mandate regular inspection of vehicles and retirement of those not meeting the standards. Besides standards, there also exist some regulatory measures, such as imports ban of polluting vehicles in many Latin American countries, partial and complete driving restrictions in some European cities and the no driving day program in Mexico City and the mandatory conversion of public bus in New Delhi from diesel to compressed natural gas (CNG).

Fuel economy standards, emission standards, fuel quality standards and I/M programs are not mutually exclusive and they are introduced for different purposes. Different countries could give priority to different measures depending upon their needs and institutional capacity to enforce the standards. Since most developing countries are particularly concerned about local air pollution, they are found to prioritize the introduction of emissions standards and fuel quality standards over fuel economy standards.

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