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Office of Energy and Information Technology

Vehicle Inspection and Maintenance Programs: International Experience and Best Practices

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FOREWORD

This report was prepared by PA Government Services under the Energy IQC, a contract for the Office of Energy and Information Technology, US Agency for International Development (Work Order No. 179, Contract No. LAG-I-00-98-00005-00). The authors gratefully acknowledge the support and guidance of Simone Lawaetz and Jas Singh of USAID.

The project supervisor was John Armstrong. Karl Hausker served as project manager and principal author. Lennart Erlandsson provided research and drafting for Chapter 4 and sections in some other chapters. June Taylor of Guild Communications provided valuable assistance in writing and editing. A draft of the report was reviewed by Jon Bickel, Frank Dursbeck, David Gourley, Fred Herren, Cornie Huizenga, Simone Lawaetz, Rajat Nandi, Jas Singh, Christopher Stock, Eugene Tierney, and Jeffrey Vogt.

The contributions of various other individuals notwithstanding, the author remains wholly responsible for any errors, omissions, and misrepresentations.

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EXECUTIVE SUMMARY

Governments at all levels and donor organizations are grappling with the challenge of reducing air pollution in burgeoning cities in the developing world. To control rapidly growing vehicle emissions, government must not only affect the actions of vehicle manufacturers and fuel suppliers, but also the actions of millions of drivers in terms of how far they drive and how well they maintain their vehicles. A common policy tool for controlling emissions via maintenance practices is a vehicle inspection and maintenance (I/M) program.

The U.S. Agency for International Development (USAID) commissioned this report to draw together a set of best practices that can assist policymakers in launching or strengthening I/M programs, and to explore activities that might merit increased donor support to spur innovation and success in this policy arena.

The rationale and concept for an I/M program is simple: modern vehicles are dependent on properly functioning components to keep pollution levels low. Minor malfunctions in the air/fuel or spark management systems can increase emissions significantly. Major malfunctions can cause emissions to skyrocket. Government can require that vehicles be tested or “inspected” (the “I” in “I/M”) to determine whether their emissions exceed levels appropriate for that vehicle type. Vehicles that fail the test must undergo repairs or maintenance (the “M” in “I/M”) to bring their emission performance up to par, or they must cease operating, at least within the geographic jurisdiction of the I/M program. Studies suggest that a small fraction of the vehicle fleet typically are responsible for a very large share of total vehicle emissions, so an I/M program that reduces the emissions of these “gross emitters” can bring substantial air quality benefits.

Though simple in concept, the detailed design and implementation of I/M programs is far from simple, as this report will illustrate in abundance. The challenges are many: some vehicles may appear to emit little pollution but their harmful emissions may not be noticeable to the human eye, thus sophisticated testing equipment is needed. When emission control equipment malfunctions, vehicle performance may be unaffected, hence the driver has no private incentive to seek repairs. Finally, to state the obvious, I/M programs are a form of regulation. They create a public benefit by demanding private expenditures of money and time by vehicle owners. Like virtually any regulatory program, this creates the usual tensions that lead many actors to try to evade the regulation in numerous ways. Nonetheless, there are also some success stories in both developing and industrialized countries that provide valuable lessons.

A key message of this report is an emphasis on *how hard it is to implement an effective I/M program.* Policymakers should make a decision to launch (or strengthen) an I/M program only if fully cognizant of the challenges involved. Successful programs *can* reduce vehicle emissions in a cost-effective manner. Major behavioral change among the drivers of a nation, state, or city is never easy, but it is *possible* with committed leadership, the right institutional design, and the right incentives. A threshold condition for even contemplating an I/M program is for senior government officials to commit to multiple years of strong leadership and capacity-building.

The basic design recommended here calls for private operation of centralized “test-only” I/M facilities with government oversight. This too poses a fundamental challenge: how can government create a new “market” for the testing of vehicles from scratch? There is no historic or natural “demand” for testing on the part of the drivers. Government must create the demand for testing and convince one or more companies to “supply” the testing, with the necessary investments typically running in the millions of dollars. This poses a formidable risk management issue for governments and potential suppliers of testing. Compare this to privatization efforts related to energy, water, or transportation services. In those cases, consumers clearly want the services; their demand is “natural” and potential investors can assess consumers’ history. Investment risks remain, of course, but they are far more manageable.

Given the challenges involved, policymakers must reflect on the alternatives to I/M and on the question of timing. Generally speaking, every country in the developing world with heavily-polluted cities should *consider* instituting an I/M program now or in the coming years. However, policymakers must choose when and where to invest their financial as well as political capital. Experts recommend elimination of lead in gasoline, control of Reid Vapor Pressure, and reduction of sulfur content in fuels as first priorities, along with setting and enforcing emission standards for new vehicles and imported used vehicles. I/M programs are considered among a list of second priorities that are harder to implement and more difficult to rank. This list includes: programs of retrofitting or re-powering equipment (e.g., diesel particulate traps, replacement of 2-stroke engines); banned entry of certain vehicles in certain areas; forced retirement of older vehicles; and programs aimed at cleaner fuels or improved maintenance in public or private fleets (buses, trucks, taxis, etc.). Some of these options may make sense to focus on before an I/M program. There are no easy options in the transportation field, but some are easier than others and some don’t require the massive behavioral change implicit in I/M programs.

Policymakers in developing countries face added complexity in deciding whether and when to launch an I/M system. Relevant technology is changing rapidly:

- Currently I/M systems lack the capability to measure the vehicle emission of greatest health impact: particulate matter (PM). However, a PM meter suitable for use in the I/M context is likely to be commercially available in 1-2 years. PM meters could change dramatically what constitutes “best practice” in test procedures and standards for diesel engines and two- and three-wheeled vehicles (i.e., motorcycles, scooters, mopeds, 3-wheel taxis, etc., or “2&3 wheelers” as used in this report).
- Technology is improving in the realm of “on-board diagnostics” (OBD)—micro-computers that can report and diagnose problems in emission control equipment. Many U.S. states have already eliminated traditional emission testing in their I/M systems for newer automobiles that have OBD, and more change is expected. (At the same, there is little progress in OBD for 2&3 wheelers and trucks.)
- Overall, the benefits of I/M programs are decreasing in the U.S. due to improvements in the performance and longevity of emission control technologies.

Policymakers must consider whether to invest now in I/M systems using current technologies and practices, or wait for some period of time with the expectation that their resources will be put to better use with a later generation of I/M technology and practices. The answers for any country may depend in part on the current composition of its fleet, how fast it turns over, the severity of the air pollution problem, and other factors. The complexity of the issues involved prevents this report from offering a "one-size-fits-all" recommendation on whether and when to launch an I/M system. Some countries probably should get started immediately while others might take smaller steps to prepare for I/M or focus on other policy options

ES-1. Selecting Best Practices

The selection of best practices in any policy arena should be guided by objective assessment of various practices and program designs. Unfortunately, there is a dearth of quantitative data to guide such assessments in developing countries. Instead, experts in the field (and this report) must rely largely on qualitative and anecdotal data to assess program performance. They make inferences about the underlying causes related to policy and program design, and try to apply the more detailed studies available in industrialized countries.

The selection of best practices is further hampered by the fact that some industrialized countries have focused their I/M programs on cars (their biggest source of vehicle emissions). In contrast, truck and 2&3 wheeler emissions present the biggest challenges in many developing countries. Related to their natural focus on cars, industrialized countries have focused on vehicle emissions of carbon monoxide, hydrocarbons, and nitrogen oxides, and given far less attention to fine particulate emissions, widely acknowledged as the most significant air problem in developing countries (and a major component of 2&3 wheeler and truck emissions). The result is that policymakers have access to very sophisticated approaches for conducting I/M for cars, but far less sophisticated approaches for 2&3 wheelers and trucks—ironically, the greatest need in the cities of the developing world.

Acknowledging these difficulties in selecting best practices, this report argues further that "all best practices are *not* created equal." Identified here are a handful of "essential" best practices that rise above the others in importance. Policymakers in the developing world should recognize that I/M programs that incorporate these essential best practices have a much greater chance of succeeding than programs in which these practices are absent. The report also identifies other "ordinary" best practices that enhance program effectiveness.

In part, this report provides a synthesis of the wisdom of previous studies of I/M best practices, in some cases adding richness of detail or example and offering the reader ready links for delving deeper into the literature. In part, this report breaks new ground in probing areas covered rather lightly in the existing I/M literature, e.g, contracting issues and enforcement and compliance promotion options.

The report is structured around a set of four key questions policy-makers must grapple with in designing an I/M system:

- What institutional design can best accomplish the goals of I/M?
- What emission standards should apply, and what testing procedures should be used?

- How can government ensure a high level of compliance with I/M standards?
- How can government ensure that following key resources are in sufficient supply?
  - Financial resources—for typically a multi-million dollar undertaking
  - Institutional capacity—especially in the vehicle service sector
  - Political support—critical for the I/M program to survive

ES-2. Eight Essential Best Practices

Four of eight *essential best practices* concern "institutional design" questions. The other four relate to the categories of: test procedures and emission standards; enforcement and compliance promotion; and managing resources.

Institutional Design

An I/M program should conduct inspections using "test-only" facilities. Policymakers must choose between a relatively small number of centralized or "test-only" facilities, and a relatively large number of decentralized or "test-and-repair" facilities. Advantages of the former approach include the ability to spread costs over a high volume of inspections, and achieve a low cost per inspection. Additionally, test-only facilities can afford more costly, sophisticated test equipment by the ability to spread costs. Oversight of the facilities by government is also relatively easy due to their small number.

Government should set the policy framework and provide overall management of the I/M program while private contractors perform the actual inspections. This conclusion likely will disturb those who believe every public service should be performed by a government employee. However, expert opinion is unified on the desirability of private firms performing this role under the oversight of a governmental body. In general, this conclusion is driven by the same reasoning that underlies the broader privatization movement affecting energy, water, transportation, and other sectors: many services of a public nature are best delivered by a private firm accountable to the government rather than by a state-owned entity that essentially holds a perpetual monopoly in providing the service. The latter organizational form often suffers from low technical competence and a general inability to punish poor performance or fraud at the individual employee level and the organizational level as a whole. A capital-starved public monopoly can be subject to budgetary pressures from external forces that threaten service quality and its ability to generate revenue, even if it is otherwise capable of providing that service in a financially viable manner.

Policymakers should exert strong oversight and institute a quality assurance (QA) program for the I/M program. There is no escaping the need to "inspect the inspectors." Effective oversight and QA is essential to deliver the actual emission reductions sought and help maintain public support for the program. Oversight and QA involve a set of highly technical tasks that can be performed by government (if the capacity exists) or contracting out in part.

Policymakers should implement I/M programs in a phased approach that allows learning, adaptation, and capacity building along the way. Ideally, I/M programs should begin with the vehicles that emit the most (due to their emission rates, high mileage, or both). A phase-in of stringency of emission standards should also be considered if standards would otherwise fail an unacceptably high percentage of vehicles or if capacity in the repair industry does not exist to repair vehicles to tighter standards.

Test Procedures and Emission Standards

Policymakers should set I/M emission standards based on statistics on the distribution of emission levels, analysis of what proper maintenance can achieve and how much it costs, and prudent judgment on what level of standards will command political support. The pollutants covered will vary for gas versus diesel engines (CO/HC/NOx versus PM/smoke/NOx). A very tough standard that many vehicles flunk could erode support, as could a very easy standard that made the I/M program appear ineffectual. When phasing-in standards, policymakers should set standards or "cut-points" so that 15 to 20 percent of vehicles fail. However, this rate could be higher or lower depending on technical and cost factors. As emission standards for new vehicles are tightened, policymakers should set I/M standards for these vehicles that are appropriately stringent, reflecting newer technology and improved emissions performance.

Enforcement and Compliance Promotion

Policymakers should make I/M compliance a requirement for being able to operate a vehicle, and enforce this requirement with an effective, periodic vehicle registration system. This linkage is a powerful tool for promoting compliance with I/M requirements, and a similar linkage to safety inspections is recommended. Government records of vehicle ownership are a building block of a functioning society. Accurate tracking of the status and owners of vehicles can assist in urban planning, tax collection, accident and crime investigation, as well as air emission inventories and I/M compliance. Given these multiple benefits of periodic vehicle registration, policymakers should put in a foundation of periodic vehicle registration before or concurrent with the effort to launch or strengthen an I/M program.

Managing Resources

Policymakers should set inspection fees at levels that will support costs of the recommended design of I/M programs set forth here, i.e., privately-operated test-only centers with strong oversight and quality assurance components. Although the resulting fees may appear high, they are likely to be affordable to citizens owning vehicles. Subsidies of initial capital costs for land or fixed facilities could be considered but inspection fees absolutely must cover ongoing operating costs.

Policymakers should ensure that all the actors in an I/M program have the capacity to carry out their roles, paying special attention to the vehicle service sector. Policymakers often neglect the critical task of building capacity to provide the "M"—the maintenance and repairs for vehicles that fail I/M tests. Donors and vehicle manufacturers are often willing to provide training and policymakers should seek their involvement in capacity-building in the vehicle service sector.

ES-3. Best Practices

Additional "ordinary" best practices are noted in Chapters 2 through 5, and Chapter 6 provides a comprehensive summary of all the best practices identified in this report. Several that receive light treatment in the existing literature are noted below. All can improve I/M program effectiveness.

Institutional design

Policymakers should consider the following practices in contracting private firms to operate I/M programs:

- In order to bring their expertise and capital, encourage international I/M firms to partner with local firms in the bidding process.
- Make awards to a single firm (rather than multiple firms) operating within a jurisdiction (i.e., state or metropolitan region). Government oversight is easier for a uniform program run by one firm. Encourage competition by making awards in more than one jurisdiction, and by ensuring that an incumbent firm does not have an unfair advantage when re-bidding a concession.
- Contract lengths should be seven years or longer. This will keep costs down by allowing a firm to amortize equipment over a good number of years. However, vigilant oversight of the firm must continue through the entire length of the contract to ensure that the firm is meeting program goals.
- Provide for appropriate inflation-indexing or wage-indexing of inspection fees. These are costs not under the control of the firm.
- Consider government ownership of land and buildings for test-only I/M centers, either at the outset or at the end of the first concession. This will help prevent unfair advantage by the incumbent at time of re-bid.
- Provide appropriate risk management contract provisions to account for the possibility of the actual number of inspections being far different from the forecast number. Especially in a new program in a developing country, compliance levels are hard to forecast and are not wholly under the control of the firm (being typically more a function of government efforts). Contracts can aim to keep the firm reasonably "financially whole" by adjusting revenues up or down to account for the actual number of inspections conducted.

National policymakers should establish an I/M policy framework; state and local governments should tailor some program details within this framework to address specific conditions within regions or cities. The I/M framework should be part of a larger policy framework that addresses vehicle emissions in an integrated manner. I/M program elements should account for new vehicle emission standards, equipment warranties, and fuel standards, all of which are typically set at the national level. Coordination improves I/M effectiveness.

Policymakers should integrate an I/M program with safety inspections. Safety problems pose risks of a similar magnitude as air pollution and deserve to be addressed with the same rigor. Government can achieve "economies of scope" in addressing both problems in an integrated way. The efficiencies will be manifest in shared costs for the two programs (e.g., land, facilities, staff) and in allowing drivers to get tested for both in a single trip.

Test Procedures and Emission Standards

Policymakers should base emission standards on fleet characterization studies. They should secure data on how many vehicles are plying the roads of a state or city, along with their types, ages, the quantities of pollutants they are emitting (see Box ES-1), and the number of miles they travel. This exercise is known as fleet characterization. In addition to aiding the process of setting standards, the data is essential to estimating total vehicle emissions and making decisions such as how many test facilities will be needed.

> ***BOX ES-1. MAJOR VEHICLE POLLUTANTS***
>
> **Gasoline Engines (Most autos and light trucks, some 2&3 Wheelers)**
> - Carbon Monoxide (CO)
> - Hydrocarbons (HC)
> - Nitrogen Oxides (NOx)
>
> **Two- Stroke Engines (Many 2&3 Wheelers)**
> - Carbon Monoxide (CO)
> - Hydrocarbons (HC)
> - Smoke/Particulate Matter (PM)
>
> **Diesel Engines (Heavy Duty Trucks, Buses, Some Autos)**
> - Nitrogen Oxides (NOx)
> - Smoke/Particulate Matter (PM)

With regard to emission test procedures, policymakers should closely monitor the development and availability of PM meters in the next one to two years. As noted above, PM meters suitable for I/M programs are likely to become available in that time period. This could change dramatically what constitutes "best practices" in test procedures, especially for diesel trucks but potentially for 2&3 wheelers and automobiles as well. Until PM meters become available, policymakers should apply the following test procedures (see also Box ES-2):

- **No-load testing for 2&3 wheelers.** Policymakers should consider adding a "high idle" and/or opacity test to a simple idle test for 2&3 wheelers. Loaded test procedures are under development and should be considered when available.
- **No-load testing for cars that are not equipped with catalytic converters, and loaded testing for cars with this emission control technology.** Using dynamometers, even test facility staff with low technical skill are capable of conducting short steady-state/single-load tests, achieving acceptable accuracy in measurement and holding costs down. Transient loaded tests (those that run the vehicle through simulated driving cycles and loads) are longer and more accurate, but are costlier and require relatively skilled staff. These tests might be deferred in developing countries until conditions warrant.
- **Snap-idle testing using the Society for Automotive Engineering (SAE) J1667 method for commercial diesel vehicles.** Some policymakers have opted for more costly loaded testing, seeking greater accuracy and reduction of fraud, however, it is unclear whether the added costs are justified.

Policymakers should set the required frequency of inspections by balancing technical, economic, and political factors. Six months to two years is a reasonable range (with an option for a somewhat longer initial period for new cars in which emissions performance is not expected to deteriorate much in the early years). Policymakers should examine how fast vehicle emission performance deteriorates, and

BOX ES-2. *VEHICLE EMISSION TESTS*

Loaded Test

- Vehicle is placed on a dynamometer (rolling treadmill) and run at various speeds and weights to simulate real driving conditions.
- Probe inserted into tailpipe measures emissions—CO, HC, and NOx.
- Test takes up to 10 minutes.

No-Load Test

- With vehicle stopped and idling, a probe is inserted into the tailpipe to measure emissions—CO and HC (not accurate for NOx).
- An additional measurement can be taken at a high idle speed.
- Test takes less than 1 minute.

Snap Idle Opacity Test for Diesel Engines

- A no-load test for diesel engines in which the engine is revved several times (e.g., per SAE J1667 procedure).
- An average value of smoke opacity (or density) in the exhaust stream is derived.

NOTE: These tests are described further in section 3.2.

how this varies with age or vehicle type. Economic factors include number of test centers and lanes needed which is a function, in part, of frequency. Political factors include what frequency drivers are willing to tolerate without undermining support for the program.

Enforcement and Compliance Promotion

Policymakers should apply common sense in design and location of I/M stickers that indicate compliance. Stickers must be resistant to forgery and to degradation in sunlight. I/M stickers should be large enough so police can determine the expiration date at a short distance. Color coding can assist in conveying the date. A rule should determine the location of stickers (e.g. front or rear windshield). 2&3 wheelers without windscreens should have I/M stickers placed on a designated spot on the frame. Where I/M is required for vehicle registration, a sticker indicating registration makes a separate I/M sticker unnecessary.

Roadside emission testing is a useful enforcement tool to complement others. The primary function of roadside testing should be the identification of gross polluting vehicles. Policymakers should consider the option of using private contractors to conduct such testing with police accompaniment.

Policymakers should devote appropriate resources to public awareness campaigns to promote compliance. Awareness campaigns are often overlooked and under funded. Awareness campaigns should educate the public on I/M requirements, including linkage to vehicle registration (if applicable). Campaigns can also tout the public benefits of I/M (in terms of reducing air pollution and better health) or the private benefit. A well-tuned vehicle typically burns less fuel and saves money. Proper adjustment of an engine can improve fuel efficiency by 5 to 15 percent.

Managing Resources

Policymakers should ensure the ongoing education of citizens on the benefits of I/M programs to build and maintain political support. Environmental and public health officials and nongovernmental organizations (NGOs) should be enlisted in this effort.

ES-4. Key Recommendations to Donors

Donors are already very active in the I/M arena in various countries. The recommendations below address “public goods” that donors can create through research and analysis.

Institutional Design

Donors should consider funding the creation of a model tender (or Request for Proposal) that policymakers could then tailor to their circumstances. Also useful would be model policy guidelines on conducting the bidding process, selecting the contractor, and implementing an I/M contract.

Where donors have leverage with policymakers, they should use it to ensure that the bidding process is fair, transparent, and effective.

Donors should support exploration of “one-stop” government facilities for emission and safety inspections as well as vehicle registration. This approach deserves support given its promise to improve air quality, safety, and vehicle registration.

Test Procedures and Emission Standards

Donors should support the development of I/M test procedures and standards for PM that take advantage of PM meters that will soon become commercially available. Currently, policymakers lack resilient and reliable instruments for measuring PM in an I/M setting, and have relied on a proxy: measurements of smoke opacity. This is likely to change in the next 1-2 years, and donors should gear up for the data gathering and analysis that will be necessary to refine test procedures and establish cut-points for diesel engines (at a minimum) and potentially gasoline engines as well.

Managing Resources

Donors should assist policymakers in ensuring that they have sufficient capacity to carry out their own roles. Engaging independent experts is a demonstrated method of having access to the needed technical knowledge.

Program Evaluation

Donors should consider funding more rigorous program evaluations along with the data collection efforts that would support them. Policymakers need better data on air quality benefits and on cost-effectiveness of various policy tools for reducing air pollution.

1. INTRODUCTION

1.1. Background and Purpose

Poor urban air quality in cities in the developing world takes a terrible toll in terms of human health and economic losses. Governments at all levels and donor organizations are grappling with the challenge of reducing air pollution. Vehicle emissions are one of the largest and fastest growing sources of air pollution in these cities, and present particularly difficult challenges. One sampling of vehicle contributions to air pollution in some of the megacities of the developing world found vehicles responsible for 80-90 percent of carbon monoxide (CO) and hydrocarbon (HC) emissions.[1] Vehicles can also account for half or more of particulate matter emissions in major cities.[2]

Increases in vehicle emissions in these cities are driven by population growth, urbanization, and increasing incomes that allow vehicle ownership, compounded by congestion when vehicle growth rates far exceed road capacity growth rates. Urbanization is rapidly escalating in developing countries, with the number of city dwellers growing from 1.7 to 2.2 billion over the past decade. By 2025, that figure will leap to over 3.5 billion.[3] In rapidly growing countries such as China and India, vehicle sales are doubling every five to eight years. By 2025 there will be over 1 billion vehicles worldwide, double the number in 1985.[4]

Scooters, 3-wheel taxis, cars, and rickshaws crowd a Delhi road. (Source: Author)

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1 World Business Council for Sustainable Development, Mobility 2001, p. 4-14.

2 Michael Walsh, Contribution of Vehicles to Overall Air Pollution in Asia, prepared for Asian Development Bank, Workshop on Transport Planning, Demand Management and Air Quality, February 26-27, 2002.

3 United Nations Secretariat, Department of Economic and Social Affairs, World Population Prospects: The 2002 Revision and World Urbanization Prospects: The 2001 Revision <http://esa.un.org/unpp>.

4 World Resources Institute, Proceed With Caution: Growth in the Global Motor Vehicle Fleet <http://www.wri.org/wri/trends/autos.html>.

To control vehicle emissions, government must not only affect the actions of vehicle manufacturers and fuel suppliers, but also the actions of millions of drivers in terms of how far they drive and how well they maintain their vehicles. Reduction of motor vehicle pollution requires a comprehensive strategy to influence four key determinants of that pollution:

- Emission performance of new vehicles
- Emission performance of in-use vehicles
- Types and characteristics of fuels used
- Demand for vehicle use

Various policy tools can affect these factors including regulations, market-based incentives, government purchasing, land-use and transportation planning, etc. Historically, policymakers have leaned heavily on regulatory approaches to affect emission performance and fuels. Experts generally agree that regulations on emissions from new vehicles and requirements for cleaner fuels (e.g., elimination of lead, reduction of Reid Vapor Pressure, and sulfur content) are the first steps a country should take.

There are limits to what any policy tool can achieve, limits that are technological or economic, or related to social feasibility. The impacts of different policies are inter-related as well. For example, the performance of emissions control technology can be crucially dependent on the availability of clean fuels. The emissions from in-use vehicles, as they age, are related to factors such as new vehicle emission standards and warranties on emission control equipment. Finally, where adulterated fuels are widely used, emission performance is bound to suffer.[5] Given these linkages, policymakers should strive to design comprehensive and integrated strategies for reducing vehicle pollution.

This report focuses on the most common policy tool for affecting emissions from in-use vehicles: inspection and maintenance (I/M) programs. The rationale and concept for an I/M program is simple: modern vehicles are dependent on properly functioning components to keep pollution levels low. Minor malfunctions in the air/fuel or spark management systems can increase emissions significantly. Major malfunctions can cause emissions to skyrocket. Government can require that vehicles be tested or "inspected" (the "I" in "I/M") to determine whether their emissions exceed levels appropriate for that vehicle type. Vehicles that fail the test must undergo repairs or maintenance (the "M" in "I/M") to bring their emission performance up to par, or they must cease operating, at least within the geographic jurisdiction of the I/M program.[6] Some studies suggest that a small fraction of the vehicle fleet can be responsibility for a large share of total vehicle emissions, so an I/M program that reduces the emissions of these "gross emitters" can bring substantial air quality benefits. One prominent study for the U.S. indicated that less than 10 percent of vehicles emit more than 50 percent of emissions.[7] But this view has its critics:

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[5] In some developing countries, fuel vendors may mix kerosene, solvents, or other liquids with gasoline or diesel fuel if they can reap an economic gain and if the chance of punishment is small. Drivers may substitute kerosene for diesel, especially if the former is subsidized (e.g., in India).

[6] In addition to reducing emissions from in-use vehicles, I/M programs can generate valuable data to guide the design of new vehicles and their emission control equipment. Policymakers can also apply I/M standards to used, imported vehicles to ensure that their emissions are appropriately controlled.

[7] National Research Council, Evaluating Vehicle Emissions Inspections and Maintenance Programs. (Washington DC: National Academy Press, 2001), p. 5.

This is a widely held but dramatic misconception of the problem. Ten to fifteen percent of the vehicles are responsible for roughly 50% of any one vehicle pollutant, e.g., NOx. But when you consider NOx, CO, HC, and PM together, the problem is much larger than 10 to 15 percent and is more likely 30 to 50 percent depending on the nature of the fleet you are examining. So, the notion of focusing I/M efforts on the "dirty few" is simply wrong.[8]

Though simple in concept, the detailed design and implementation of I/M programs is far from simple, as this report will illustrate in abundance. The challenges are many: some vehicles may appear to emit little pollution but their harmful emissions may not be noticeable to the human eye, thus sophisticated testing equipment is needed. When emission control equipment malfunctions, vehicle performance may be unaffected, hence the driver has no private incentive to seek repairs. Finally, to state the obvious, I/M programs are a form of regulation. They create a public benefit by demanding private expenditures of money and time by vehicle owners. Like virtually any regulatory program, this creates the usual tensions that lead many actors to try to evade the regulation in numerous ways.

Most industrialized nations and some developing countries have national laws creating a framework for I/M programs. Implementation is typically carried out at the state or city level. Some developing countries have I/M programs with a track record of a decade or more of operation, with some U.S. states operating I/M programs for over 30 years. However, in more countries, such programs do not exist or are just getting underway. Although no country's track record is perfect, I/M programs in developing countries are more likely to suffer from low public awareness; lax enforcement; petty corruption; and a lack of data, funding, and institutional capacity to operate an effective program.[9] This has led some observers to question whether I/M programs are being implemented too early in some countries; and whether other policy options should be given priority. There is also considerable uncertainty over how large a reduction in emissions can be attributed to I/M programs. However, there are also some success stories in both developing and industrialized countries.

The U.S. Agency for International Development (USAID) commissioned this report to draw together a set of best practices that can assist policymakers in launching or strengthening I/M programs, and to explore activities that might merit increased donor support to spur innovation and success in this policy arena. This report is intended for senior policymakers in developing countries and donor officials. It is not a technical manual, but provides summaries of key technical issues. Citations allow the reader to probe deeper into the technical literature as desired.

In researching this report, the author drew on his own experiences working on I/M systems in developing countries. He also drew on the extensive work in this area conducted or funded by the U.S. Agency for International Development, World Bank, Asian Development Bank, GTZ, Swisscontact, and other donor organizations, and he consulted with experts that have worked in multiple countries (see References and List

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[8] Eugene Tierney, personal communication.

[9] Asian Development Bank, *Vehicle Emission Standards and Inspection and Maintenance*, ADB: Manila, 2003, p. 25. Weaver, C. and L. Chan, *Sri Lanka Vehicle Emissions Control Project - Revised Final Report,* prepared for the Ministry of Environment, Government of Sri Lanka, July 23, 2003, p. 25

of Interviews at the end of this report). Detailed case studies of two cities were prepared: Mexico City and Delhi.[10] Countries examined in less depth include Chile, Argentina, Cost Rica, Philippines, Thailand, and other Asian Countries. Industrialized country experience was reviewed for the U.S., the European Union, Canada, and Australia.

1.2. Structure of the Report

In designing and implementing an I/M program, policy-makers must grapple with an array of questions:

- What institutional design can best accomplish the goals of I/M?
- What emission standards should apply, and what testing procedures should be used?
- How can government ensure a high level of compliance with I/M standards?
- How can government ensure that the following key resources are in sufficient supply?
    - Financial resources—for typically a multi-million dollar undertaking
    - Institutional capacity—especially in the vehicle service sector
    - Political support—critical for the I/M program to survive

Chapters 2 through 5 are organized around these key questions. These chapters reflect a fairly broad consensus on the best practices that lead to a successful I/M program. This consensus is embodied in recent studies by prominent experts,[11] in the recommendations that emerged from several donor-sponsored forums held in the past several years,[12] and in the research conducted for this report.

Chapter Two addresses basic institutional design questions such as: who does the testing and where? What tasks are best done by the public sector and what tasks are best done by the private sector? How is oversight best accomplished, holding public and private actors responsible for carrying out their tasks? What coordination

[10] These two cities were chosen on the basis of several factors: availability of existing literature; first hand experience by authors; varying degrees of program effectiveness; and geographic diversity.

[11] Especially valuable are: Faiz, A., C. Weaver, and M. Walsh, *Air Pollution from Motor Vehicles*. Washington DC: The World Bank, 1996; Kolke, Reinhard, *Module 4b Inspection & Maintenance and Roadworthiness*, prepared for GTZ Sustainable Urban Transport Project, 2002; Rogers, John, "Lessons on Audit Quality Assurance Mechanisms," presented at Workshop on Strengthening Vehicle Inspection & Maintenance, sponsored by Asian Development Bank, Chongqing, China, November 7-9, 2001; Rogers, John, *Assessment of the Pollution Under Control Program in India and Recommendations for Improvement*, prepared for the South Asia Urban Air Quality Management Program, World Bank, October 2002; Asian Development Bank, op. cit.; Weaver, C. and L. Chan, op. cit.

[12] Prominent among the recent donor-sponsored fora are:

- Asian Development Bank, Strengthening Vehicle Inspection and Maintenance, November 7-9, 2001, Chongqing, China <www.adb.org/Documents/Events/2001/RETA5937/Chongqing/downloads.asp>.
- Global Initiative on Transport Emissions, Regional Workshop on Transport Sector Inspection and Maintenance Policy in Asia, December 10-12, 2001, Bangkok, Thailand <www.un.org/esa/gite/iandm/index.html>.
- World Bank, Reducing Emissions from In-Use Diesel Vehicles in Developing Country Cities: Challenges, Opportunities and Costs, January 17, 2003, Washington DC, USA <www.worldbank.org/wbi/cleanair/global/learningactivities/diesel_days/diesel_day2.htm>.
- Clean Air Initiative-Asia, Better Air Quality 2003, December 17-19, 2003, Manila, Philippines <www.cleanairnet.org/baq2003/1496/channel.html>.

and management issues are likely to arise among different levels of government and between ministries, and how can they best be addressed? Should policymakers launch comprehensive I/M programs for all vehicles? Or take a phased approach?
Chapter Three addresses the issues of the appropriate emissions standards that in-use vehicles should meet and the test procedures for measuring those emissions. These elements involve questions such as: What standards should apply to various vehicle types (e.g., trucks, buses, taxis, personal cars, motorcycles, and other two- and three-wheeled vehicles)? How should standards vary by age of vehicle or type of engine (e.g., diesel, 4-stroke gasoline, 2-stroke gasoline)? Should testing be done in a quick, low-cost way with the engine idling, or with a longer, higher-cost but more reliable procedure involving placing the vehicle on a dynamometer (or treadmill)? Many of these questions are highly technical in nature but also involve critical policy questions such as: How many vehicles are likely to fail the test? How will this affect public acceptance of the I/M program? How expensive is the test procedure? Can the costs be recovered by inspection fees? Or are subsidies needed?

Chapter Four examines how government can ensure that drivers bring their vehicles in for testing and carry out the necessary maintenance and repairs. How can government promote compliance in general among drivers? How can government best identify violators of I/M rules and take enforcement actions? This key behavioral aspect of I/M programs is sometimes given inadequate attention by policymakers.

Chapter Five explores key resource issues in both the public and private sectors: How much do I/M programs cost and how should those costs be recovered? What are appropriate levels of inspection fees? When, if ever, should I/M programs be subsidized? Do institutions and individuals have the knowledge and training they need to perform the roles they are assigned? Political support is a key resource as well: how can adequate political support be generated and maintained during design and implementation?

Chapter Six provides a summary of key conclusions and recommendations for donor activities.

The Appendixes to this report provide a brief review of studies of the air quality benefits of I/M programs and two case studies of I/M programs (Mexico City and Delhi) that provide further support for the report's conclusions.

1.3. The Fundamental Challenges in I/M

A key message of this report an emphasis on *how hard it is to implement an effective inspection and maintenance program.* Typically, an I/M program requires massive behavioral change among thousands (or up to millions) of drivers; among those who test and repair vehicles; and, among those who manage, oversee, and enforce such programs. Drivers must restrain their instincts to cheat on tests and/or offer bribes to pass inspection. Inspectors and mechanics must restrain their tendency to conspire with drivers and pocket bribes.

Contrast this scope of behavioral change to that associated with some other steps in reducing air pollution. Improvements in new vehicle standards can focus on the actions of a handful of manufacturers. Improvements in fuel quality can focus on a handful of refineries, though fuel adulteration can remain a problem. I/M programs are similar to policies that aim to reduce the total number of vehicle-miles-traveled (e.g., by encouraging car pooling, use of mass transit, or other alternatives): they aim to impact the behavior of countless individuals.

As detailed in Chapter 2, many developing countries are attempting to launch I/M programs using privately operated emission testing facilities (reflecting a consensus among experts that this approach is superior to that of government-operated facilities). Privatized I/M testing creates a further fundamental challenge: how can government create a new "market" for the testing of vehicles from scratch? There is no historic or natural "demand" for testing on the part of the drivers. Governments in developing countries must create the demand for testing and convince one or more companies to "supply" the testing, with the necessary investments typically running in the millions of dollars. This poses a formidable risk management issue for governments and potential suppliers of testing. Compare this to privatization efforts related to energy, water, or transportation services. In those cases, consumers clearly want the services; their demand is "natural" and potential investors can assess consumers' history. Investment risks remain, of course, but they are far more manageable.

The I/M literature and experts consulted for this report can cite some examples of relatively effective I/M programs in the developing world. Those of Chile and Mexico City receive the most praise (see Appendix B).[13] However, ineffective programs far outnumber these. Most major cities in India have I/M programs that exist "on paper" but are widely ignored or prone to fraud (see Appendix C). Cities such as Almaty, Kazakhstan and Bogota, Columbia have dysfunctional I/M systems. Cities in the Philippines, Egypt, and Indonesia have received substantial donor aid to launch I/M programs, but the lack of progress is discouraging.[14]

An ineffective I/M program has serious consequences. It may merely create a new avenue for the bribery and petty corruption that plague many developing countries, and thus set back efforts to build public confidence in and respect for government. Ineffective programs also divert time and money away from other approaches to air pollution that may have a better chance of success.

Policymakers should make a decision to launch (or strengthen) an I/M program only if fully cognizant of the challenges involved. Successful programs *can* reduce vehicle emissions in a cost-effective manner. Massive behavioral change is never easy, but it is *possible* with committed leadership, the right institutional design, and the right incentives. A threshold condition for even contemplating an I/M program is for senior government officials to commit to multiple years of strong leadership and capacity-building. An Asian Development Bank study concluded:

> *The single most important determining factor for I/M success is support by senior decision-makers and the institutional capacity to manage and regulate the system.*[15]

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[13] See Kolke, 2002, op. cit., p. 16-18 for details on Chile's I/M system.
[14] Reinhard Kolke and Lennart Erlandsson, personal communications.
[15] Asian Development Bank*, Vehicle Emission Standards and Inspection and Maintenance, 2003*, p.16.

Some of the existing literature on I/M does not convey fully the difficulty of these challenges and presents a variety of best practices without highlighting those that are most critical to implementing an effective program. This report identifies a handful of "essential" best practices that rise above the others in importance. Policymakers in the developing world should recognize that I/M programs incorporating these essential best practices have a much greater chance of succeeding than programs in which these practices are missing. There is, in fact, a high likelihood of greatly diminished benefits for programs without these practices. The report also identifies other "ordinary" best practices that enhance program effectiveness.

1.4. Assessing I/M Program Performance

In selecting best practices, this report labels individual I/M programs effective/ ineffective, successful/failed, etc., and inferences are made about the underlying causes related to policy and program design. Unfortunately, there is a dearth of quantitative data that would allow ideal program evaluations of I/M in developing countries. Instead, experts in the field (and this report) must rely largely on qualitative and anecdotal data to assess program performance. When experts find a prevalence of any of the following in their field work, they will conclude that a program is not effective:

- Vehicles not displaying an I/M sticker
- Vehicles belching smoke despite displaying an I/M sticker
- Absence of police or other authorities paying attention to I/M stickers or smoke belching vehicles
- Test facilities that pass virtually all vehicles regardless of their emissions
- I/M test lanes that are clearly in disrepair
- I/M test equipment that is not functioning or not calibrated properly
- I/M facility staff who are incapable of performing their duties
- I/M staff who have come to view their job as helping drivers pass the I/M test by manipulating the vehicle or the test
- I/M staff who take bribes and issue stickers
- Absence of any oversight of, or quality assurance procedures for, test facilities

And so on. All of the above are real-world examples. They are useful, if imperfect, indicators of program performance. Donors should consider funding more rigorous program evaluations along with the data collection efforts that would support them.

1.5. Key Questions for Policymakers

The challenges involved in I/M also require policymakers to reflect on the alternatives and on timing. The remainder of this opening chapter poses some key questions that policy-makers should ask before launching a new I/M program (or strengthening an existing one). First, what impact can I/M have on vehicle emissions and at what cost?[16] The cost-effectiveness of different air pollution control options should form a basis

[16] The cost side of the equation is much clearer, but typically ignores the time that drivers spend in securing their I/M stickers. These costs are not trivial and must be an important factor in determining the number and location of test centers. For example, Taipei has located its I/M stations 15 miles outside of the central city area causing long trips for drivers (K.G. Duleep, personal communication).

for policymakers' decisions as they design strategies to improve air quality. Ideally, policymakers should have reasonable estimates of how much vehicle pollution will decrease as a result of I/M and how much it will cost. This would allow comparison with other options, guiding the stringency, mix, and sequencing of different control options.

Improved maintenance of a single high-emitting vehicle can dramatically reduce emissions by 50 percent or more, and the cost of the maintenance can be trivial in some cases (adjusting a carburetor or cleaning a spark plug or air filter). However, reliable estimates of the impact and costs of I/M systems as a whole are rare (just as quantitative program evaluations are rare). Studies conducted in the U.S. and Canada suggest that an effective I/M program can decrease an automobile fleet's annual emissions of hydrocarbon (HC) or carbon monoxide (CO) by as little as a few percentage points or as much as 10 to 20 percent. Nitrogen oxide (NOx) emission reductions are likely to be less than 10 percent. Cumulatively over several years, an I/M program can reduce HC or CO emissions by over a third and NOx emissions by 10 percent.[17] A summary of this literature appears in Appendix A. Some studies have generated ex ante estimates of benefits and costs for I/M programs, but these need much more solid grounding in empirical data.[18] This is an area where donors should invest more resources in better informing policymakers what they can expect from an I/M program.[19] The synthesis presentation at a major ADB workshop highlighted this need:

> *Although I/M is increasingly used as [an] instrument to reduce pollution, no efforts are made to quantify [the] environmental impact. Little is known about actual cost-effectiveness of I/M systems in Asia.*[20]

A second question worth asking: Is the host country truly ready for a modern I/M system? Is there an effective vehicle registration system in place to promote compliance? Are police ready to help in enforcement? (See Chapter 4 on both points.) Is there a national body competent to take on the highly technical tasks of oversight and quality assurance (see Chapter 2). If the answer to any of these questions is no, then investing in these building blocks of I/M should be required in launching an I/M system.

Finally and in tandem with the "readiness" question above, one must look at timing. Generally speaking, every country in the developing world with heavily-polluted cities should consider instituting an I/M program now or in the coming years. However, policymakers must choose when and where to invest their financial as well as political capital. Experts recommend elimination of lead in gasoline and reduction of Reid Vapor Pressure and sulfur content in fuels as first priorities, along with setting and enforcing emission standards for new vehicles and imported used vehicles. I/M programs are considered among a list of second priorities that are harder to implement and more

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[17] Specific program results, of course, will be function of overall stringency of the program.

[18] See, for example, Larsen S. et al, *Urban Air quality Management Strategy in Asia: Metro Manila Report*, J. Shah et al, eds., Technical Paper 380. Washington DC: World Bank, 1997.

[19] Emission reductions could be greater in developing countries due to poorer "baseline" maintenance. Alternatively, reductions could be smaller due to inability to match the compliance rates of industrialized countries.

[20] Fu Lixin, "Vehicle Standards and Inspection and Maintenance: Synthesis Chongqing Workshop," presented at Concluding Workshop: Action Plans for Reducing Vehicle Emissions, sponsored by Asian Development Bank, Manila Philippines, February 28-March 1, 2002.

difficult to rank. This list includes: programs of retrofitting equipment (e.g., diesel particulate traps, replacement of 2-stroke engines); banned entry of certain vehicles in certain areas; forced retirement of older vehicles; and programs aimed at cleaner fuels or improved maintenance in public or private fleets (buses, trucks, taxis, etc.).[21] Some of these options may make sense to focus on before an I/M program. There are no easy options in the transportation field, but some are easier than others and some don't require the massive behavioral change implicit in I/M programs.

Policymakers in developing countries face added complexity in deciding whether and when to launch an I/M system. Relevant technology is changing rapidly:[22]

- Currently I/M systems lack the capability to measure the vehicle emission of greatest health impact: particulate matter (PM). However, a PM meter suitable for use in the I/M context is likely to be commercially available in one to two years. PM meters could change dramatically what constitutes "best practice" in test procedures and standards for diesel engines and two- and three-wheeled vehicles (i.e., motorcycles, scooters, mopeds, 3-wheel taxis, etc., or "2&3 wheelers" as used in this report).
- Technology is improving in the realm of "on-board diagnostics" (OBD)—micro-computers that can report and diagnose problems in emission control equipment. Many U.S. states have already eliminated traditional emission testing in their I/M systems for newer automobiles that have OBD, and more change is expected. (At the same, there is little progress in OBD for 2&3 wheelers and trucks.)
- Overall, the benefits of I/M programs are decreasing in the U.S. due to improvements in the performance and longevity of emission control technologies.

Policymakers must consider whether to invest now in I/M systems using current technologies and practices, or wait for some period of time with the expectation that their resources will be put to better use with a later generation of I/M technology and practices. The answers for any country may depend in part on the current composition of fleet, how fast it turns over, the severity of the air pollution problem, and other factors. The complexity of the issues involved prevents this report from offering a "one-size-fits-all" recommendation on whether and when to launch an I/M system. Some countries probably should get started immediately while others might take smaller steps to prepare for I/M or focus on other policy options

A troubling but perhaps realistic notion is that policymakers might have to wait until air quality has deteriorated to some low level sufficient to create public support for an I/M program. Such a threshold level might be below the level that experts would otherwise recommend, but political realities may dictate otherwise.

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[21] One city in the Philippines provided interest-free loans to 3-wheel taxi owners for replacement of 2-stroke engines with new 4-stroke engines (see Mayor Mary Jane Ortega, City of San Fernanco: Air Track Best Practice, 2003). One expert suggested that donors consider loan programs to individuals to replace some of the oldest, high-emitting vehicles (Fred Herren, personal communication). There are a growing number of options for retrofits for diesel engines (e.g., see John Guy, Update on EPA Diesel Rules and the Role of Diesel Retrofit, conference presentation, Mexico City, February 27, 2004. Available from Guy.John@epa.gov.)

[22] Eugene Tierney, personal communication.

2. INSTITUTIONAL DESIGN

This chapter identifies best practices in the area of basic institutional design, asking questions such as:

- Who should do the testing and where?
- What tasks are best done by the public sector and what tasks are best done by the private sector?
- How is oversight best accomplished, holding public and private actors responsible for carrying out their tasks? What coordination and management issues are likely to arise among different levels of government and among ministries, and how can they best be addressed?
- Should policymakers launch comprehensive I/M programs for all vehicles? Or take a phased approach?

2.1. Test-Only Versus Test-and-Repair

A critical first design question for policymakers is where to conduct the I/M tests or inspections. The basic choice is between a relatively small number of centralized or "test-only" facilities, and a relatively large number decentralized or "test-and-repair" facilities. The latter option involves authorizing private repair shops to conduct the testing in addition to their normal role of maintaining and repairing vehicles.[23]

Test-only facilities can be operated by a government organization or by a private firm under contract to the government. Test-only facilities can achieve a relatively low cost per inspection because each facility can spread facility and equipment costs over a high volume of inspections.[24] This high utilization rate also allows these facilities to afford more sophisticated, reliable, and durable test equipment. Test-only facilities can also achieve relatively low labor costs because the skill level needed to conduct tests is less than that needed for vehicle repair. Oversight of the facilities by government is also relatively easy due to their small number. Some experts argue that relatively few testing facilities mean less convenience for drivers, i.e., they will likely travel farther and wait longer for testing.[25]

The advantages and disadvantages of test-and-repair facilities are the inverse of those of test-only facilities. Private repair shops must spread the costs of testing over a lower volume of inspections, probably resulting in a higher cost per inspection. Labor costs can be higher, too, if high-skill mechanics conduct the testing.[26] Oversight is more difficult due to the larger number of testing stations. In theory, government can limit the

[23] There is a third option of a mixture of test-only and test-and-repair facilities (see Mexico City case study, Appendix B). A fourth option, receiving little attention in the I/M literature, is a system driven entirely by roadside inspections. This subject is explored in Chapter 4.
[24] Weaver, C. and L. Chan, op. cit., p. 27.
[25] Other experts argue that a well designed test-only system may, in fact, involve less waiting time because of the high throughput nature of the system.
[26] Some would argue that the relative costs are ambiguous, given that: 1) test-and-repair shops may be able to add the test function without expanding facilities; 2) they may already own some of the needed test equipment; and 3) they may be able conduct tests without hiring extra workers.

number of licensed tests-and-repair facilities, but, in practice, this is rarely done because it is politically unacceptable. Finally, some experience indicates that private shops can engage in excessive repair under this approach.[27] However, private repair shops can offer greater convenience to drivers. They can also avoid the "ping-pong" effect in which a driver might go back and forth between test facility and repair shop until the vehicle passes inspection.

For developing countries, experts are virtually unanimous in recommending test-only facilities for I/M programs.[28] This conclusion is based on the poor performance of the test-and-repair approach in developing countries, and the far-from-perfect record in industrialized countries as well.[29] India's test-and-repair I/M program has operated for over a decade and is universally acknowledged as a failure. Bogotá, Columbia presents another example of a failed test-and-repair program.[30] Chile has conducted a test-only I/M program since 1977, and after some strengthening in government oversight and control in 1994, the program is considered effective. In the U.S., two states have replaced failed test-and-repair programs with test-only systems.[31]

Perhaps most compelling are cases in which the test-and-repair approach was tried and then dropped in favor of test-only. Mexico City allowed test-and-repair shops to conduct inspections for several years but switched to test-only centers in 1996. The government estimated that about one half of vehicles inspected were receiving a fraudulent "pass" from the test-and-repair shops (see case study in Appendix B). Costa Rica switched from test-and-repair to test-only in 2002 due to widespread concerns over bribery in the test-and-repair shops.[32] Guatemala also tried the test-and-repair approach but halted the whole I/M program after 12 months for multiple reasons.[33]

In industrialized countries, both approaches are used. For example, Sweden has operated a successful test-only I/M system since 1965 with one firm operating 177 inspection stations. Switzerland is a counter example: it effectively employs test-and-repair shops for I/M (while conducting safety inspections in test-only facilities).

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[27] Lennart Erlandsson, personal communication.

[28] Faiz, A. et al, op. cit., pp. 138-140. Asian Development Bank, op.cit., p.15. Weaver, C. and L. Chan, op. cit., p. 25. Kolke, 2002, op. cit., p. 3-4. Global Initiative on Transport Emissions, op. cit., p. 2. Research for this report did uncover two opposing views, the first appearing in studies by Swisscontact (e.g., *Clean Air Project: Report of Activities 1993-2002*, 2003, p. 41, covering activities in Central America, which argued that test-only versus test-and-repair does not affect program effectiveness very much.) In addition, in a report prepared for Swisscontact recommending decentralized testing for Jakarta's I/M program, the authors argued that repair shops typically had some of the necessary equipment, and that the convenience of "one-stop service" was most important. See Steckdaub, M. and R. Sekartini, *Environmental Policy & Vehicles Inspection in Indonesia*, prepared for Clean Air Project—Swisscontact, Jakarta, December 2001. The second opposing view appeared in the review comments of Christopher Stock of Applus+ Technologies, who emphasized: 1) hardware and software now allows sophisticated and effective oversight over test-and-repair facilities; 2) the "ping-pong" effect is very costly to drivers; and 3) the test-and-repair design promotes better skills and equipment in the vehicle service sector (see Chapter 5 on the need for this). The review memo from Mr. Stock is available from this author.

[29] Weaver, C. and L. Chan, op. cit., notes that auditors of U.S. state programs have found rates of improper inspections as high as 50 percent in test-and-repair I/M programs.

[30] Frank Dursbeck, personal communication.

[31] Gene Tierney, personal communication.

[32] Swisscontact, *Clean Air Project: Report of Activities 1993-2002,* 2003, p. 9.

[33] Jon Bickel, personal communication.

Experience in the U.S. offers some perspective as well on the question of test-only versus test-and-repair design. The U.S. EPA has not mandated that states adopt either design. With states able to choose, 17 jurisdictions have chosen test-only, 18 have chosen test-and-repair, and 3 have adopted a hybrid approach.[34] However, when assessing whether a state will come into compliance with air quality standards, U.S. EPA models the effect of I/M programs and assumes that the test-only approach results in greater emission reductions.

Adoption of the test-only design alone is not a guarantee of success. Ostensibly, Almaty, Kazakhstan, has test-only center for vehicles, but its I/M program is moribund.[35] Cities in Peru such as Cusco and Arequipa have tried centralized I/M systems for buses and taxis but they are not very effective. Good management, quality control, and political will are all missing.[36]

This report concludes that test-only facilities are an *essential best practice* for developing countries. This conclusion is based on historical experience and on two principal arguments. First, any inconvenience to drivers is far outweighed by the ability to reduce fraud in the inspection process. As described in detail in Chapter 3, no emissions test procedure is immune from fraud, and indeed the most common test procedures are the most highly susceptible to fraud. Drivers have incentive to fool honest testers, and testers have incentive to fool honest drivers. As one expert put it:

> *No garage will tell his client that he does not have the technical ability to repair the vehicle and pass the test. To save face he will always prefer to cheat on the test.*[37]

When both drivers and testers are dishonest, they have “room for a deal”—conspiring to give a vehicle a fraudulent “pass.” In developing countries with low incomes and weak respect for government regulations, these incentives are very powerful. Test-only facilities do not eliminate fraud, but they make it a more manageable problem due to government’s ability to better oversee a relatively small number of test facilities.

The second argument favoring test-only facilities is that the economic advantage of test-only centers will grow over time. As argued in Chapter 3, there is a natural progression in I/M test procedures toward more complex and sophisticated tests using more expensive test equipment. The ability of test-only centers to spread these costs over a large number of tests is critical to keeping the cost per inspection at an affordable level.[38] Mexico City’s experience with no-load and loaded testing illustrates the economics of test-only facilities (see Box 2-1).

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[34] U.S. Environmental Protection Agency, Office of Transportation and Air Quality, “Major Elements of Operating I/M Programs,” March 2003. Jurisdictions are counted here because in some states, different counties and cities take different approaches.

[35] This was Lennart Erlandsson’s assessment after working on an project there sponsored by the European Commission.

[36] Jon Bickel, personal communication.

[37] John Rogers, “Lessons on Audit Quality Assurance Mechanisms,” prepared for Asian Development Bank, Workshop on Strengthening Vehicle Inspection and Maintenance, November 7-9, 2001, Chongqing, China, p. 3.

[38] Asian Development Bank, op. cit., p. 18. Weaver, C. and L. Chan, op. cit., p. 27.

BOX 2-1. COSTS OF VEHICLE TESTING IN MEXICO CITY

A 2001 World Bank paper provides the following cost estimates for testing in Mexico City

"For test-only facilities, each test lane costs between $35,000 and $50,000 and generates more than twice the number of tests per day than a test-and-repair center. The costs of centralizing and monitoring components add approximately 20 percent to the costs. Overall, the investment per vehicle tested on a dynamometer (loaded test) in a test-only center is about 50 percent higher than that required for static (no-load) testing in a test-and-repair center. A test-only centralized system operating at 35 percent installed capacity (ten hours a day Monday through Saturday) requires an equipment investment about $60,000 per lane to generate 10,000 tests per year. The investment per test is $5.30 and recouped in a relatively short period of time as each test costs the vehicle owner $11."

Source: World Bank Institute*, Vehicle Emissions Program in Mexico,* September 2001

2.2. Public Versus Private Operation of Test Facilities

The next key design question for policymakers is: who will operate the testing facilities? There are examples of operation both by public entities and by private firms under contract to government. No case can be made that conducting the actual testing of vehicles is an "inherently governmental function."

Here again, expert opinion is unified on the desirability of private firms performing this role under the oversight of a governmental body.[39] In general, this conclusion is driven by the same reasoning that underlies the broader privatization movement affecting energy, water, transportation, and other sectors: many services of a public nature are better delivered by a private firm accountable to the government rather than by a state-owned entity that essentially holds a perpetual monopoly in providing the service. The latter organizational form often suffers from low technical competence and a general inability to punish poor performance or fraud at the individual employee level and the organizational level as a whole. A capital-starved public monopoly can be subject to budgetary pressures from external forces that threaten service quality and its ability to generate revenue, even if it is otherwise capable of providing that service in a financially viable manner.

This is not to say that privatization is a panacea for I/M programs or for any public service. Government oversight and contractor performance will never be perfect, and they carry their own set of challenges in both industrialized and developing countries.[40] In 2000, the U.S. state of New Jersey selected a contractor to operate its I/M system. A fiasco ensued immediately over equipment failures and understaffing, and later over charges that the contract award resulted from political influence and a non-competitive

[39] See, e.g., Asian Development Bank, op.cit., p.15. Weaver, C. and L. Chan, op. cit., p. 25.

[40] For instance, the private companies that won I/M franchises in Costa Rica are currently in court with the government after completing about 70 percent of construction of test-only centers, and a new bidding round is likely (Jon Bickel, personal communication).

bidding process.[41] Only a truly competitive bidding process can produce the advantages of private operation of an I/M system (see section below). In addition, government must play a vigilant role after award of the contract. As one observer commented on the New Jersey I/M fiasco:

> *There are plenty of good arguments to be made about privatization, both pro and con. Either way, outsourcing should never be viewed as the soap with which government officials wash their hands of complex issues….Government officials can privatize services. But they can't privatize accountability…. The problem in New Jersey was not that the government mistakenly bought a vendor's claim that it could do the job cheaper, faster, and better. It was that state officials… never took steps to make sure that [the contractor] would follow through on its promises.*[42]

The message here is that private operation of test facilities is more likely to provide better performance than public operation, and it should be considered an *essential best practice*.

Many policymakers will be uncomfortable with this conclusion. For example, as part of the Cairo Air Improvement Project, the Egyptian government and USAID engaged in a long debate over public versus private operation of I/M facilities with the government supporting public operation largely on ideological grounds.[43] Allegations of price gouging or private interest trumping the public interest abound in the whole privatization debate, and that debate cannot be resolved in this report.

2.3. Contracting Issues

If policymakers do opt for privately operated, test-only I/M facilities, then they face a number of issues in selecting the private firm(s) and designing the I/M contract. Experts recommend that the government conduct an open, transparent, competitive bidding process for one or more firms to operate the test facilities according to the government's policy framework and subject to its oversight.[44] Ideally, the bidding process should produce a winning firm that is capable of conducting high-quality I/M operations at the lowest possible price (consistent with the needed quality and firm profitability). Government also has an interest in promoting competition among I/M firms, both within any given bidding process and over time as contracts come up for re-bid.

In addition, contract design and implementation involves a formidable risk management issue. As noted in Chapter 1, the question of whether government can effectively create demand for a new "market" —vehicle testing— creates risks for businesses making investments to serve this new market. This section addresses how policy makers can address issues of contract design and risk management. These issues have received

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[41] Parsons Audit Team, *Report to Governor James E. McGreevey on the State of New Jersey's Enhanced Motor Vehicle Inspection Contract with Parsons Infrastructure & Technology Group*, May 6, 2002.
[42] Swope, Christopher, Blame for a Fiasco, Governing, March 13, 2000.
[43] David Fratt, personal communication.
[44] Asian Development Bank, op.cit., p.15. Weaver, C. and L. Chan, op. cit.

little treatment in the I/M literature, and the conclusions below should be taken as preliminary.

2.3.1. In Pursuit of Quality

As documented throughout this report, it takes significant technical and managerial skills to operate a sophisticated I/M program. Policymakers should set tough minimum qualifications for bidding firms to ensure that the winning contractor can deliver the needed quality. Widespread adoption of I/M in the industrialized world has led to a global market in the supply of I/M services. Firms with this specialization include ESP, SGS, and Agbar/Applus+ Technologies.[45] Experts frequently cite the advantages of inviting international firms to bid on I/M contracts in the developing world, both in terms of experience and skill and ability to provide capital. The investment needed up front to launch an I/M program using test-only centers is substantial, typically running in the millions of dollars. Firms can also be required to implement a quality management system that meets the International Organization for Standardization (ISO) standard for "inspection body accreditation"—ISO/IEC 17020 (or alternatively ISO 9003).[46]

In general, opening up government contracting to non-domestic firms often raises concerns, e.g., foreign firms will charge too much and/or economic development, jobs, and profits should be kept "at home." These concerns can be addressed in part in the I/M context by requiring that international firms ally themselves with local firms in bidding to operate I/M test facilities.

2.3.2. Single Versus Multiple Contractors

Policymakers face a difficult trade-off in deciding whether to aim for a single versus multiple contractors in the I/M market they aim to create. A firm granted a monopoly on I/M services for an entire state may be able to spread its fixed costs over a large volume of sales, and thus offer a low price for inspections. On the other hand, there may be value in having more than one firm providing I/M services. Multiple firms may give policymakers better benchmarks with which to assess performance and quality. If a firm is providing poor service, policymakers may have the option of quickly terminating its contract if other firms are operating and can increase their market share.[47] In the U.S., the experience with multiple firms supplying test-only services is limited to one state (Florida), and a USEPA expert described the lessons learned as follows:

> *It costs more to have multiple firms; it is extremely difficult to create consistency among the differing firms products; it is much more difficult for government to oversee multiple firms; and it is harder to institute changes when dealing with multiple firms, etc. The big danger of multiple firm awards is that the firms will then compete with each other for customers by passing vehicles that should fail.*[48]

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[45] See www.esp-global.com, www.sgs.com, and www.agbar.es or www.applustech.com. (Applus+ Technologies is the new name for the firm that includes Agbar Technologies inspection services.)

[46] The Geneva-based International Standards Organization (ISO), with 148 member countries, sets standards for a broad array of equipment and practices, each given an ISO number.

[47] Weaver, C. and L. Chan, op. cit., advocates multiple operators whenever feasible (p. 26).

[48] Gene Tierney, personal communication.

Undoubtedly, there are some economies of scale in providing I/M services, but the existing literature provides no guidance. In Germany, six firms provide inspections to about 56 million cars. In Ireland, one firm operates 36 stations conducting roughly 1 million inspections per year. Interviews with I/M firms done for this report posed the question: What is the minimum size of an I/M market below which costs per inspection escalate substantially?[49] Firms provided a range of responses. Two firms offered a rough rule of thumb of one million cars, but emphasized that many factors come into play, foremost the expected levels of compliance which in turn drive the expected number of inspections. One firm declined to offer an opinion on the minimize size, but felt that policymakers sometimes go too far in dividing the market among multiple firms. For example, Cameroon, with a population of 600,000 vehicles, awarded contracts to 10 local firms. One firm felt that the Philippines plan to have 4 firms operating in different regions of the country was unwise, and that only the region containing Manila had a sufficient volume of vehicles to keep the cost per inspection to a reasonable level. One firm offered that it didn't bid in Sri Lanka because the tender specified that 3 firms would be awarded contracts, and the firm felt the resulting sales volume per firm would be too low.

Firms also felt that some countries aim for national I/M systems that extend programs into rural or semi-rural areas where the small volume of vehicles drives costs very high. For example, in Costa Rica, about 70 percent of all cars operate in the city of San Jose —enough to create a profitable market. But the government has extended I/M requirements to the entire country which probably results in a cross-subsidy from urban to rural areas.[50] Such cross-subsidies may represent a poor use of resources. On the other hand, an I/M program at the state or city level can create an enforcement problem: drivers may attempt to register their cars in a jurisdiction with no I/M program while using them predominantly where there are I/M requirements. The U.S. has never had a national I/M program. Instead states must adopt I/M requirements only when air pollution reaches certain levels, and they have the option of applying I/M on a county by county basis.

2.3.3. Contract Length

Policymakers face another tough trade-off in choosing the length of an I/M contract. The longer the contract, the more years a firm has to amortize its investment, and this could result in relatively low bid prices. On the other hand, long contracts may have anti-competitive effects if bidding occurs very infrequently and if incumbent firms become entrenched. Long contracts may also harm performance if government's only recourse for poor performance is to abrogate a contract, and endure the transaction cost and disruption that may entail.

Some experts recommend only one or two years, while others recommend five, eight, or ten years.[51] Several I/M firms consider 7 years as a minimum contract length, seeing

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[49] These opinions can only offer a starting point for more in-depth analysis of the economies of scale in I/M. Firms may have a institutional bias toward over-estimating the minimum size of the market. Here and throughout, additional research on this question would be useful to policymakers

[50] Jon Bickel, personal communication.

[51] John Rogers, Chris Weaver, and Frank Dursbeck, personal communications.

it as a long enough amortization period to hold down costs. ESP holds many contracts at the state level in the U.S. with many lasting 10 years, several lasting 7 years, and some lasting 14 or 15 years. Costa Rica and Quito (Ecuador) recently entered ten-year contracts with options for ten-year extension options with an international I/M firm.[52] Chile's most recent tender was for 10 years. Sri Lanka offered 5 years with a 1 year renewal. In this area, too, additional research could throw light on what might constitute an optimal contract length under what circumstances.

2.3.4. Setting and Adjusting Prices

The I/M literature says very little about how a tender process should set the prices for inspection. Policymakers may choose to weigh bids on both price and quality. Alternatively, they can set minimum requirements related to quality and then rank bids wholly on the price firms state they will charge drivers—an approach that probably lends greater transparency to the process. Some experts recommend a price floor to encourage a minimum level of quality, and/or a price ceiling to prevent an inspection fee so high as to discourage compliance. Chile took a pure "free market" approach without any government controls which resulted in reasonable price levels and arguably beneficial price variation among different test locations (see Box 2-2).[53]

BOX 2-2. CHILE'S APPROACH TO BIDDING AND I/M PRICING

In 1994 the Chilean government offered a tender for a revamped I/M program. About 20 firms bid for 4 licenses. All bidders met the minimum qualifications and bids were compared on price alone. The winning bids offered prices of approximately $10, $12, $15, and $18, and the bidding terms were such that each firm would be allowed to charge the specific price it bid.

One firm dropped out after the bidding and was replaced with the next lower bidder. The firm that dropped out feared drivers would flock to the lowest price test centers, making it incapable of generating sufficient revenues. This was a perfectly rational fear, and should make policymakers consider an award based on the highest winning bid ("first price auction"). The outcome, however, was far different: all winning firms survived and prospered because drivers cared about things other than just price, and firms were able to differentiate prices. First of all, people did not want to drive long distances and tended to go to test stations near their homes. Second, the low-bid firm had a bad reputation from the earlier I/M system, and some drivers simply did not want to use that firm. Third, government allows firms to vary their prices as longs as the average price was in line with their accepted bid price. Thus, firms charged more in affluent neighborhoods and less in poor neighborhoods, going as low as about $7 in "bad" parts of town. This was probably an economically efficient form of price discrimination allowing more people to afford an inspection and thus moving the whole system closer to the optimal quantity of inspections.

Source: Frank Dursbeck, personal communication.

[52] Agbar Group, *Annual Report 2002*, 2003, pp. 65-66.
[53] Frank Dursbeck, personal communication.

In making a multiple award contract, policymakers can choose between holding firms to the price they bid (a “discriminating auction”), or setting a single price based on the highest winning bid (a “first price auction”) or the lowest losing bid (a “second price auction”). Economists generally consider first or second price auctions as most likely to induce firms to bid close to their actual costs.

In virtually any long-term contract, some provision exists for adjustment of prices due to circumstances beyond the parties’ control.[54] In I/M contracts, inspection fees are often adjusted for inflation.[55] In Mexico City there is a contract provision that links fees to an index of wages. I/M firms report that government decisions requiring a major equipment upgrade lead to negotiations on new fee levels allowing firms to recoup the added costs.

2.3.5. Promoting Competition at Re-Bid

Government’s interest in promoting competition when I/M contracts are re-bid raises the issue of ownership of I/M test facilities. A case can be made for government gaining or retaining ownership of the land and physical structures of test facilities, while the contractor supplies specialized equipment and operates the facility. This would allow government to control a group of favorable locations for testing centers and would prevent an incumbent bidder from locking in an unfair competitive advantage. Periodic bidding would allow a healthy competition for the right to operate the government-owned testing centers. However, government may not own suitable land nor have the capital for land purchases or facility construction. In these cases, the contract could be of the “build / own / operate / transfer” type with government taking ownership at the end of the contract. This type of contract would be suitable only for many years of operation in which the firm could amortize the fixed costs of land and facilities in its test fees. Thus this option should be coupled with a long-term contract

In some states in the U.S., land and facilities revert to government ownership at the end of the I/M contract.[56] Research for this report did not uncover other examples but the issue merits attention. As megacities in the developing world expand, land for I/M facilities will become scarcer and more expensive. Governments should plan now to hold or obtain sites for I/M facilities that will be highly valuable in the future.

An analogous point concerns software for running an I/M program. Policymakers should develop and maintain centralized software and have winning firms that operate test facilities provide software that interfaces with this centralized software.[57] This allows policymakers to contract with multiple firms, enhancing competition at the time of re-bid, with no firm having an unfair advantage.

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[54] The problem of lower-than-expected sales is dealt with in Section 2.3.6 below.

[55] Herren, Fred, “The Legislative Framework: A Journey Towards I/M Best Practices in Asia,” presented at Better Air Quality workshop, sponsored by Clean Air Initiative-Asia, Manila, Philippines, December 16, 2003. p. 19.

[56] John Pachuta, personal communication.

[57] Rogers, John, op. cit., 2001, p. 7.

2.3.6. Risk Management

What if drivers don't show up for inspections? This is the underlying risk that makes I/M programs so different from other government programs that provide services for which the public has a natural demand.[58] Private I/M firms contemplating a bid that would lead to millions of dollars of investment must have an adequate answer to this question or the tender will fail to attract legitimate bids from firms that can deliver an effective program.

In the U.S., states can make fairly accurate forecasts of how many drivers will bring their vehicles in for inspections. Relying on reasonably accurate vehicle registration records that provide both good data on fleet characteristics and an effective lever for compliance promotion, these forecasts typically differ by no more than a few percentage points from the actual number of inspections. However, even with this forecasting ability, risk management provisions are common in the U.S. For example, Massachusetts' contract with an I/M firm sets a forecast level of 4.2 million cars per year. If the actual number falls below that level, a formula determines an increase in the inspection fee (and vice versa if actual inspections exceed the contract-specified level).[59] This type of contract provision makes sense given that the firm conducting the inspections typically cannot control the level of compliance, which in turn determines the number of inspections.

In British Columbia's first I/M contract, a similar contract provision provided that in case actual inspections were less than the forecast level, the government would pay some compensation to the firm. Conversely, if actual inspections exceeded the forecast level, the firm shared some of the excess revenue with the government. In the early years, actual inspections were below the forecast and the firm sought compensation. There was disagreement over the cause of the shortfall and this generated some ill will between the firm and the government. Given the ill will plus the fact that several years experience allowed more precise forecasts of inspections, British Columbia's second I/M contract dropped the revenue adjustment provision.[60]

This risk management issue deserves greater attention from policymakers in the developing world. One executive with an I/M firm lamented that it "never crosses their minds" despite the likelihood that the number of inspections will be particularly difficult to forecast in the early years of I/M implementation. There are some exceptions: contract terms in Costa Rica provided for a lump-sum compensation payment if inspections fell below forecast levels in one year, with increased fees in the next year.[61] In the Buenos Aires province of Argentina, the inspection fee contains a "risk management" component that the government keeps if inspections meet forecasted levels, but goes to the I/M firm as compensation if actual inspections fall below the forecast.[62]

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[58] Privatization efforts related to energy, water, or transportation services have a fundamental difference in that consumers clearly want the services, and there is typically a track record of operation by a state-owned firm.
[59] Christopher Stock, personal communication.
[60] David Gourley, personal communication.
[61] Jon Bickel, personal communication.
[62] Frank Dursbeck, personal communication.

2.3.7. Preliminary Conclusions and Roles for Donors

The literature in this area (thin as it is) and the interviews with experts and I/M firms conducted for this report suggest the following as best practices in I/M contracting:

- In order to bring their expertise and capital, encourage international I/M firms to partner with local firms in the bidding process.
- Make awards to a single firm (rather than multiple firms) operating within a single jurisdiction (i.e., state or metropolitan region). Encourage competition by making awards in more than one jurisdiction, and by ensuring that an incumbent firm does not have an unfair advantage when re-bidding a concession.
- Contract lengths should be seven years or longer.
- Provide for appropriate inflation-indexing or wage-indexing of inspection fees.
- Consider government ownership of land and buildings for test-only I/M centers, either at the outset or at the end of the first concession.
- Provide appropriate risk management contract provisions to account for the possibility of the actual number of inspections being far different from the forecast number.

A clear role for the donor community here is to conduct further research in this area that could result in a model tender and policy guidelines on conducting the bidding process and implementing an I/M contract. Research for this report found only one existing donor study that produced a publicly available draft tender. It illustrates the challenges in tender design and risk management (see Box 2-3).[63]

BOX 2-3. A DRAFT TENDER FOR SURABAYA

In a project that culminated in 2001, GTZ assisted Surabaya, Indonesia in preparations for the launch of an I/M system. Although Surabaya did not carry out the plans, the project provided useful analysis and draft tender documents that are instructive. The tender documents called for a technical proposal and a financial proposal. Evaluation of the technical proposals to be submitted would aim to create a pool of highly qualified firms clustered in their technical scoring. Surabaya would then evaluate the financial proposals of each of these qualified firms. The financial proposal would consist of the bid for each proposed inspection fee. The final evaluation would involve a weighting of each firm's technical score and fee bid.

The draft contract language set a term of seven years and required teaming by Indonesian firms and experienced international firms. The draft contract also spelled out the contractor's and the city's responsibilities under the new I/M system. The city was responsible for enforcing the I/M system in order to create demand for a specified minimum number of inspections each year. A key aspect of risk management in the draft contract was a provision for the city to compensate the contractor if the number of inspections fell below the specified minimums

Source: Reinhard Kolke*, Inspection & Maintenance and Roadworthiness Program for Surabaya.*

[63] Kolke, Reinhard, *Inspection & Maintenance and Roadworthiness Program for Surabaya*, prepared for GTZ Sustainable Urban Transport Project, June 2001.

Many of the experts and I/M firms interviewed would welcome a model tender document. The actual tenders they have encountered often lack quality and integration. One interviewee commented that one can recognize that some tenders are a patchwork of text that meld provisions from other tenders (e.g., U.S. state tenders) or language from a presentation at an I/M workshop. Key provisions are absent or poorly drafted and this results in a long process of tender amendment as potential bidders raise problems.

These same interviewees also see benefit from greater involvement by donors in the selection of the contractor and implementation of the contract. If donors are providing funding, they can exert leverage to ensure that the process is fair, transparent, and effective.

2.4. Oversight and Quality Assurance

There is no escaping the need to “inspect the inspectors.” Experts agree that without a comprehensive oversight and quality assurance (QA) program, an I/M program is likely to be ineffective and that is grounds for making it an essential best practice.[64] Effective oversight and QA is necessary to deliver the actual emission reductions sought and help maintain public support for the program. As one expert concluded:

> *You should only implement a vehicle emissions program… [if] you are willing and able to invest the resources, manpower, and effort in auditing and supervising the program to guarantee its objectivity and transparency. It is not a commitment that can be taken lightly.*[65]

Oversight and QA involve a set of highly technical tasks that are suitable for contracting out, as it is unlikely that government staff in developing countries will have the needed capacity. A private firm or a non-profit organization with the requisite skills could be tasked as the “QA entity” if a public agency cannot play the role.[66] For example, private firms provide this service to the U.S. states of Pennsylvania and Alaska and to Ontario, Canada. The QA entity’s tasks should include:[67]

- **Standards and Procedures.** Policymakers need technical assistance on determining the details of decisions on emission standards and test procedures, including calibration standards. Test centers will be held accountable for following these.
- **Certification of Test Centers Staff.** Individual test centers should be required to adhere to the ISO standards noted earlier (ISO 17020 or ISO 9003). The QA entity should set minimum qualifications for test center staff, and verify that they are met.
- **Control and Issuance of I/M Certificates.** The QA entity should be responsible for creating forgery-resistant I/M certificates and controlling their distribution.

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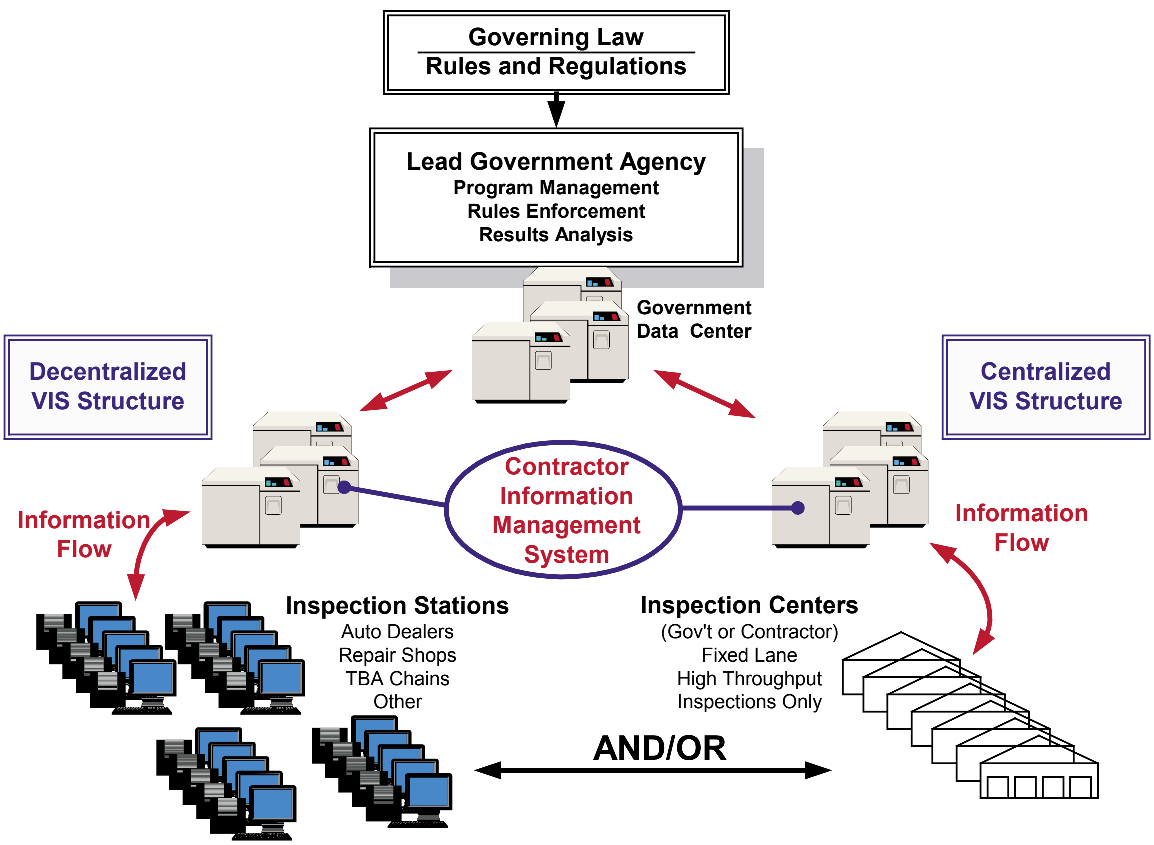
[64] Asian Development Bank, op. cit., passim. Weaver, C. and L. Chan, op. cit., pp. 29-30.
[65] John Rogers, “Lessons on Audit Quality Assurance Mechanisms,” p. 2.
[66] Asian Development Bank, op. cit., p. 25.
[67] See discussions in: Asian Development Bank, op. cit.; Weaver, C. and L. Chan, op. cit.; and Kolke, 2002, op. cit.

- **Data Management.** The QA entity should be the recipient of real-time data reported by the test centers on each inspection they conduct. Collection and analysis of these data is key to compliance promotion (via linkage to vehicle registration), auditing of test center performance, and policy development (how standards should evolve).
- **Audits.** The QA entity should conduct three types of audits: calibration audits of test equipment; audits of test centers using data reported; and, covert audits of test centers in cooperation with law enforcement.
- **Roadside Inspections.** The QA entity should provide technical support and personnel to work with police in roadside checks of vehicles.

The current effectiveness of Mexico City's program is due in significant part to major upgrades of its QA system (see Appendix B). The figure below illustrates how inspection data should flow to a Vehicle Information System (VIS) from either test-only or test-and-repair facilities, and then link with official government data sources.

Figure 2-1: Information Flow in a Vehicle Information System (VIS)



Source: SGS

2.5. Government Coordination and Management

By placing the operation of test facilities in private hands, and contracting out the oversight and quality assurance tasks, government can focus on critical roles that cannot be privatized: selection of standards and test procedures along with overall program management and coordination. Above all, only government can produce the conditions that essentially create a market for a new service: the inspection of vehicles. Policymakers must conduct a bidding process that creates reliable suppliers of this service, and it must simultaneously create the demand for the service by drivers. If successful, policymakers will mobilize millions of dollars of private capital that provide many more millions of dollars of economic benefits to drivers in reduced fuel consumption and to all citizens from reduced air pollution.

Success also requires mobilizing political capital to make politically tough decisions. Owners of commercial vehicles may constitute powerful interest groups. If an existing I/M program uses repair shops for testing, the owners will likely fight having that business taken away. There may be opposition to providing business to international I/M firms to solve a “local” problem.

Effective management and coordination requires substantial technical expertise exceeding what is available typically within most government agencies at the outset. Outside expertise could come from within or outside the country. Some experts recommend retaining an international expert group to review the bidding procedure and conduct an overall program audit after one to two years of operation.[68]

A variety of coordination issues arise both “vertically” (through federal, state, and local levels of government) and “horizontally” (across different agencies at the same level of government). Experts agree on the following best practice: national governments should establish an I/M policy framework, and that state and local governments should tailor some program details within this framework to address specific conditions within regions or cities.[69] (See Box 2-4 on the European Union approach to central versus delegated authority.) The I/M framework should be part of a larger policy framework that addresses vehicle emissions in an integrated manner. I/M program elements should account for new vehicle emission standards, equipment warranties, and fuel standards, all of which are typically set at the national level.[70] I/M standards should be partly a function of: what vehicles achieved when they were new; how well certain pollution control equipment should perform over time; and, the quality of fuel available (e.g., high sulfur fuel can degrade some equipment). Thus, coordination improves I/M effectiveness. In Brazil, for instance, failure to reach agreement between the State of Sao Paulo, the Municipality of Sao Paulo and the national government has delayed implementation of I/M for several years.[71]

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[68] Kolke, 2001, op. cit., p. 35.

[69] Kolke, 2002, op. cit., p. 3. Global Initiative on Transport Emissions, op. cit., p. 2. China and Indonesia offer contrasting examples: China has provided a strong national framework while Indonesia has largely deferred to state and local government.

[70] Asian Development Bank, 2003, op. cit., p. 17. Global Initiative on Transport Emissions, op. cit., p. 2.

[71] Michael Walsh, personal communication.

BOX 2-4. I/M AUTHORITY IN EUROPE

In the European Union, EU Directive 96/96/EC regulates I/M programs and safety inspections. The directive specifies 6 vehicles classes, stipulates the frequency of the inspections, and sets forth emission test procedures and standards. However, the directive also allows each member state to:

- Set a higher frequency of tests
- Make the testing of optional equipment compulsory
- Expand test requirements to other classes of vehicles
- Prescribe additional or more stringent tests

In effect, the directive sets a floor on I/M regulation and allows states to take stronger steps at their discretion. For example, Sweden adds an HC standard to the minimum CO standard, and Germany is experimenting with on-board diagnostics (OBD) and "loaded testing" (see Chapter 3). The directive leaves member states to choose between test-only versus test-and-repair systems but requires that: "The roadworthiness test provided for in this directive shall be carried out by the State, or by a public body entrusted with the task by the State or by bodies or establishments designated and directly supervised by the State, including duly authorized private bodies. In particular, when establishments designated as vehicle testing centers also perform motor vehicle repair, Member States shall make every effort to ensure the objectivity and high quality of the vehicle testing".

Source: EU Directive 96/96/EC

Within the same level of government, coordination is often needed among multiple government agencies. Coordination is especially important between the environmental agency (focused on emissions) and the transport agency (typically responsible for vehicle registration and safety inspections). In many countries, safety (or "roadworthiness") testing of vehicles has a long history, given that vehicle safety problems were recognized far earlier than air quality problems. Unfortunately, in some developing countries, the system of safety inspections suffers from high levels of corruption (see case study of New Delhi).

Linking both vehicle registration and safety inspection to emission inspection can be a valuable strategy. Emission and safety inspections are integrated in Costa Rica, the EU, and many U.S. states. Egypt plans to integrate emission inspections, safety inspections, and vehicle registration in "one-stop" government facilities.[72] GTZ is promoting a "one-stop" approach in Sri Lanka.[73] This approach deserves additional donor support given its promise to improve air quality, safety, and vehicle registration.

Consistent with the recommendations of many experts, this report advocates integration of emission and safety inspections as a best practice (for those countries that choose to do both).[74] One important caveat: policymakers should not attempt to graft an I/M

[72] David Fratt, personal communication.
[73] Weaver, C. and L. Chan, op. cit., p. 30-32.
[74] Kolke, op. cit., p. 3. Weaver, C. and L. Chan, op. cit., p. 31. One reviewer of this report supported elevation of this recommendation to an *essential* best practice, while another suggested deleting the recommendation altogether due to the alleged inefficacies of safety inspections. The scope of this study did not allow a definitive review of safety inspection systems, but the author's intuition is that such a review would support the elevation of this recommendation to the *essential* category.

system onto an existing, corrupt safety inspection system. Safety problems pose risks of a similar magnitude as air pollution and deserve to be addressed with the same rigor.[75] Government can achieve "economies of scope" in addressing both in an integrated way.[76] The efficiencies will be manifest in shared costs for the two programs (e.g., land, facilities, staff) and in allowing drivers to get tested for both in a single trip. In addition, safety inspections have more personal benefit to drivers than emission testing. Integrating the programs may increase compliance with emission testing relative to a standalone I/M program.

At a minimum, these coordination issues demand in-depth dialogue among all relevant agencies, both "vertically" and "horizontally," during program design leading to clear definitions of roles and responsibilities during implementation.[77] A stronger step to promote coordination is to create permanent interagency group to help oversee I/M implementation.[78] For example, in India, the Mashelkar Committee[79] has proposed the establishment of the National Automobile Pollution & Fuel Authority in India with overall responsibilities such as:

- Setting standards and establishing test procedures
- Overseeing the program and collection of data
- Certifying inspectors and repair systems, and
- Conducting audits and evaluating program benefits and costs

Almaty, Kazakhstan, provides a good illustration of the management and coordination problems that can arise in an I/M program. Consultants found that 6 different agencies played significant roles in the existing, ineffective I/M program (see Box 2-5).

BOX 2-5. ORGANIZATIONAL BOXES IN ALMATY, KAZAKHSTAN

In 2001-2002, the European Commission conducted a project entitled "Support to the Ministry of Natural Resources and Environmental Protection of Kazakhstan." Air pollution-related work in the city of Almaty included a component on strengthening the existing I/M program.

Consultants on the project quickly became aware that the roles of various organizations involved in the I/M program were poorly defined, and that it was very difficult to find anyone in government that could give a full explanation of how the system was intended to work. Consultants identified at least 6 significant players who often acted independently and with little coordination:

- National Center of Expertise and Certification
- Almaty city administration

Continued on page 37

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[75] See, e.g., World Bank, "Road Safety: A Development Change for South Asia," undated. Wall Street Journal, "New World Health Goal: Halting Rise in Traffic Deaths," April 7, 2004, p. B1.
[76] Herren, Fred, op. cit.
[77] Asian Development Bank, 2003, op. cit., p. 16
[78] For example, see proposals for two Indonesian cities in Kolke, 2001, op. cit., pp. 14-15 and Steckdaub and Sekartini, 2001, p. 4.
[79] See Appendix C for details.

Continued from page 36

- Almaty Ecologostry
- Almaty police
- Ministry of Interior
- “Gosnazor” (for accreditation of service sector)

Consultants also identified the Ministry of Trade and Economics and the Department of Transport and Communication as having some marginal roles in I/M. Their effort to piece together how the system worked (or didn’t work) is summarized below.

The National Center of Expertise and Certification had responsibility for accreditation and certification in vehicle sector (and food sector). The Center certifies all kinds of repair shops and issue accreditations valid for one year. About 30 repair shops for vehicles were able to comply with the standards for accreditation, and the main points of concern were adequate calibration of equipment and the urgent need for modern 4-gas analyzers.

The Almaty city administration issues orders and Almaty Ecologostry implements its orders in the field of environmental protection and safety. Ecologostry’s responsibilities included the operation of 8 checkpoints (5 stationary and 3 mobile) at the main entrances of Almaty. At those checkpoints incoming vehicles not registered in the city of Almaty are randomly tested according to an idle CO emission standard. If vehicles at the checkpoints did not comply with the CO idle requirements, the inspector would attempt to adjust the carburetor with a screwdriver, and the driver might pay a fine. The equipment at the checkpoints was very old and poorly maintained and calibrated. The inspectors at the checkpoints were mostly former military employees wearing rank insignia based on their former positions in the army. They were not trained to carry out measurements in a technically correct manner. Nor did they have any authority to pursue drivers who have ignored their signal to stop at the checkpoint.

The Almaty traffic police have responsibility for checking vehicles for valid I/M stickers, and carrying out road-side inspections at mobile inspection stations (though the stations rarely moved!). The traffic police measured CO at idle using equipment in condition similar to that at the checkpoints. For vehicles exceeding the CO standard, the inspector would fine the driver and direct him to an authorized repair shop for adjustment of the carburetor.

The Ministry of Interior accredits privately-operated test-only facilities to issue I/M stickers. To reduce the risk for corruption and influence from the vehicle owner, a police officer is stationed at each facility, supervising the whole operation. Accreditations are granted yearly after a bidding procedure. Although any company can bid in theory, the same 6 facilities appear to get accreditation year after year. Consultants found that three facilities would probably be adequate for the volume of inspections.

Perhaps the most confusing aspect of the situation in Almaty concerned the requirement of certifications for repair shops. About 30 shops had certification. Across Kazakhstan, there are about 40 different organizations, some of them operated as private enterprises, with the right to issue certifications for repair shops. Four of those organizations were located in Almaty and there was some competition among them. A governmental agency named “Gosnazor” had authority over these certifying agencies, but also had authority to issue certifications itself.

One of the recommendations that came out this donor-funded project was to better define the responsibility of all these organizations, and establish a new Vehicle Authority for Almaty to coordinate implementation of the I/M program.

Source: Lennart Erlandsson

2.6. Phase-In and Adaptation

A final key aspect of institutional design is whether policymakers should launch a new I/M program in a comprehensive way covering all vehicle types, or proceed more slowly using a phased approach. The same question applies to any attempt at reforming an existing I/M program. There may be some economies of scale in being comprehensive (see earlier discussion of contracting issues), and there may be some benefit in terms of public perception of fairness if all vehicles are subjected to I/M requirements at once. However, most experts strongly support a phased approach that allows learning, adaptation, and capacity building along the way to a comprehensive I/M program, and that begins with the vehicles that emit the most (due to their emission rates, high mileage, or both).[80] Indeed, this should be considered a essential best practice.

For example, Arequipa, Peru, has run an I/M program for taxis, buses, and trucks for three years, and is now planning to expand it to private cars.[81] The consultant study for Sri Lanka recommended a three-year phase-in as follows:[82]

- Year 1: Light-duty diesel vehicles and 3-wheel taxis
- Year 2: Heavy-duty diesel vehicles and 2-stroke engine motorcycles, scooters, mopeds
- Year 3: Automobiles (gasoline-fueled) and 4-stroke engine motorcycles

Some would argue for even slower phase-in periods in which additional vehicle types are added only after extensive experience is accumulated in a first round. As one expert put it:

> *To maximize the social benefits from the program, the main investment in emissions control must be focused on the dirtiest vehicles. Once those gross polluters are under control, the program should be extended to embrace the next level of high polluters, and so on until the air quality is seen to improve.*[83]

Political forces may prevent targeting of the dirtiest vehicles first. For example, Nicaragua is contemplating a phased-in I/M program that starts with new cars and then brings in older cars and trucks later. This strategy reflects consideration of “ability to pay” with higher income drivers presumed to own the newer cars.[84]

A second type of phase-in of an I/M program relates to the stringency of standards.[85] Rather than limiting the classes of vehicles first affected by I/M, policymakers can set lenient standards at first and then tighten them over time. This does not reduce the number of vehicles affected, but it reduces the number of vehicles that fail the I/M test.

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80 Rogers, John, op. cit., 2001, p. 2. Economies of scale could still be captured by a winning firm for a long-term contract that calls for phased implementation.

81 Jon Bickel, personal communication.

82 Weaver, C. and L. Chan., op. cit., 2002, p. v.

83 John Rogers, Lessons on Audit and Quality Assurance Mechanisms, p. 2.

84 Jon Bickel, personal communication.

85 For a good discussion of this issue, see SGS, op. cit. Phase-in of stringency is also relevant to safety inspections where the number of parameters to be tested (brakes, lights, suspension, etc.) can be phased-in over a period of time as well as the pass-fail margin of tolerance.

This can promote public acceptance at the outset and help drivers become accustomed to bringing their vehicles in for inspection. It can also control the number of re-inspections that must be performed in the early years, and thus reduce the I/M inspection capacity needed at the outset.

One of the most important reasons for phasing in emission standards is to give the repair industry time to adjust. The tighter the standards, the harder it is for mechanics to effectively diagnose and repair failed vehicles. Gradual tightening of standards gives the industry the necessary time to acquire the training, tools and associated skills to fix vehicles to meet tight standards.

Mexico City provides a good example of how the stringency of I/M standards can be phased in over time, gradually putting pressure on drivers but not causing so many to fail in a given year that public support was undermined (see Appendix B). Mexico City also leaves 2&3 wheelers out of the I/M system as an insignificant part of the problem. Part of the failure of I/M in Delhi (and India in general) can be attributed to the lack of any notion of phase-in. Policymakers there tried to require all vehicles to meet I/M standards from the very start (see Appendix C).

3. TEST PROCEDURES AND EMISSION STANDARDS

This chapter addresses the issues of test procedures and emission standards. Experts agree that standards should be based in part on the actual and potential performance of vehicles in the host country. The data gathering to assess vehicle performance is described in the section below. The availability of test procedures necessarily limits the kinds of standards that can be set. For most pollutants, policymakers have several test procedures from which to choose, but they face trade-offs regarding cost, accuracy, and susceptibility to fraud. Section 3.2 below examines best practices in making these trade-offs. Finally, Section 3.3 explores how the data and test procedures should inform standard setting.

Historically, I/M programs have focused on measuring carbon monoxide (CO), hydrocarbons (HC), smoke opacity, and, to a lesser extent, nitrogen oxide (NOx). Ironically, policymakers lack I/M test procedures to directly measure the air pollutant with greatest health impact—fine particulate matter (PM). The diesel engines of trucks and buses are large emitters of PM, and two-stroke gasoline engines powering millions of scooters, motorcycles, and 3-wheel taxis in developing countries emit large quantities of PM in white or gray exhaust. Although PM is commonly measured in controlled test laboratory settings, policymakers currently lack resilient and reliable instruments for measuring PM in an I/M setting. In the absence of such instruments, policymakers have relied on a proxy: measurements of smoke opacity. [86]

Policymakers should be aware that a PM meter capable of measuring PM mass and suitable for use in the I/M context is likely to be commercially available in one to two years. PM meters will likely change dramatically what constitutes “best practice” in test procedures and standards for diesel engines and 2&3 wheelers. The U.S. EPA has worked with industry to develop the technology, and candidate instruments have been under evaluation for the past two years. EPA’s primary interest has been technology to measure PM emissions on the road with a portable device, as part of the implementation of new diesel engine standards. However, this same technology will be suitable for I/M systems (see Box 3-1).[87]

BOX 3-1. PM METERS UNDER DEVELOPMENT

In an ongoing test program in Kansas City, USEPA is evaluating a quartz crystal microbalance to provide mass measurements of particulate matter emissions from motor vehicles. This device is capable of measuring PM mass on a continuous basis in real time. It is anticipated that future systems employing the same or similar technology will be useful in both I/M applications and for use in portable emission measurement systems for on-road testing. For more information, see *www.sensors-inc.com*.

Source: Eugene Tierney and Rob Wilson, personal communications.

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[86] Erlandsson, L. and M. Walsh, *Motor Vehicle Inspection in the National Capitol Area (NCR) of India: A Plan for Progress*, prepared for the Center for Science and Environment, March 7, 2003, p. 27.
[87] Gene Tierney, personal communication.

Ultimately, policymakers must choose what standards to apply to various types of engines and vehicles, and how to test vehicles for compliance with those standards.[88] There is a huge variation in the emissions performance (actual and potential) of a heavy-duty commercial diesel truck versus a modern gasoline-engine car versus an aging scooter. Key questions include: How should standards vary by type of vehicle; by technology; or, by age of vehicle? Should testing be done in a quick, low-cost way with the engine idling, or with a longer, higher-cost procedure involving placing the vehicle on a dynamometer?[89] Many of these questions are highly technical in nature but also involve critical policy issues and are often intertwined with other issues in I/M program design. To state just one obvious example, policymakers cannot set standards purely on the basis of vehicles' technical capabilities. If such a standard resulted in a very high percentage of vehicles failing the test, it could undermine the political support necessary to sustain a program.

3.1. Fleet Characterization

A best practice in developing standards for an I/M program is to "know your fleet," i.e., to secure data on how many vehicles are plying the roads of a state or city, along with their types, ages, the quantities of pollutants they are emitting, and the number of miles they travel. This exercise is known as fleet characterization. In addition to aiding the process of setting standards, the data is critical to estimating total vehicle emissions and making decisions such as how many test facilities will be needed. The alternative to using fleet characterization in standard setting is to pick standards based on data that may be inaccurate or irrelevant to the host country, or to adopt standards developed for other countries (that may not be appropriate for the host country).

The basic data on vehicle number, type, and age are usually available in industrialized countries because of annual vehicle registration requirements and computerized records. However, in many developing countries, such data are unavailable.[90] In some countries such as India, vehicles are registered once at time of purchase (and are supposed to be re-registered after 15 years of service). In these countries, government has no record of whether a vehicle has been retired or sold to a new owner in another jurisdiction. In other countries, vehicles are registered annually but a lack of centralized, computerized recordkeeping is a huge obstacle to fleet characterization.[91]

Where vehicle registration data is lacking, fleet data can be estimated through modeling and sampling techniques. For example, a study for Sri Lanka resulted in a total fleet

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[88] The focus of this report is on gasoline and diesel vehicles which constitute the overwhelming portion of fleets in all countries. However, the emergence of gas-electric hybrids and vehicles fueled by compressed natural gas (CNG) and liquefied petroleum gas (LPG) in niche markets demands that I/M programs develop appropriate standards for these fuel and engine types. Bogota exempts CNG buses from I/M requirements, yet a "cleaner" fuel alone does not solve the problem of emissions from buses or any type of vehicle.

[89] A dynamometer is essentially a treadmill for vehicles that can simulate different speeds and engine loads.

[90] Gwilliam, K., M. Kojima and T. Johnson, Urban Air Pollution: Policy Framework for Mobile Sources (draft), prepared for the World Bank, December 2003, p168. Rogers, John, Assessment of the Pollution Under Control Program in India, Prepared for the World Bank, October 2002, p. 44.

[91] Weaver, C. and L. Chan, *Sri Lanka Vehicle Emissions Control Project - Revised Final Report*, prepared for the Ministry of Environment, Government of Sri Lanka, July 23, 2003, p. 12.

estimate of about 1 million vehicles compared to cumulative registrations of 1.7 million vehicles in 2000.[92] The age profile is particularly important in developing countries because of the greater proportion of older, high-emitting vehicles.

Data on vehicle emissions are even harder to come by. Emissions are a function of many variables including engine type, fuel used, miles traveled, speed and acceleration, and pollution control equipment (if any). Here again, modeling and sampling play key roles. Conducting truly random samples is a daunting task. Selection of roads and drivers from which to sample is always problematic. Drivers need to be persuaded or forced to pull over and delay their travel while their vehicle is examined. Typically, dynamometers cannot be used in roadside sampling. Available resources sometimes dictate that analysts secure a handful of vehicles with the aim and hope that they are reasonably representative of the vehicle population. Researchers then put these vehicles through a simulated drive cycle on dynamometers and measure the emissions.

Remote sensing can be a useful complement in this task. This technology uses a light beam projected across a lane of traffic to sense emissions from vehicles as they drive by. A camera can take an image of each license plate and, ideally, can link emission data with vehicle model, engine type, age, etc. USAID is conducting extensive fleet characterization using remote sensing in several Indian cities. Remote sensing can also play a role in compliance and enforcement (see Chapter 4).

Efforts to improve emissions data can involve voluntary I/M “clinics” or “camps.” In a private sector initiative in India, drivers were invited to have their vehicles tested, free of charge, for both emissions and safety. Simple maintenance was provided free and on-the-spot for vehicles that failed the test.[93] These I/M camps produced useful date on current emissions as well as what could be achieved with improved maintenance. Details on these I/M camps appear in Delhi case study in Appendix C.

In addition to data on what vehicles are currently emitting, a fleet characterization exercise ideally should include analysis of what lower emission levels vehicles are capable of meeting after maintenance is performed. This kind of data, along with the cost of the maintenance, can help policymakers judge what emission standards they can impose on in-use vehicles. The Indian I/M camps generated this kind of data. Consultants generated similar data for the Sri Lankan government as part of a comprehensive I/M program design study.[94]

3.2. Test Procedures

In an ideal world, policymakers would know with reasonable certainty the quantity of pollutants that vehicles emit, and this information would be a building block of an I/M program or other policy regime to control in-use vehicle emissions. In reality, policymakers must muddle through with very imperfect information on what the vehicles they are regulating are actually emitting.

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[92] Weaver, C. and L. Chan, ibid, 2003, pp.12-13.

[93] Das, S. et al, “Prospects of Inspection and Maintenance of Two-Wheelers in India,” Journal of Air and Waste Management Association, 51:1391-1400, October 2001.

[94] Weaver and Chan,op. cit., pp.12-13.

The measurement of emissions from a vehicle is far more complicated than simply hooking up a gas analyzer to the tailpipe. Emissions vary greatly among similar vehicles and even an individual vehicle's emissions can vary tremendously under different operating conditions. As noted earlier, any attempt to quantify a vehicle's emissions necessarily involves assumptions, modeling, and sampling.

The U.S., European Union (EU), and Japan have each developed elaborate test procedures for carefully measuring the mass of emissions from vehicles during simulated driving conditions. Regulators conduct these tests in laboratories on vehicles fresh from the assembly line to verify that they meet increasingly rigorous emission standards for new vehicles. Engineers place a vehicle on a dynamometer and put it through a driving cycle of different speeds and with different weights or "loads," while a gas analyzer measures the physical mass of emissions (e.g., in grams per kilometer traveled). The driving cycle is designed to approximate real world driving by typical vehicles. The resulting emission estimates are only as good as the assumptions underlying the driving cycle, and researchers periodically modify these assumptions to reflect actual drivers' behavior as accurately as possible. These drive cycles can last 20 to 40 minutes or more.

These lengthy test procedures have become the benchmark against which less elaborate and inherently less accurate I/M test procedures are compared. I/M programs need tests that are less expensive and last no more than 10 minutes (probably the upper limit of what drivers will accept in waiting time). Engineers have developed a range of options for I/M tests and policymakers face trade-offs in choosing among them.[95]

At one end of the range are "no-load tests" in which the engine merely idles and the test duration can be as short as thirty seconds. This type of test can include idling at both a low and high speed or revving the engine several times. These simple, low-cost test procedures, when properly done, can serve as rough screening devices for high-emitting vehicles. However, the results are sometimes inconsistent and prone to manipulation and suffer from high error rates yielding false failures.

At the other end of the range are "loaded tests" that use sophisticated, higher-cost equipment and test cycles that take up to 10 minutes, operating the vehicle on a dynamometer with simulated engine loads. "Steady state loaded tests" run the vehicle on a dynamometer at a steady speed and load and are relatively easier to administer. "Transient loaded tests" run the vehicle through a simulated driving cycle of varying speeds and loads and are more technically demanding and take about twice as long. Loaded tests are more accurate than no-load tests, and more difficult to manipulate, but the total time a driver needs to spend at the I/M facility can be 20 minutes or longer (and he must drive to and from the facility). On-board diagnostic (OBD) equipment offers a potential alternative to direct emission measurement by verifying the operation of emission controls on a vehicle (see Section 3.2.2 below). OBD can also cut the time needed to conduct the inspection.

[95] For a detailed but concise summary of the range of options, see Wash, Michael, op. cit., 2003, Appendix C.

Best practices in making trade-offs among cost, accuracy, and manipulability are explored below for the three major vehicle classes: 2&3 wheelers, automobiles, and diesel trucks.[96] Up until now, policymakers have overwhelmingly chosen no-load tests, but there is some movement toward loaded testing.

3.2.1. 2&3 Wheelers

Historically, emission testing for motorcycles, scooters, mopeds, and 3-wheel taxis[97] received little attention in industrialized countries because these vehicle types accounted for such a small part of the total fleet.[98] In contrast, for many cities in the developing world, especially Asian cities, they can make up a huge part of the fleet and be responsible for a major portion of total vehicle emissions.

The most significant emissions from these gasoline-powered vehicles are carbon monoxide (CO) and hydrocarbons (HC). Nitrogen oxide (NOx) emissions tend to be low and are not measured in I/M programs. Two-stroke engines pose the added problem of high emissions of particulate matter (PM) in the form of oil particles that result from unburned fuel in white or gray exhaust.[99] Although new two-stroke engines with advanced control equipment can have quite low emissions, the vast numbers of older two-stroke 2&3 wheelers on the road and the inherently dirtier combustion process have led to calls for forcing retirement of two-strokes and banning of new two-stroke engines.[100] Four-stroke engines are relatively clean by comparison.

Given the lack of practical, direct PM measures, the second-best solution is to measure smoke. A smoke opacity meter measures the density of smoke.[101] Data suggest that, for 2&3 wheelers, there is a reasonable correlation between opacity (measured with the engine at idle) and PM emissions under simulated driving conditions.[102] However, opacity testing for 2&3 wheelers is rare, and better techniques are needed to measure opacity for this vehicle class under controlled conditions.[103] Donor organizations should support development of improved techniques for opacity testing.[104]

Simple, inexpensive gas analyzers can measure CO concentration (as a percentage) and HC concentrations (in parts per million or ppm) in no-load tests of 2&3 wheelers. When done properly, these concentration measures have a reasonable correlation with mass CO and HC emissions measured over a driving cycle. However, because of the large

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96 For a more in-depth technical treatment, see Faiz, A., C. Weaver, and M. Walsh, op.cit., and Kolke, Reinhard, *Inspection & Maintenance and Roadworthiness, Module 4b,* of *Sustainable Transport: A Sourcebook for Policymakers in Developing Cities*, prepared for GTZ, 2002, p. 12.

97 In some I/M studies, the term “motorcycle” refers to all such vehicles.

98 Only a single U.S. state, Arizona, requires motorcycles to participate in the I/M program. U.S EPA, op. cit., 2003.

99 Weaver and Chan, op. cit., p. 40.

100 The demand for two-stroke engines remains high because, relative to four-stroke engines, they are less expensive, easier to maintain, and provide better acceleration.

101 For a discussion of the two types of opacity meters, Hartridge (partial-flow) and full-flow, and the little-used Bosch method, see Faiz, A., C. Weaver, and M. Walsh, op. cit. 1996. p. 133-135.

102 Weaver and Chan, op. cit., p. 40.

103 Erlandsson and Walsh, 2003, op. cit., p. 13. Thailand is one of the few countries that conducts opacity testing on motorcycles.

104 Weaver and Chan,op. cit., pp. 40-41.

variation in exhaust pipe diameter and configuration among 2&3 wheelers, even simple CO and HC measurements must be conducted carefully using standard protocols.[105]

No-load tests are overwhelmingly prevalent for 2&3 wheelers in I/M programs in the developing and industrialized world with a simple "idle" test being the overwhelming choice. "Two-speed idle" tests (at idle and at 2500 rpm) and "snap acceleration" tests (which the engine is revved up once to full speed quickly) are also possible but rarely used. [106] All these tests measure CO and HC only. Loaded testing on dynamometers is used extensively for certifying the emission performance of new 2&3 wheelers, however, no practical loaded test procedure exists for I/M applications. Such procedures are under development in Asia,[107] but until they are ready, policymakers face limited options.

There are several ways that drivers and staff at testing facilities can attempt to generate a false "pass" of a no-load emission test.[108] The most serious vulnerability relates to older 2&3 wheelers with simple carburetors. A driver can temporarily adjust the air/fuel mixture to be leaner and thus reduce the CO and HC emissions (and engine power).[109] This can result in a "pass", after which the driver happily readjusts the air/fuel mixture and emissions go back up. The I/M literature labels this practice "lean and late" or "clean for a day."[110] A study of I/M in Nepal presents an excellent example:

> *A survey of auto-repair workshops and vehicle drivers showed that vehicles failing the emissions inspection do not undergo proper repair of emissions control components. Usually temporary engine adjustments are made before the inspection so that the vehicle can obtain a Green Sticker. For example, in gasoline vehicles, the idle screw is adjusted to obtain a lean fuel-air mixture or the air filter is simply removed prior to the emissions test. After the vehicle passes the test, the engine settings are reversed to their pre-inspection condition. This business has become a lucrative industry in Kathmandu Valley. It is also alleged that the current system of manual recording of emissions data and issuance of Green Stickers allows the emissions inspectors to falsify the test results, given an appropriate 'inducement'.*[111]

Estimates from this study indicated that vehicle owners paid eight to ten times as much for this "clean for a day" service as they did for their I/M inspections.

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[105] Kolke, 2002, op. cit., p. 21. Inadvertent (or deliberate) dilution of the exhaust stream can be identified by four-gas analyzers that measure CO2 and O2 in addition to CO and HC.

[106] The two-speed idle test can achieve better consistency than a simple idle test yet remains little used. The "snap acceleration" (also known as "free acceleration") test is used in Thailand in testing motorcycle emissions for opacity.

[107] John Rogers, personal communication.

[108] One example is conspiring to not insert the gas analyzer probe far enough into a tailpipe, a problem that can be addressed by applying strictly quality assurance protocols in test-only centers.

[109] If adjusting the air/fuel mixture is not sufficient, a driver can retard the ignition timing as a more extreme option.

[110] Asian Development Bank, op. cit., p. 22.

[111] Faiz, A., B.B. Ale, and R.K. Nagarkoti, "The Role of Inspection and Maintenance(I/M) in Controlling Vehicular Emissions in Kathmandu Valley, Nepal." Proceedings. 13th International Symposium on Transport and Air Pollution , National Center for Atmospheric Research, Boulder, Colorado, Sept 13-15, 2004, p. 5.

Dynamometer testing should allow detection of “late and lean” 2&3 wheelers. However, until dynamometer testing is available for this class of vehicles, the “late and lean” problem defies solution and no-load testing is the “best practice” because, for now, it is the only option.[112]

What are the implications for policymakers of the I/M testing options available for 2&3 wheelers? No-load testing, if done properly, can still be a useful screen for high emitters if the driver is not playing the “clean for a day” game. [113] Many experts recommend a “two-stage” idle test, first at 600 to 1200 rpm and then again at 2000 to 3000 rpm or pre-conditioning the engine for 30 seconds at 2500 rpm before conducting a simple no-load test at normal idle speed.[114] The need to carefully conduct no-load tests (given exhaust pipe variability among 2&3 wheelers) and the ease of other forms of manipulation of no-load tests should lead one to select an institutional design that can reduce the odds of cheating, i.e., test-only facilities.

As noted earlier, PM meters under development will likely change dramatically what constitutes “best practice” in test procedures and standards for two- and three-wheeled vehicles.

3.2.2. Automobiles

As incomes rise in the developing world, automobiles[115] become a larger segment of the total vehicle population. In this section, “automobiles” encompasses gasoline-powered cars and light trucks (SUVs and minivans). The most significant emissions from these vehicles are carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NOx); PM emissions may be relatively minor. (This is an area of ongoing research in the U.S.) In contrast, diesel cars have significant PM emissions and testing options are the same as for diesel trucks (see next section).

As is the case with 2&3 wheelers, simple, inexpensive gas analyzers can measure CO concentration (percent) and HC concentrations (ppm), and these concentration measures have a reasonable correlation with mass emission measures done over a driving cycle. Relatively little variation in exhaust pipe diameter and configuration mean that CO and HC measurements are less likely to suffer from human error. Accurate measurement of NOx emissions requires dynamometer testing.

No-load tests are prevalent for cars in I/M programs in the developing and industrialized worlds. Simple idle tests are most common but there are some examples of two-stage

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[112] One prominent expert disagrees. In Mexico City, I/M testing for motorcycles was discontinued altogether. “[S]tatic tests depended too much on the test technician, were not practical or effective, and were stopped. It was too easy to generate a false pass on this test. I am convinced that the only effective and easy-to-apply test procedure requires a dynamometer test.” John Rogers, 2001, op. cit., p.5.

[113] As described in Appendix B, Mexico City chose to abandon motorcycle testing rather than use no-load tests.

[114] Erlandsson and Walsh, 2003, op.cit., p. 12. Rogers, 2002, op.cit., p. 16. K.G. Duleep, personal communication.

[115] This section does not apply to diesel-powered automobiles.

idle tests (in which emissions are measured at a low and high speed).[116] Adding a "lambda" test (measuring the air/fuel ratio) at high idle can help reveal whether the catalytic converter is functioning, the exhaust pipe is leaking, and the testing has been carried out properly. [117]

Older cars with simple carburetors pose the same problem as carbureted 2&3 wheelers: "lean and late" manipulation can fool no-load tests. Loaded testing, adopted in a few countries, can detect this manipulation by its ability to detect NOx (which increases in an engine tuned "lean and late"). The trade-off, as noted earlier, is the greater hardware costs plus the extra time a driver must spend in the test facility.

Even loaded testing is not foolproof, given that there no limits to human ingenuity. In some countries, drivers can "rent" what they need to pass a test, e.g., a catalytic converter for an emission test or a headlight for a safety test.[118]

The U.S. and Mexico City have led the way in applying loaded testing (dynamometer testing) to automobiles. Many states in the U.S. use loaded testing and have experimented with various drive cycles, always searching for a balance among accuracy, reasonable cost, and reasonable length of time.[119] Mexico City first adopted loaded testing in 1997 using an acceleration simulation mode test and has made minor modifications since (see Appendix B).[120]

On-board diagnostics (OBD) offers a potential way to avoid loaded testing. Modern automobiles with computer-controlled engines can diagnose and signal various types of malfunctions, including those with emission controls. In the U.S., every light duty vehicle built since 1996 has an OBD system that checks the emission control system and generates a standardized set of data that indicates if the system is working properly. The USEPA has encouraged states to substitute a check of the OBD system as a substitute for testing of actual emissions, though there are still a host of issues surrounding the costs and efficiencies of this approach.[121] However, outside the U.S., there is no standardized OBD data protocol—the key obstacle to the application of OBD testing to I/M systems. Even after OBD testing becomes available in developing countries, market penetration will be slow because of slow turnover and conventional I/M will still need to play a large role. Nevertheless, one can expect OBD to play a growing role worldwide in the years ahead.

Collectively, states in the U.S. use just about every conceivable test on automobiles ranging from component inspection (with no actual emission testing), to no-load tests (idle and two-speed idle), to a panoply of loaded tests (ASM2, ASM2525, ASM5015, IM240, MA31, RI2000, etc.) to OBD testing. Box 3-2 illustrates how the state of Maryland sorts out testing by age and type of vehicle.

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[116] Examples include Hong Kong and the Philippines. Asian Development Bank, Vehicle Emission Standards and Inspection and Maintenance, 2003, p. 19.
[117] Erlandsson and Walsh, 2003, op. cit., p. 29.
[118] Frank Dursbeck, personal communication.
[119] National Academy of Sciences, op. cit., pp. 62-63. Erlandsson and Walsh 2003, pp. 20-26.
[120] World Bank Energy Sector Management Assistance Programme, Mexican Energy Environment Review, May 2001, p. 63.
[121] National Academy of Sciences, op. cit., pp.92-103.

BOX 3-2. MARYLAND'S DIVERSITY IN I/M TEST PROCEDURES

- On-Board Diagnostics (OBD) Test: 1996 or newer model year vehicles weighing less than 8,501 pounds and equipped with a computer controlled engine and fuel system.
- Loaded Test (IM240): 1984 to 1995 model year vehicles weighing less than 10,000 pounds and 1996 or newer model year vehicles weighing between 8,501 and 9,999 pounds.
- No-load (Idle) Test: 1977 to 1983 model year vehicles; vehicles with a carbureted fuel system; and trucks weighing 10,000 pounds or more regardless of model year.

What is the bottom line? Experts consider best practice in auto testing to be no-load testing for cars that are not equipped with catalytic converters, and loaded testing for cars with this emission control technology.[122] Using dynamometers, test facility staff with low technical skill are capable of conducting short steady-state/single-load tests, achieving acceptable accuracy in measurement and holding costs down. Transient loaded tests, those that run the vehicle through simulated driving cycles and loads, are longer, costlier, and require relatively skilled staff and might be deferred in developing countries until conditions warrant.[123] Applying these best practices to a diverse auto fleet results in a complicated I/M system, again lending itself to centralized testing.

3.2.3. Diesel Trucks

Billowing black smoke from aging diesel trucks and buses is a common sight in the developing world.[124] Although their numbers may be relatively small, their high emission rates and high mileage combine to produce a disproportionate share of total emissions. The principal emissions from large diesel vehicles are PM, HC, NOx, and SO2. In addition, most citizens consider the visible smoke a nuisance. NOx emissions vary little with maintenance, being dependent primarily on engine design, and SO2 emissions vary with sulfur content of the fuel. However, I/M programs can reduce smoke (or PM) and HC emissions.[125]

In the U.S., I/M testing for diesel trucks has received far less attention than in the rest of the world. This reflects the fact that the U.S. diesel truck fleet is relatively new and well maintained, hence the impact of an I/M program would be relatively small. The small number of diesel automobiles in the U.S. also results in little attention to diesel I/M. Reinforcing this is the fact that reduction in the pollutants that cause health-threatening ozone and smog–NOx and HC, not PM—has been the main driver of I/M programs in the U.S.. For instance, USEPA models for Clean Air Act compliance do not contain elements that quantify the effect of diesel I/M programs. Only a handful of states have

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[122] Asian Development Bank, op. cit., p. 18.
[123] Rogers, John, 2001, op. cit., p. 6.
[124] This report does not explicitly address commercial trucks that are gasoline-powered, however, test procedures for these vehicles should be similar to those for automobiles.
[125] Weaver and Chan, 2003, op. cit., p. 32.

a diesel I/M program at all. [126] In contrast, the EU requires I/M testing using opacity measures for all diesel-powered cars and trucks.

As noted earlier, a test procedure for PM suitable for an I/M program remains elusive, yet PM is widely acknowledged as posing the largest health risk of any vehicle pollutant. Smoke opacity meters are commonly used and accurately measure something that the public cares about: visible diesel smoke. Most experts agree that there is no correlation between a vehicle's emissions of PM and its smoke opacity. However, a contrary view holds that there is some correlation in developing countries due to lower penetration of advanced diesel technologies.[127] Regardless of this debate, experts generally agree that policymakers should use opacity testing, arguing that it can serve as a useful screen for major engine malfunctioning or tampering (which is likely but not certain to result in increased PM emissions) and that reduction of visible smoke still serves a public purpose.

Several choices for opacity test procedures are available.[128] Testing an idling diesel engine is not recommended because smoke levels at idling speed are nearly always low regardless of the condition of the vehicle. A common no-load test is "snap acceleration" (or "free acceleration"): in which the engine is revved up once to high speed quickly (with vehicle stationary) and smoke is measured. A more complex test is the "snap-idle" test where the engine is revved several times and an average smoke value is derived.

Aiming for an accurate and replicable snap-idle test, a committee organized by the Society of Automotive Engineers (SAE) developed a standardized procedure for this test known as "J1667."[129] Nonetheless, accuracy and replicability remain a problem with both the snap acceleration and snap-idle tests. The acceleration(s) are performed manually and should be guided by the vehicle's tachometer measuring engine rpm. If they are not done properly, the emission measurements will vary substantially. Accidental dilution of the exhaust stream will result in low readings. These same factors leave the snap and snap-idle test open to fraud. If the engine is revved to less than full speed (a "lazy" snap), lower emissions will result.[130] Temporary adjustments to the fuel injection pump can also lower emissions.[131] There are also concerns that the snap-idle test poses some risk of damage to older diesel engines. This increases the likelihood that drivers and testers will not conduct the test according to its design specifications.

A variety of loaded tests are available for diesel trucks. In the "road load" test, the dynamometer simulates steady driving at moderate speed. The "lug down" test loads the

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[126] Many states have a less formal program that tries to catch gross diesel emitters at truck stops and weigh stations (see Chapter 4). U.S. attention to diesel may increase with tighter PM standards coming into effect. Joe Pedelty and Dan Meszler, personal communications.

[127] See Gilliam, op. cit., pp. 171-173, and Erlandsson and Walsh, 2003, op. cit., p. 27 for the conventional view. In contrast, Weaver argues that the lack of correlation is partly a function of the emissions effects of turbochargers and puff limiters which have a sizable presence in industrialized countries but relatively low market penetration in developing countries (personal communication).

[128] For a detailed and concise summary of diesel test options, see Weaver and Chan, op. cit., 2003, pp. 32-40.

[129] Society of Automotive Engineers, SAE Standard J1667, February 1996.

[130] Weaver, C. and L. Chan, op. cit., p. 38.

[131] Gwilliam, K. et al, op. cit., pp. 170-171.

engine to near its maximum torque.[132] The dynamometer can also simulate acceleration from a dead stop. These tests provide more accurate and replicable measures of smoke than no-load tests. However, different driving cycles can produce very different opacity results. Globally, far less time has been invested in developing appropriate loaded test-cycles for diesel trucks relative to that invested for cars.

Loaded testing of diesel trucks is still relatively rare, with Chile being a prominent exception[133] along with a few US states. Despite many years of advocacy by environmental experts, EU countries have still not adopted loaded testing for diesel trucks. One expert argues that the accuracy and replicability problems of “snap acceleration” tests are so severe as to render them virtually useless in the I/M context:

> *The control and reduction of particulate emissions from in-use diesel vehicles requires a short transient dynamometer test procedure to be defined and implemented in which both visible smoke and particulates are measured. The benefits of including HC and NOx measurements together with control elements such as CO, CO2, and O2 should also be considered.*[134]

Other experts are doubtful whether the added costs of loaded tests are justified. In addition, as noted earlier, PM meters likely to be available soon will probably change dramatically what constitutes “best practice” in test procedures and standards for diesel engines. Therefore, policymakers should avoid investing in loaded opacity testing until the implications of the new PM meters become clear. In the meantime, the common snap-idle test (J1667) remains a good option for diesel truck testing.

If it turns out that PM testing is best performed on dynamometers, then commercial diesel vehicles are likely candidates for the first class of vehicles to undergo a loaded PM test. In many countries, diesel trucks and buses must already report to test-only centers that are suitable for dynamometers. These vehicles are driven longer distances than private vehicles and emit proportionally more pollution. Loaded PM testing might logically begin with diesel engines.

3.3. Emission Standards

Data analysis of vehicle emissions across different countries and different vehicle types consistently indicates that a small fraction of vehicles is responsible for a large, disproportionate share of total vehicles emissions. As stated in Chapter 1, the proper aim of an I/M program is to target these vehicles and improve their performance. If standards (or “cut-points” in testing lingo) are set appropriately, I/M programs can have a big impact while inconveniencing a relatively small fraction of drivers.

In practice, some policymakers have set standards rather arbitrarily while others have applied rigorous analysis. Reflecting the common test procedures outlined in the previous section, the standards most commonly applied for cars and 2&3 wheelers are

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[132] The lug-down test can also be done without a dynamometer using the brakes to simulate load.
[133] Frank Dursbeck, personal communication. In Canada, the province of British Columbia conducts loaded testing of light duty diesel vehicles.
[134] Rogers, John, 2002, op. cit., p. 42.

for CO (as a percent of emissions) and HC (as parts per million); but for diesel trucks, smoke opacity is the overwhelming choice. In the few countries that have adopted dynamometer testing, NOx standards for diesel trucks are possible as well.

With a few exceptions, policymakers have chosen CO and HC standards for 2&3 wheelers with a no-load "idle" test procedure. Many Asian countries have chosen a uniform CO standard of 4.5 percent (e.g., India, Indonesia, Thailand, Vietnam) while others apply this standard to older 2&3 wheelers while applying a tighter standard to new ones (e.g., 2 percent in Beijing for 2&3 wheelers made after 2000 and 3 percent in Taipei for those made after 2003). Similarly, some countries apply a uniform HC standard (e.g., Cambodia and Thailand both use 10,000 ppm) while others differentiate between 2-stroke and 4-stroke engines (e.g., Vietnam holds 2-strokes to a 10,000 ppm standard while setting a much tighter 1,500 ppm standard for 4-strokes). India, Philippines, and Sri Lanka set a CO standard but no HC standard, and Mexico City and all but one U.S. state set no I/M standards for 2&3 wheelers at all. Thailand is unique in setting an opacity standard of 30 percent using a snap acceleration test.

Automobiles present a more mixed picture due to the adoption of dynamometer testing in some countries. Mexico, one of the few developing countries using dynamometers for automobiles, requires cars to meet: a NOx standard of 2500 ppm along with an HC standard of 200 ppm and a CO standard of 2 percent for vehicles made after 1990 (older cars have HC and CO standards of 300 ppm and 3 percent, respectively).[135] Some states in the U.S. and provinces of Canada combine dynamometer testing with elaborate tables of "cut-points" for different model years and vehicle weights.[136] Under these systems, computerized test equipment automatically applies the correct cut-point based on vehicle identification.

Many countries that still apply simple no-load idle tests typically set a single set of CO and HC standards applicable to all automobiles. Examples include:

- Indonesia: CO standard of 4.5 percent, HC standard of 1200 ppm.
- Nepal: CO standards of 3.0 percent, HC standard of 1000 ppm.
- Cambodia: CO standard of 4.5 percent HC standard of 1000 ppm.

Other countries create two age categories, with tighter standards for newer vehicles. Examples include:

- Egypt: CO standards of 7 percent (pre-1995) and 4.5 percent (1995+), HC standards of 1000 ppm (pre-1995) and 900 ppm (1995+).
- Sri Lanka: CO standards of 4.5 percent (pre-1998) and 3.0 percent (1998+), HC standard of 1200 ppm.
- Thailand: CO standards of 4.5 percent (pre-1993) and 1.5 percent (1993+), HC standards of 600 ppm (pre-1993) and 200 ppm (1993+).

[135] Mexico City also has special standards related to its "day-without-a-car" that allows cars with lower emissions to have increased operating rights. See discussion of "Zero" and "One" standards in Mexican Energy Environment Review, op. cit., May 2001, pp.59-64.
[136] See for example, AirCare Program, Table of Emission Standards, undated.

The European Union has created four categories for automobiles referencing both age (pre- and post-1986) and technology (catalytic converters, OBD). The EU applies a two-stage idling test and a “lambda” test to vehicles with catalytic converters, and uses OBD systems in lieu of emission testing when they are present (see Box 3-3).[137] The Philippines has adopted similar standards but with different dates, reflecting later introduction of catalytic converters.

BOX 3-3. EU: I/M STANDARDS FOR AUTOMOBILES

Initial Date of Operation	*CO Standard (%)*	*Lambda*
Before Oct. 1, 1986	4.5 (idle)	
After Oct., 1, 1986	3.5 (idle)	
With catalytic converter	0.5 (idle)	
	0.3 (high idle - 2000 rpm)	1.00 +/- 0.03

With OBD: check for correct operation of emissions control system (and OBD system)

Source: EU Directives 96/96/EC and 2001/9/EC.

For diesel trucks, opacity measured with the snap acceleration test is by far the most common standard. The most common form of measurement is the Hartridge Smoke Unit (HSU). As noted earlier, only Chile and a few U.S. states apply loaded testing to diesels. Most developing countries set a single standard for all trucks. For example, Singapore, Malaysia, and Cambodia all use an opacity standard of 50 percent. India and Nepal are more lenient at 65 percent. Egypt sets more lenient standards for older trucks: 65 percent for pre-1995 trucks and 50 percent for 1995 and newer models. Some U.S. states set two or three age categories with opacity standards of 40 to 70 percent (see Box 3-4).[138]

More complex approaches involve varying standards by engine type (naturally aspirated vs. turbo-charged) or altitude. The Philippines makes both types of distinctions and some U.S. states apply this kind of distinction (e.g., Colorado distinguishes engine types and Arizona varies the opacity standard for three altitude zones).[139]

As this brief review illustrates, policymakers often set standards that are “round numbers” in common use (e.g., CO standards of 4.5, 3.5, or 0.5 percent, or opacity measures of 50 or 65 percent). Such standards do not necessarily identify the gross emitters nor are they appropriate for circumstances of a particular country.

Reflecting a wide consensus in expert opinion, this report considers it an essential best practice to set standards based on statistics on the distribution of emission levels, analysis of what proper maintenance can achieve and how much it costs, all mixed with

[137] EU Directives 96/96/EC and 2001/9/EC. The directives states that an acceptable alternative standards is the “maximum permissible CO content in the exhaust gases is that stated by the vehicle manufacturer.”
[138] Diesel Technology Forum, web page entitled “Smoke Testing Programs”, <www.dieselforum.org/retrofit/smoketest_map.html>.
[139] MECA, I/M Implementation Status Report, Part 7, June 1999.

BOX 3-4. HEAVY-DUTY DIESEL I/M PROGRAMS IN THE U.S.

Heavy-duty diesel vehicle emission inspection programs have been initiated in a number of locations in the U.S. in the last decade in an effort to identify, test and repair vehicles that emit excessive smoke. The earliest of these programs dates back to 1974 for the Arizona program, but most programs were initiated in the mid to late 1990s. At present, there are 16 programs in operation in the U.S., and two in Canada. All of the 18 programs in operation as of March 2004 measure smoke opacity only as a surrogate for diesel emissions, but program structures and test methods vary across states.

At present, there are three specific types of programs used:

- Roadside Inspections: A sample of all trucks is selected at varied locations for smoke opacity testing.
- Periodic Inspections: Trucks registered in a specific area are inspected annually or biennially at an inspection facility.
- Self-Certification Program: This program is for fleets, which are allowed to conduct periodic tests in their own maintenance facility and report the results to the state.

Most states use a test approved by the Society of Automotive Engineers for identifying a diesel vehicle's smoke emissions, called the SAE J1667 "snap-acceleration" test, with pass/fail standards of 55 percent smoke opacity for pre-1991 vehicles and 40 percent for 1991 and later vehicles.” (Author’s note: some states add a third category of pre-1974 or pre-1976 trucks with a 70 percent opacity standard)

Source: Diesel Technology Forum, Smoke Testing Programs

prudent judgment on what level of standards will command political support.[140] The pollutants covered will vary for gas vs. diesel engines (CO/HC/NOx vs. PM/smoke/NOx). A very tough standard that many vehicles flunk could erode support, as could a very easy standard that made the I/M program appear ineffectual. When phasing-in standards, policymakers should set standards or “cut-points” be set so that 15 to 20 percent of vehicles fail.[141] However, this rate could be higher or lower depending on technical and cost factors. A consultant study for Sri Lanka provides a good example of how analysis and judgment can inform the recommendation of a set of standards (see Box 3-5).

As emission standards for new vehicles are tightened, policymakers should set I/M standards for these vehicles that are appropriately stringent, reflecting newer technology and improved emissions performance. Older vehicles emit more due to the nature of their technology, as well as the inevitable deterioration of age. While this should lead to relatively lenient standards for older vehicles, at the same time, policymakers may want to set a relatively tough standard for older high-emitting vehicles in order to create some pressure for retiring the vehicle rather than maintaining it.[142]

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[140] Faiz, A. et al, op. cit., pp. 141-144. Asian Development Bank, 2003, op. cit., p. 13-14. Weaver, C. and L. Chan, op. cit., p. 41-42. One reviewer argued that current EU I/M standards represent “internationally recognized” cut-points, but this was a lone viewpoint.

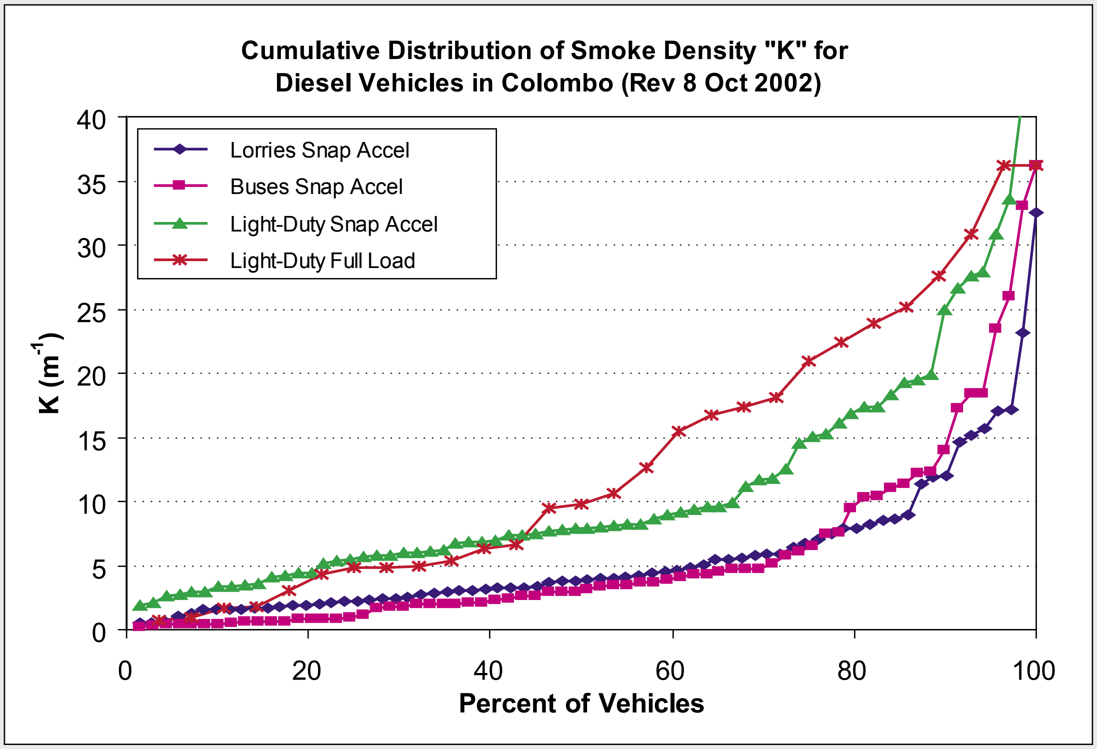
[141] Asian Development Bank, 2003, op. cit., p. 14.

[142] One reviewer argued strongly that technology alone should determine cut-points, and that age should not be a factor.

BOX 3-5. USING CUT-POINT ANALYSIS IN SRI LANKA

A fleet characterization exercise for diesel trucks and buses produced the cumulative distribution curve for opacity for these vehicles shown in the figure below (here a "K" value of opacity is used rather than percent opacity). The effect of an I/M standard is to create a horizontal line on this graph (i.e., a "cut-point"). Those vehicles below the line pass the test and those vehicles above the line flunk the test. The shape of the distribution is typical, revealing a relatively small group of gross emitters.

Figure 3-1



Here is how the consultants used the data and judgment in recommending a set of standards: "Based on [data collected], EF&EE recommended interim smoke opacity standards of 8.0 m-1, rather than the more stringent standard of 3.22 m-1 stated in the existing regulation.… EF&EE's recommended standard would be expected to result in roughly 20 percent of buses, 20 percent of trucks, and 40 percent of light duty vehicles failing and having to undergo repairs. Enforcement of the 3.22m-1 standard, if it were possible to do so, would cause 50 percent of buses, 60 percent of trucks, and 90 percent of light-duty vehicles to fail. In EF&EE's judgment and experience, that would be likely to lead to political unrest, widespread evasion, and the failure of the I/M program. The projected failure rate of 40 percent for light-duty diesel vehicles is relatively high—high enough to lead to political difficulties in many cases. To achieve a more-comfortable 20 percent failure rate, however, it would have been necessary to relax the proposed smoke limit to more than 17 m-1. The air quality implications of allowing such high smoke emissions would have been unacceptable, in our view. Further, our judgment was that it would be better and more consistent to enforce the same smoke limit for light-duty and heavy-duty diesels. Finally, our experience and [data]… show that the proposed emission limit of 8 m-1 can be achieved readily and at modest cost by nearly all light-duty diesel vehicles."

Source: Weaver and Chan, 2003.

When cut-points are chosen to fail only the worst polluters and strong oversight and auditing produce a program that is objective, transparent and achieves its goal, then public support is likely. This is demonstrated by Mexico City's ability to strengthen its program over time (see Appendix B).

3.4. Frequency of Inspection

A final aspect of standard setting is to determine how often drivers must bring their vehicles in for inspection. The more frequent the testing, the higher the probability of identifying a failing vehicle soon after its emissions performance deteriorates. However, testing is costly to all stakeholders in I/M programs, and a balance must be struck. In this decision, policymakers must take into account:[143]

- **Technical factors.** How fast does vehicle emission performance deteriorate? How does this vary with vehicle type, age, average miles traveled, road conditions?
- **Economic factors.** Frequency affects the number of test centers and lanes needed. The choice between 6 month and 1 year frequency affects demand for space, equipment, and staff by a factor of two.
- **Political judgment.** What frequency are drivers willing to tolerate without undermining support for the program?

Best practice in this aspect of I/M is a judicious blending of these factors. Frequencies of 6 months, 1 year, and 2 years are common. Typically, newer vehicles have better emission performance than older vehicles, and deteriorate more slowly. Commercial vehicles drive longer distances under tougher conditions and this leads to more frequent maintenance needs. Policymakers have reflected these factors in a variety of ways. Most states in the U.S. have adopted uniform requirements of 1 or 2 years in most cases, while three states have two tiers based on age: cars built before 1981 or 1982 must have annual inspections while newer cars have biennial inspections.[144] Generally, in the EU, a new car need not be inspected until it is 4 years old, then every 2 years thereafter.[145] In an arguable case of regulatory overkill, Delhi requires all private vehicles to be tested every 3 months, apparently the shortest frequency found anywhere (see Appendix C).[146]

[143] Kolke, 2002, op. cit., p. 14-15.
[144] U.S. EPA, op. cit., 2003.
[145] SGS, op. cit. 2003, p. 7.
[146] As noted in Appendix C, compliance with this "stringent" requirement is low.

4. COMPLIANCE PROMOTION AND ENFORCEMENT

This chapter examines how government can ensure that drivers bring their vehicles in for testing and carry out the necessary maintenance and repairs. This key behavioral aspect of I/M programs is sometimes given inadequate attention relative to the more technical aspects of standard setting. If significant numbers of drivers fail to comply with I/M rules, air quality will suffer, resources are wasted, and there may not be an adequate revenue base to sustain the program.

"Enforcement" is the common label for government efforts to ensure that drivers comply with I/M requirements. However, outside of the I/M arena, regulatory analysts have made a distinction between enforcement and "compliance promotion." That distinction is useful in the current context as well:

- Enforcement tools aim to find and punish drivers who are out of compliance with I/M requirements.
- Compliance promotion tools encourage drivers to conform to I/M requirements, typically with incentives or information.

The sections below address best practices in both areas.

Compliance and enforcement policies must work hand in hand with the design of other program elements. If, for example, I/M standards are overly stringent, the result could be an unwillingness to comply by vehicle owners and/or inability of repair shops to bring vehicles into compliance. Avoiding ironic outcomes should be a touchstone: overly stringent standards combined with poor enforcement, in effect, could penalize honest drivers for complying while allowing dishonest drivers to evade the requirements. Appropriate standards plus strong enforcement will only penalize dishonest drivers. Similarly, I/M fees that are too high might discourage compliance.

4.1. Enforcement

Enforcement requires "foot soldiers" deployed on the streets of the city: police officers (or other authorities) with the responsibility of checking vehicles for a valid I/M certificate and/or examining the actual emissions from vehicles. Both tasks present challenges.

4.1.1. Checking for Valid I/M Certificates

Enforcement efforts begin with a means of identifying vehicles that have passed inspection. Typically this involves a paper certificate issued to the owner (containing detailed information on owner, vehicle, expiration of certificate, and a unique I/M certificate number) and an I/M sticker placed on the windshield or license plate (containing expiration date and certificate number). Ideally, the I/M authority also stores all of this information in a centralized computer database, and police can access this data if necessary.

Best practices in the design of I/M stickers are quite straightforward: stickers must be resistant to forgery and to degradation in sunlight. Generally speaking, I/M stickers should be large enough so police can determine the expiration date at a short distance.

Color coding can assist in conveying the date. A rule should determine the location of the stickers. A common rule is to require the sticker to be on the front windshield, however, the rear windshield seems preferable. Mexico City requires placement on the rear windshield to facilitate visual checks by police driving in the same direction (and this does not decrease visibility for police on foot). For 2&3 wheelers without windscreens I/M stickers should be placed on a designated spot on the frame.[147]

Where I/M compliance is prerequisite to vehicle registration, police can check for a valid vehicle registration sticker and, in effect, “kill two birds with one stone” (see Section 4.2.1 for more details on this linkage). In this regard, placement of a small sticker on the vehicle license plate is common in the U.S. and in Europe. The success of this approach is due, in part, to the fact that police are usually more vigilant about enforcing vehicle registration requirements than I/M requirements. A common arrangement in the US for promoting enforcement involves creating the right incentives. Typically, the state government registers vehicles and collects registration fees, while local government police enforce the requirement on the street. States often encourage the vigilance of local governments by sharing the revenue collected from fines for invalid vehicle registrations. This sets up all the right incentives for local government to pressure police officials to pressure officers on the beat to actually issue citations to vehicle owners who do not meet registration requirements.

Having determined I/M certificate and sticker requirements, policymakers must then decide who will serve as the “foot soldiers” in enforcement. The choice here is whether to rely on police who are on the street for more general purposes or to create a specialized police unit aimed at finding I/M violators (or to use a mixture of both approaches). The former approach may be more efficient (in theory) in terms of the use of officers’ time, but it carries the risks that I/M enforcement will not be a priority among their other responsibilities. Conversely, a specialized unit is more likely to make I/M a priority but may suffer from inefficiency. Mexico City has experimented with both approaches (see Appendix B).

Sadly, police corruption is all too common in developing countries and I/M enforcement will suffer along with enforcement of other laws if drivers can escape enforcement through bribery. Thus, air quality can be partially dependent on whether police are adequately paid and whether there is a culture of corruption. The effectiveness of Chile’s I/M program is due in part to a police force relatively free of corruption:

> *A major factor of successful I/M enforcement in Chile is simply due to the “code of honor” of the Chilean police. They don’t accept any bribes although they are paid badly. If you really want to have problems with them simply offer some money to be let go.*[148]

One expert believes that even a corrupt police can be harnessed in the service of air quality: if fees for I/M violations are set high, police will demand a large bribe and drivers

[147] As noted in Appendix C, in Delhi and other Indian cities, I/M stickers are issued but rarely seen on vehicles. In theory, the driver must keep I/M paper certificates somewhere in the vehicle. Stickers that are issued are small and reveal the expiration date only at a distance measured in inches.
[148] Frank Dursbeck, personal communication.

will be more inclined to comply with I/M rather than pay a large bribe (see Mexico City case study, Appendix B).[149]

4.1.2. Roadside Emission Inspections

A valid I/M certificate by no means guarantees that a vehicle is in compliance with emission standards. Unintended deterioration of emission performance may cause some vehicles to exceed standards. More likely, drivers may make their vehicles “clean for a day” in order to pass the I/M test with carbureted engines being particularly easy to manipulate (see Chapter 3). The ingenuity (and dishonesty) of drivers goes much farther: some are willing to swap entire parts in and out of the vehicle in order to pass the test. Some repair shops will “rent” a functioning catalytic converter to a driver to pass the emissions test, or “rent” a functioning headlight to pass a safety test.[150]

The problem of intended or unintended deterioration in emission performance has led many governments to conduct roadside emission inspections as part of their overall enforcement program. In addition, if a large portion of vehicle traffic in a state or city comes from vehicles licensed outside of that jurisdiction, policymakers might consider roadside inspections as a way of imposing emission standards on these vehicles. Example of countries/cities implementing systems for roadside inspection include: Delhi, Manila, Taipei, Santiago, Singapore, and Chongqing, China. Ten U.S. states and two Canadian provinces have roadside inspection programs for diesel trucks.

Clearly, a roadside inspection is more technically demanding than checking for a valid I/M sticker on windshield. Typically, such inspections are carried out by teams of police and emission inspectors. They are limited to no-load tests using portable equipment. Vehicles can be selected for roadside testing randomly and/or by visual screening for particularly smoky vehicles. The city of Santiago does both.

Roadside inspections can be an efficient means of identifying high-emitting vehicles and forcing them to be repaired. In Chongqing, China, inspection stations failed about 10 percent of vehicles brought in by drivers. In contrast, roadside inspectors failed about 40 percent of vehicles that they flagged down.[151]

It is much harder to conduct oversight and quality assurance on mobile roadside inspection teams than test-only facilities or test-and-repair workshops. One expert observed that a Bangkok roadside inspection program was utterly corrupt.[152] He accompanied a team for one day searching for smoky vehicles. The team issued one-quarter of its annual average citations in that single day. This expert concludes that the best approach to roadside inspections is for a technically competent private firm to conduct them in conjunction with a police presence, and that the inspections be limited to smoke opacity from diesel vehicles. Another expert views the oversight problems

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[149] John Rogers, personal communication.
[150] Frank Dursbeck, personal communication.
[151] Xu Shubi, “Action Plan on Strengthening Inspection and Maintenance in Chongqing,” China, presented at CAI-Asia Concluding Workshop: Reducing Vehicle Emissions Project, February 28 – March 1, 2002, Manila, Philippines.
[152] Chris Weaver, personal communication. See also discussion in Weaver, C. and L. Chan, op. cit., p. 28.

as so inherently difficult that he recommends that an I/M program never use roadside inspections.[153]

Though not unanimously endorsed, most experts view roadside emission testing, properly conducted, as a best practice.[154] The Asian Development Bank concluded:

> *Roadside testing can complement a more comprehensive Motor Vehicle Inspection System but not replace it. Policymakers should ensure that roadside testing is designed as a complement to testing in fixed stations, but not as an alternative to it. The primary function of roadside testing should be the identification of gross polluting vehicles. Apart from the privatization of inspection centers, policymakers should also consider whether to outsource roadside apprehension to the private sector. They should ensure that the inspection fee fully provides for the costs of an adequate roadside apprehension program. Certain countries have tried to strengthen enforcement by allowing enforcers to retain a portion of the fines collected from apprehended vehicles. Policymakers need to study the effectiveness of this approach to be sure it doesn't increase the likelihood of corrupting the overall system.*[155]

The imposition of fines by roadside inspectors raises issues of fairness and who is being punished for violations. In this context, a Clean Air Initiative participant from India observed:

> *Consideration must also be given to the fact that the rickshaw driver is very seldom the owner. Most of the fleet is owned by bulk buyers who provide the rickshaws in exchange for daily rent. This requires careful application of the "polluter pays" principle if there is a need to develop a system of levies and fines on vehicles.*[156]

Normally, one would fine the owner of the vehicle but, in some cases, it is conceivable that a (non-owner) driver manipulated the vehicle and increased the emissions.

A final observation on roadside inspection programs: in several U.S. states, they are the *only* component of the I/M system for diesel trucks. Examples include Connecticut, Nevada, Maine, and Maryland. These states enforce opacity standards solely through roadside inspections, some done randomly and some done on visual screening for excessive smoke. One can consider this a distinct variation on the test-only design for I/M systems recommended in Chapter 2, perhaps suitable only for trucks but worth further exploration. If roadside inspections are numerous enough and effective enough, an I/M system may not need periodic inspections in centralized test facilities. In a similar vein, remote sensing (see section below) may evolve to a degree where it can complement or substitute for roadside inspections in identifying violators without requiring all vehicles to go through periodic testing.

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153 John Rogers, personal communication.
154 Faiz, A. et al, op. cit., p. 140-141. Kolke, 2002, op. cit., p. 6.
155 Asian Development Bank, op. cit., pp. 26-27.
156 Ahmed Ghazali, posting on CAI-Asia Web Dialogue, August 29, 2003 <www.cleanairnet.org/caiasia> (no longer on web, but available from author).

The notion of a "test-only" I/M system based on roadside inspections has received little attention in the I/M literature. Perhaps it is suitable only for trucks or other subsets of the total vehicle fleet, but the idea certainly merits further exploration. Technological developments may also elevate the role of roadside inspections. Remote sensing technology (see section below) is evolving and improving. Conceivably, in the future, remote sensing could play a major role in enabling an I/M system to shift away from periodic testing and toward roadside inspections as the backbone of the system. "

4.1.3. A Role for Remote Sensing

Chapter 3 noted that remote sensing can assist in the task of fleet characterization. Remote sensing may also be able to complement or substitute for roadside inspections and thus play a role in enforcement. As the technology improves it could have an impact on future I/M program design. Remote sensing devices (RSD) can be used to identify vehicles in violation of I/M norms, leading enforcement teams to pull the vehicles off the road and issue citations (or conduct confirming tests and issue citations). Alternatively, the process can be automated using a camera that takes an image of each license plate and helps identify the owner of the vehicle in violation. In the future, citations could be issued by mail. Using remote sensing to find vehicles in violation is referred to as "dirty screening." In contrast, "clean screening" uses remote sensing to identify "clean" vehicles and exempt them from I/M testing for a certain period. This can reduce costs and increase public acceptance of a program.[157]

The USEPA has issued regulatory guidance on "clean screening" used in Missouri and on "dirty screening" used in Texas. Taiwan will initiate a "dirty screening" program in 2005.[158] Remote sensing studies and pilots have been conducted in a variety of other countries (see Box 4-1 for a summary of a recent major European study).[159] Some experts see remote sensing as a promising technology but not yet capable of being the sole basis for enforcement against a vehicle.

For virtually any developing country, remote sensing can provide immediate value in fleet characterization. It may become even more valuable in coming years in aiding enforcement, thus building capacity in its use now could have a long term payoff.[160]

4.1.4. Citizen Reporting of Smoky Vehicles

Another possible way to strengthen the enforcement effort is to enlist citizens to contact authorities and report vehicles emitting large quantities of smoke. Several U.S. states have toll-free numbers that citizens can call to report the license plate numbers of diesel trucks that might be violating I/M standards. The call results in the vehicle's owner receiving an advisory letter recommending the truck be tested; however, the owner is

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[157] For a good review of remote sensing applications, see Vescio, Naranjan, US Remote Sensing Experience, presented at CITA Use of New Technology Workshop, Paris, May 29-31, 2003.
[158] Jeffrey Vogt, personal communication.
[159] For example, see <www.rsd-remotesensing.com/index.asp>.
[160] Some experts speculate that remote sensing and other technological developments could someday eliminate the need for periodic inspection.

not compelled to have a test. The United Kingdom has similar program, as does the Philippines.[161]

BOX 4-1. EUROPE'S REVEAL PROJECT ON REMOTE SENSING

The European Community funded the REVEAL project ("Remote Measurement of Vehicle Emissions at Low Cost") to investigate a range of applications of remote sensing devices (RSD), and the instrumentation necessary to support them. As summarized in its Final Technical Report (p. 4):

"The REVEAL project was driven by the primary objective of producing a robust low cost instrument which measures gaseous pollutants in motor vehicle exhaust plumes with sufficient accuracy to be a useful tool for regulatory authorities and for environmental impact researchers. Supporting this goal were subsidiary objectives of developing application protocols, best practice in deployment of remote sensing devices, and useful information about emissions in various European locations through measurement campaigns undertaken using the REVEAL prototype instruments. A third further set of objectives related to validating the instrument's performance against other measurement techniques so as to demonstrate its applicability and to prepare for its potential exploitation as a commercially available device. (p.4)

Ten partners from seven EU countries formed the REVEAL consortium, including government agencies, national environmental laboratories, and hardware and software companies. During the four major field trials (held in UK, Netherlands, Greece and Italy) some 60,000 vehicles were analyzed in continuous operation through day and night cycles of up to 36 hours.

The three key findings most relevant to remote sensing and enforcement:

- "The results illustrate that REVEAL is especially relevant for monitoring the impact of (urban) traffic management on emissions and also to identify 'gross polluters'. The method seems less suitable to establish quantitative measurement of individual vehicle emissions due to the relatively large fluctuations of vehicle emissions on the measurement scale of the RSD."
- "REVEAL can rank vehicles in order of increasing emissions. As expected from previous RSD publications, a small per cent of high emitters contributes a large share of the total vehicle emission. Therefore, vehicles belonging to the most polluting subset can be sorted out for further inspection and maintenance."
- "The present REVEAL prototypes are more suitable for gasoline- than for diesel-fuelled vehicles, because of the high resolving power of the CO measurement and of the poor resolution for smoke emissions. The latter is also due to the fact that dust and particulate matter from all sources, not only from the combustion in the engine, contribute to the measurement in the channel which is used to assess smoke emissions. Nonetheless assessment of NO emissions can be successfully undertaken but this is only one of the two key pollutants for diesel-powered vehicles."

Source: Sira Ltd., Remote Measurement of Vehicle Emissions at Low Cost—Final Technical Report, January 2004.

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[161] Santiago, Ramon, "Roadside Apprehension in Manila," presented at Workshop on Strengthening Vehicle Inspection & Maintenance, sponsored by Asian Development Bank, Chongqing, China, November 7-9, 2001.

The most effective citizen reporting program encountered in the research for this report was the Tarjeta Negra ("black card") program in Santiago. Authorities provided citizens with a simple card with a Ringelman opacity scale printed on it that citizens could use to determine approximately if a bus was in violation of opacity standards. If a bus number was called in, authorities quickly tracked down the bus and performed a snap acceleration test for opacity. The program resulted in a significant decrease in the number of smoky buses.[162]

Needless to say, citizen reporting can only be a small complement to vigorous enforcement effort, but it may also have value in raising public awareness.

4.2. Compliance Promotion

Rather than discovering violations, compliance promotion tools encourage drivers to conform to I/M requirements. Some common sense steps fall in this category: having an adequate number of test facilities located conveniently to drivers; setting inspection fees at affordable levels (see Chapter 5); offering free or reduced-price retests for vehicles that fail; establishing a fair appeals process in case of disputes; etc.[163] More sophisticated approaches use incentives, information, and awareness.

Several policy options exist to promote compliance with I/M requirements, but one stands out among all: linking periodic vehicle registration to I/M compliance. Other potential linkages and strategies are explored below.

4.2.1. Linkage to Vehicle Registration

Most industrialized countries maintain sophisticated, computerized registries of vehicles in operation. Typically this task is delegated to the state or provincial level. Authorities require that a new vehicle be registered when it is first sold, recording basic data about the owner and vehicle. If the owner moves to a new jurisdiction or sells the vehicle, it must be registered again to reflect these changes. Common practice requires the owner to renew the registration periodically (e.g., each year). Registration fees are collected and are often devoted to vehicle-related services that government provides.

Making I/M certification a requirement for being able to operate a vehicle, and enforcing this requirement with an effective, periodic vehicle registration system is a powerful tool for promoting compliance, and it is commonly cited as a best practice in the I/M literature. This linkage is a compelling *quid pro quo*: if a driver wants the "private good" of driving a vehicle, he must provide the "public good" of ensuring that the vehicle's emissions are under control. Experts also recommend a similar linkage to safety inspections. These linkages typically requires coordination among different agencies as described in Chapter 2 (e.g., transport and environment agencies), and is facilitated greatly by computerized records. Emissions and safety linkage is widespread in the USA and the EU. Chile has established the linkage to emission testing.

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[162] Frank Dursbeck, personal communication.
[163] Some U.S. states increase convenience by allowing a driver to set up an appointment for inspection.

Some developing countries require owners to register vehicles only when first purchased (e.g., India, as described in Appendix C) and the fate of the vehicles after that becomes unknown. To paraphrase De Soto writing in The Mystery of Capital, knowing “who owns what” is a critical task for any society that wishes to prosper economically.[164] That principle applies to vehicles as well in a broader sense: government records of vehicle ownership are a building block of a functioning society. Accurate tracking of the status and owners of vehicles can assist in urban planning, tax collection, accident and crime investigation, as well as air emission inventories and I/M compliance. The difficulties in fleet characterization, in the absence of good vehicle records, were noted in Chapter 3.

Given these multiple benefits of periodic vehicle registration, this report deems linkage of an effective, periodic vehicle registration system to I/M compliance an essential best practice.[165] Policymakers should put in a foundation of periodic vehicle registration before or concurrent with the effort to launch or strengthen an I/M program. Ironically, Mexico does not link emission testing to vehicle registration despite its prominence here as a success story in the developing world. Readers should interpret this as illustrating that there is no single factor that makes or breaks an I/M program; instead, it is the constellation of “best” and “bad” practices that will determine program success.

In creating emissions-registration linkage, one cannot assume away the challenge of enforcing requirements for vehicle registration. In developing countries, in particular, some drivers may flaunt these requirements. In Pakistan, for instance, one participant in a Clean Air Initiative web dialogue observed:

> *Out of an estimated total of 35,000 rickshaws in Lahore [Pakistan], only 12,000 are registered with the Regional Transport Authority. The 70 percent remaining perhaps have never fallen under the purview of the Motor Vehicle Examiner.*[166]

Transfer taxes on vehicle re-sales or new fees may also discourage drivers from updating vehicle registrations. Policymakers should commit to promoting a “package” of driver license, vehicle registration, emission inspection, and safety inspection, as the normal responsibilities of anyone seeking to operate a vehicle.

4.2.2. Other Possible Linkages

Linkage of I/M certification to other activities has been tried or suggested. Some Indian cities have experimented with requiring drivers to have an I/M certificate in order to purchase fuel. This has not been successful given that the private fuel stations are put in the position of denying themselves business and thus compliance by the stations was low (see Appendix C).

In another example from India, the Mashelkar Committee recommended that drivers be required to demonstrate I/M compliance in order to purchase vehicle insurance.

[164] De Soto, Hernandez, The Mystery of Capital. New York: Basic Books, 2000. De Soto’s emphasis is on the multiple benefits of accurate public records on ownership of property, including the fostering of access to capital markets even by poor citizens.
[165] See also: Asian Development Bank, op. cit., p. 17; Faiz, A. et al, op. cit., pp. 140; Kolke, 2002, op. cit., p. 11; Global Initiative on Transport Emissions, op. cit., p. 2.
[166] Ahmed Ghazali, op.cit.

This may seem impractical because of the divergent interests of the government in I/M compliance and the private insurance companies in selling insurance, but there are some indications that insurance companies may be interested in such a partnership.[167] Costa Rica has created this linkage, requiring that that a vehicle pass the integrated emissions and safety test before the owner can purchase insurance.[168] In the Canadian province of British Columbia, drivers must purchase basic liability coverage from a state-owned auto insurance company (with additional coverage available from private insurance companies). This state-owned company (Insurance Corporation of British Columbia) also issues vehicle registrations upon demonstration of I/M compliance. Thus vehicle registration, liability insurance coverage, and I/M compliance are all linked together.[169] In Sweden, policymakers once explored the possibility of linking the vehicle register with information from insurance companies. This would offer the simultaneous ability to verify: 1) if the vehicle passed the I/M program; 2) if the vehicle owner paid his annual road tax; and, 3) if the vehicle is insured in the proper way. Further study revealed that the merger was not technically feasible due to different databases and that this proposed use was not consistent with Swedish law.[170]

Another option is linkage of I/M certification to parking privileges. Under this scheme, a large business (or government agency) could deny entry to its parking lot to employees or customers unless they show I/M certification. The San Miguel Brewery pioneered this approach in Manila with some success. Some public relations benefit is possible for a company taking this approach, but the potential costs are also obvious. There would only be token value to this approach if a few individual organizations did it. However, if government catalyzed many large employers to do it, perhaps as part of a "compliance campaign" (see below), there could be some real value.

4.2.3. Raising Public Awareness

Campaigns to increase public awareness are a very important tool in promoting compliance; experts consider such campaigns as a best practice.[171] However, governments rarely budget significant resources for it or include it in tenders for I/M programs.[172]

Awareness campaigns can tout the public benefits of I/M in terms of reduced air pollution and better health. They can also make drivers aware of the private benefit: a well-tuned vehicle typically burns less fuel and saves money. Proper adjustment of an engine can improve fuel efficiency by 5 to 15 percent.[173] Campaigns should reach out to the vehicle service sector as well as the public at large.

Typically, at the launch of a new I/M program, government will generate substantial news coverage of the launch not only to build awareness but to get credit with voters

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167 Rajat Nandi, personal communication.
168 Jon Bickel, personal communication.
169 David Gourley, personal communication.
170 Lennart Erlandsson, personal communication.
171 Asian Development Bank, op. cit., p. 24-25. Global Initiative on Transport Emissions, op. cit., p. 2.
172 Jessica Chartier, personal communication.
173 European Commission, *The Inspection of In-Use Cars in Order to Attain Minimum Emissions of Pollutants and Optimum Energy Efficiency*, May 1998. Das, S. et al, op. cit.

for doing something about air pollution. In addition to press releases and other means of generating news, experts recommend letters to all vehicle owners, advertising, and awareness-building activities that "piggyback" on public fairs, festivals, auto shows, etc.

In Buenos Aires, the government used posters extensively to publicize the launch, including maps of I/M centers, also newspaper and radio was used for information. Despite these attempts to mobilize the public over many weeks, when the first deadline approached for compliance, huge queues built up at testing stations, and government had to move quickly to establish an orderly process.

NGOs can play an important role in getting difficult measures accepted by the public. In India, the Center for Science and Environment has made this a priority. Business can also assist. To promote the twin goals of building brand loyalty and compliance with the government's Pollution Under Control (PUC) I/M program, Indian 2&3 wheeler manufacturers periodically hold "PUC Check Up" camps in large cities. For example, over the course of one or more days, the manufacturer Bajaj rents a large public venue and invites owners of Bajaj scooters and motorcycles to come in for a free PUC test and certificate for those that pass. Beginning in 1999, the Society of Indian Automobile Manufacturers (SIAM) held a series of such camps but with some new twists:

- SIAM members held the camps jointly so virtually any 2&3 wheeler could participate.
- Mechanics performed up to three simple maintenance steps on 2&3 wheelers that failed the test.
- Drivers could undergo an optional safety check-up.

SIAM I/M camp in New Delhi. (Source: Author)

Publicity and visibility was elevated significantly above the type of camp run by a single company. Similarly, in Sri Lanka, authorities offered simple maintenance to vehicles they pulled over during a fleet characterization exercise. As part of major effort to promote I/M systems in Central America, Swisscontact sponsored similar activities as part of a comprehensive awareness-building (and capacity-building) program (see Box 4-2).

I/M camps or similarly voluntary activities such as those described in India, Sri Lanka, and Central America have the greatest potential benefit when run by trained personnel working with calibrated instruments. The long-term effects of these kinds of activities and other awareness-building events have not been evaluated and are inherently difficult to evaluate. Donors should consider evaluating the relative efficacy of different approaches to building public awareness.

BOX 4-2. SWISSCONTACT'S CLEAN AIR WEEKS IN CENTRAL AMERICA

In 1993, Swisscontact began its Clean Air Program, a 10-year multi-prong effort in 6 countries that included promotion of I/M programs. "Clean Air Weeks" were the major awareness-building activity, as their report on the project describes:

Clean Air Weeks were activities in which vehicle emissions testing was done free of charge. This was done with two purposes: first to make vehicles owners aware of the emission status of their cars.

The person arrived at a testing station, generally at a gas station, and after the vehicle's emissions were tested they were given a result card with the possible limits to be implemented in his country, and indicating the reason for the results and possible ways to maintain or correct them through good engine maintenance.

The second purpose was to collect real statistic data about the state of the vehicular fleet through a random sample measured during the week and with that data let the general public and the government know of the severity of the automobile pollution problem and the feasibility of taking actions to improve this situation.

The criteria used to determine if a gasoline driven car passed the test or not was measuring the carbon monoxide, carbon dioxide and unburned hydrocarbons. The limits used were based on draft laws still under discussion or on laws that were already approved. Opacity methods were applied on diesel vehicles (a method in use in most countries for this type of engines). The ap-plied limits were again the ones of laws in countries where they exist but had not yet been ap-proved or approved limits given in existing laws or regulations.
In some cases only CO was measured at gasoline cars and depending of the equipment diesel fueled vehicles were measured with the BOSCH filter pump using another scale and other limits than the opacity method. This was done due to the availability of measuring equipment at that time or because at that moment the laws regulated it that way in that particular country.

Also, another relevant aspect of all Clean Air Weeks is that they constituted the central axis on which almost all the advertising activities turned.

All the CAWs took place accompanied by a large advertising campaign that was implemented in the following manner:

- Two weeks before the kick-off there was advertising on radio, in newspapers and in some cases on television, inviting everyone to participate by taking their vehicles for emissions testing.
- At the same time many information brochures were handed out in the streets (some times up to 40,000 brochures were distributed) about air quality, vehicle emissions, pollution's effects on health, etc. [Examples can be seen in Swisscontact's report.]
- Days before the inauguration a press conference was given to publish the results of the air monitoring, and also to invite people to participate.
- For the inauguration the press was invited and acknowledgement was made to people or companies that participated.
- During the events advertising articles were given away like T-shirts and stickers announcing the Clean Air Program and overall support to prevent vehicle pollution.
- On many occasions, various cultural activities were held at the same time as the CAW, like ecological photographs, old car expositions, plays and concerts, all allusive to ecological subjects.

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- There were amateur photography and drawing contests, also allusive to ecological subjects, which had been previously announced and the awards were given during CAW.
- For closure, there was always a Clean Air bike race or marathon.
- Finally, days after these events, the testing results were sent to the press, emphasizing the percentage of vehicles that failed and that contaminate more than permitted and the necessity to reduce this percentage through good engine maintenance.

From 1993 to 2002, 17 Clean Air Weeks have taken place all over Central America, measuring the emissions of more than 100,000 automobiles…. The dissemination of these results has been the primary way to create public awareness, not only about how much cars that are in bad shape pollute the air, but also how easy it is to reduce this pollution.

Source: Swisscontact, *Clean Air Project: Report of Activities 1993-2002,* 2003, pp. 26-28.

4.2.4. Tamper-Resistant Emission Control Systems

Many years ago, there was some experimentation in the U.S. and Europe with tamper-resistant emission control systems. In theory, this might promote compliance with I/M standards. The idea was to seal vital parts in the emission control system and make it more difficult for unauthorized manipulations of engine settings. A vehicle with broken seals would automatically fail an I/M inspection. However, the seals were not very durable and the technique was applicable only to carburetor-controlled engines, not to modern electronically controlled engines. There are no advocates of for such approaches now.

5. MANAGING RESOURCES

Conducting a successful I/M program requires obtaining and managing various resources. This chapter brings together three topics under the broad umbrella of "resources." Policymakers need financial resources: building, equipping, and operating I/M facilities in a state or large city is a multi-million dollar undertaking. They need managerial and technical resources: all the actors in successful I/M programs must have the capacity to carry out their roles. Finally, policymakers need political resources: they need popular support in order to attempt the massive behavioral change implicit in an I/M program. The sections below address each of these key resources.

I/M programs need support from drivers with many other things on their minds. (Source: Author)

5.1. Financial Resources: Setting Fees, Recovering Costs

The financial resources needed to build, equip, and operate I/M facilities are substantial. For example, Agbar recently won the I/M franchise for Costa Rica and will operate 13 test-only centers and three mobile test stations, requiring an investment in the tens of millions of dollars.[174] As argued in Chapter 2 and as demonstrated in practice, private firms are willing to provide the capital to launch an I/M program if the inspection fees and compliance system offer the opportunity to recover their costs and make a reasonable profit.

The consultant study for Sri Lanka provides a good illustration of the costs involved for test-only systems. Inspection lanes carry a capital cost of roughly $200,000 each for heavy duty vehicles, and $120,000 for light duty vehicles. This cost includes buildings, dynamometers, emission analyzers, computer hardware and software, training and start-up costs. The number of lanes needed for a fully implemented program was 6 heavy duty and 61 light duty, implying a total upfront investment cost of $8.5 million. Operating costs include labor, land rent, utilities, etc. and were estimated at $105,000 for heavy duty and $65,000 for light duty. Amortizing capital costs and dividing by about 15,000 inspections per lane per year produced an estimated cost of about $10 for heavy duty vehicles and $6 for light duty vehicles.[175] In the Cairo Air Improvement Project, the comparable estimate for light duty vehicles was $8.[176]

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[174] Agbar, op. cit., p. 66.
[175] Weaver, C. and L. Chan, op. cit., p. 87-89. It was beyond the scope of this report to reconcile these capital costs with those cited earlier for Mexico City.
[176] David Fratt, personal communication. For information on the Cairo Air Improvement Project, see <www.usaid-eg.org/detail.asp?id=10#air>.

The Sri Lanka study estimated a second cost component for oversight and management. Cost elements here included creation of a centralized I/M database, quality assurance, auditing, assessment, and the actual production of I/M stickers. This cost component was estimated at about $3 per vehicle inspected. This is similar in magnitude to charges in Mexico City, where each test center pays the government about $2 per certificate issued. These charges cover printing and were intended to provide funds to cover program supervision and auditing. However, in recent years, this money has gone into general funds, proving that one can try to dedicate user fees to benefit the user, but there are no guarantees.[177]

Full-cost pricing is widely advocated for many public services, and I/M is no exception. General agreement exists among I/M experts that inspection fees should not just recover the basic costs of operating the inspection facilities, but should also cover the costs of the oversight of those facilities, including the data management system that links them to together and periodic auditing. An Asian Development Bank study concluded:

> *Policymakers must assure that an adequate fee structure is developed in which the affected vehicle owners pay the full costs of the I/M program, including the costs of auditing and overseeing the program by government or private auditors.*[178]

In addition, some experts argue that inspection fees should fund a roadside inspections or air quality monitoring. Given various equipment and other costs that do not vary greatly across countries (unlike labor costs, for instance), most experts expect I/M fees to be in the $10 to $20 range.[179]

Often the issue of "ability to pay" arises in the pricing of power, water, and other essential public services. This concern exists with regard to I/M fees as well. For example, Egyptian officials balked at a fee based on the $8 (per inspection) cost of new, dedicated test-only I/M facilities and chose instead an option using existing government buildings and a low-tech approach that would cost less than $1 per inspection.[180]
In effect, experts advocate fees for developing countries that are not too different from fees in industrialized countries, yet incomes in the developing world are far lower. This may seem impractical, however, unlike other public services, there is a process of self-selection that may make the ability-to-pay issue manageable. If a person has sufficient income to own a vehicle, he or she has likely entered a high enough income bracket to afford to pay an I/M fee.[181] Some I/M firms use a rule-of-thumb: the inspection fee should not cost more than one tank of gas or about 40 liters of fuel.[182] In other words, an extra tank of gas once of twice a year is within the ability-to-pay of a vehicle owner, even in the developing world.

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177 Fortunately, basic supervision and auditing has not suffered heavily to date (John Rogers, personal communication).
178 Asian Development Bank, op. cit., 2003, p. 16.
179 Frank Dursbeck, personal communication.
180 David Fratt, personal communication.
181 Frank Dursbeck, personal communication.
182 Fred Herren and Jeffrey Vogt, personal communications.

As an added consideration, if the I/M program induces better maintenance of vehicles, the fuel savings can be substantial and can offset the inspection fee. As previously noted, estimates of fuel savings range from five to ten percent. One study for Jakarta estimated fuel savings of 60 liters per year for the average driver.[183] If a corrupt I/M system is already in place, vehicle owners may already be paying substantial amounts to game the system. The Nepal study cited earlier concluded:

> *At NRs. [Nepalese rupees] 35 per emissions test, the vehicle owners in Kathmandu Valley contributed over NRs 2 million to public revenues in 2002-03. It is conservatively estimated that the pre-inspection 'vehicle-adjustment-and-temporary-repair' industry in Kathmandu Valley nets about 8 to 10 times this amount to help vehicles pass emissions tests, so that they qualify for a Green Sticker. This service includes reverting the vehicles back to their pre-inspection condition after they receive the Green Sticker. These adjustments and repairs do not have any lasting effect on reducing emissions. The Kathmandu Valley I/M Program is a costly regulatory burden on the driving public in Kathmandu Valley and is in need of a major overhaul.*[184]

Policymakers also have options for addressing an ability-to-pay issue. In some circumstances, government could provide the land for I/M facilities (maintaining ownership as described in Chapter 2 while bidding out construction and operation).[185] Indian cities such as Delhi and Hyderabad have made this type of offer.[186] Price controls on inspection fees are another option, but could undermine the financial integrity of the whole I/M system. There is always the option subsidizing I/M operations out of general tax revenues or dedicated taxes (e.g., a fuel tax).

Ability-to-pay issues can also arise over the cost of repairs. U.S. data indicates that high-emitting vehicles are most likely to be owned by low-income drivers, and there is no reason to expect a greatly different situation in the developing world. States in the U.S. can offer a waiver of I/M standards if the costs of repair are too high: the 1990 Clean Air Act Amendments set a minimum waiver limit of $450. This can result in partial repairs or no repairs if the driver is unwilling or unable to meet the standard.[187] A similar program exists in British Columbia.

This report considers it an essential best practice for policymakers to set inspection fees at levels that will support costs of the recommended design of I/M programs set forth here, i.e., privately-operated test-only centers with strong oversight and quality assurance components.[188] Although the resulting fees may appear high, they are likely to be affordable to the citizens that own vehicles. Subsidies of initial capital costs for

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183 Stenbeck, op. cit., p. 9.
184 Faiz, A. et al, op. cit., 2004, pp. 6-7.
185 Kolke, 2002, op. cit., p. 5.
186 Rajat Nandi, personal communication.
187 NAS, p. 72.
188 The USEPA has prepared a detailed spreadsheet program (available from author) for estimating the cost of conducting an I/M program using a test-only or test-and-repair design. The spreadsheet takes into account a wide range of factors as inputs, including land costs, labor costs, building costs, etc.

land or facilities could be considered but inspection fees absolutely must cover ongoing operating costs.[189]

5.2. Managerial and Technical Resources: Ensuring Capacity

Policymakers must ensure that all the actors in an I/M program have the capacity to carry out their roles—this maxim is widely endorsed in the I/M literature.[190] Assuming adoption of the best practice of test-only facilities (rather than test and repair), policymakers can engage a competent private company to help bring the needed managerial and technical capacity to the various aspects of the inspection process.

Perhaps the biggest challenge facing policymakers is building the capacity to provide the "M"—the maintenance and repairs for vehicles that fail I/M tests. The vehicle service sector in developing countries typically consists of some large dealerships, small repair shops, and even one-man roadside repair operations. Inspections alone accomplish nothing. Emissions decrease only if this sector is capable of performing its job. Competent repair shops can also reduce the potential for the "ping-pong" effect noted in Chapter 2 (i.e., drivers needing to bounce back and forth between inspection station and repair shop). Thus, competent repairs promote public support for the I/M program. Experts agree that this area is often neglected. As one observed:

> *Even in industrialized countries, the supply of adequately trained mechanics lags demand. My experience in the developing world has been that the capacity to effectively repair vehicles for emissions control is virtually non-existent. The reality is that a mechanic with limited literacy skills, no electronic tools, no manuals, and training directed only at performance certainly cannot repair a Euro II vehicle and probably cannot repair an uncontrolled technology vehicle to maximize both performance and emissions simultaneously. In the absence of adequate repair capability, motorists will resort to fraud in order to continue driving the vehicle.*[191]

There are plenty of examples of efforts to provide the vehicle service sector with sufficient training and equipment to properly repair vehicles. In Sri Lanka, USAID conducted a major training program. In the Cairo Air Improvement Project (CAIP) noted earlier, USAID and Egyptian officials invested substantial resources in training gas station personnel along with 800 roadside mechanics in both emission testing and tune-ups under its "Quick Start" program.[192] CAIP complemented this effort with a public awareness campaign involving roadside testing of 58,000 vehicles, mostly pulled over at random. Vehicles that did not meet I/M standards were sent to gas stations in the "Quick

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[189] Another option related to fees concerns re-inspection: should drivers be charged for every inspection conducted; or, should the re-inspection of a vehicle that failed a first inspection be subsidized? The latter policy may encourage compliance. In Costa Rica, the I/M operator allowed unlimited free re-inspections for the first two years of operation, later tightening this to one free re-inspection within 30 days of the initial inspection (Jon Bickel, personal communication).

[190] Asian Development Bank, op. cit.; Global Initiative on Transport Emissions, op. cit.

[191] Gene Tierney, personal communication.

[192] David Fratt, personal communication. CAIP encountered what is perhaps the most egregious example of "lack of capacity" when it found that inspectors in Cairo would have to use battery-powered emission analyzers because of unreliable electricity supply.

Start" program. Indian automotive manufacturers also launched a capacity-building campaign for the service sector as part of its effort to strengthen I/M (see Chapter 4 and Appendix C). As noted earlier, when Swisscontact committed to promote I/M systems in Central America, it undertook a comprehensive program of capacity building in the private (and public) sectors (see Box 5-1). Missing, however, in the I/M literature is analysis of what "M" capacity-building efforts work best—a topic beyond the scope of this report but worthy of donor attention.

The need for capacity-building in the public sector is also strong due to the typically large turnover of staff when political power changes hand and by the low levels of technical competence at the medium to high bureaucratic levels. There are many examples

BOX 5-1. SWISSCONTACT'S CAPACITY-BUILDING PROGRAM IN CENTRAL AMERICA.

In 1993, the development agency of Switzerland began a 10-year program to improve air quality in the Central American countries of Costa Rica, Guatemala, Honduras, El Salvador, Nicaragua, and Panama. Central to that program was promotion of I/M systems and related capacity-building. Targets included:

- Transport and environment agencies that received technical and policy training via seminars, tours abroad, and consulting services.
- Vehicle mechanics and mechanic instructors that received training in repair and maintenance, particularly for advanced engines and pollution control equipment.
- Drivers that were exposed to advertising campaigns and events intended to elevate awareness of I/M issues and their future responsibilities.

Source: Swisscontact, *Clean Air Project: Report of Activities 1993-2002,* 2003.

of donor organizations building capacity in the public sector. The Clean Air Initiative supported by multiple donors is building I/M capacity in countries in Asia, Africa, and Latin America.[193] These efforts are crucial to spreading best practices to policymakers launching or strengthening I/M programs.

There are no guarantees of success in any capacity-building exercise. When the European Commission made a major effort in Almaty, Kazakhstan, noted earlier, it did not succeed in catalyzing the government to strengthen its moribund I/M system.[194]

Finally, policymakers must ensure that they have sufficient capacity to carry out their own roles. Engaging independent experts is a demonstrated method of having access to the needed technical knowledge, and donors can provide the resources. The consultant study for Sri Lanka noted earlier is a good example of the in-depth technical analysis that can be brought to bear. The consultant study for Surabaya, Indonesia noted earlier provided draft terms of reference for a bidding procedure and illustrates how experts can assist policymakers in that crucial activity.

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[193] See <www.cleanairnet.org/cai/1403/channel.html>.
[194] Lennart Erlandsson, personal experience.

With regard to the service sector, vehicle manufacturers are often willing to provide training and policymakers should seek their involvement capacity-building in the service sector. SIAM plays this role in India. Policymakers should also work with manufacturers to address quality assurance for spare parts.

5.3. Political Resources: Ensuring Popular Support

Popular support is a resource that policymakers must also cultivate if an I/M program is to succeed. This is distinct from the level of compliance discussed in Chapter 4, which

concerns whether an individual driver conforms to the rules. Here the focus is on collective political support for the whole I/M program. In its early stages, a phased-in I/M program may target only one or two classes of vehicles, and large numbers of drivers may not be affected. But gradually, more and more vehicles will be required to pass inspection, and standards will be tightened. Broad public support is critical at all stages. Even if only a small number of vehicles is targeted at the outset, policymakers may find strong opposition by a powerful interest group (e.g., truck drivers, bus drivers, or taxi drivers). For example, in Central America, private bus companies are often organized as cooperatives with many small owners of just one to three buses. They form a powerful interest group to deal with.[195]

Experts agree that policymakers should build support in part by educating the public on the health benefits of an I/M program. If I/M is coupled with safety inspections, they can treat the environmental and safety aspects as a package deal and note the dual benefits. Environmental and public health NGOs should be enlisted in the effort. An Asian Development Bank study stated the need this way:

> *Public perceptions regarding the effectiveness and transparency of I/M systems will heavily influence the willingness of the general public to cooperate with I/M regimes. To ensure a positive public perception it is important that the public understand the public health need for the program and believe that it is fair and effective…. [P]olicymakers should develop a strong and ongoing public awareness component that routinely informs the public of the need for an I/M program, its achieved benefits and overall performance*[196]

In cultivating political support, policymakers should recognize that public opinion may diverge from scientific opinion. As noted earlier, studies indicate that visible smoke is far less dangerous than fine particulate matter emissions, and that the two are largely uncorrelated. However, policymakers may want to pursue both. As one expert noted:

> *In the eyes of the public, no I/M program is successful if smoke-belching vehicles stay on the road.*[197]

Policymakers can build support in the early stage of I/M policy design by conducting a dialogue among key stakeholders (relevant government agencies, police, vehicle

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[195] Jon Bickel, personal communication.
[196] Asian Development Bank, op. cit., 2003, p. 24.
[197] Jon Bickel, personal communication.

manufacturers, repair shops, consumer and environmental groups, media, etc.).[198] Best practice requires the ongoing education of citizens on the benefits of I/M programs to build and maintain political support.

[198] Asian Development Bank, op. cit., 2003, p. 15. Kolke, 2001, p. 10.

6. *SUMMARY OF BEST PRACTICES*

As noted in Chapter 1, a key message of this report is an emphasis on *how hard it is to implement an effective I/M program.* Policymakers should make a decision to launch (or strengthen) an I/M program only if fully cognizant of the challenges involved. Successful programs *can* reduce vehicle emissions in a cost-effective manner. Massive behavioral change is never easy, but it is *possible* with committed leadership, the right institutional design, and the right incentives. A threshold condition for even contemplating an I/M program is for senior government officials to commit to multiple years of strong leadership and capacity-building.

This chapter summarizes best practices from Chapters 2 to 5, highlighting first the handful of "essential" best practices that rise above the others in importance. Policymakers in the developing world should be wary of implementing I/M programs that do *not* incorporate these essential best practices. The second section presents other "ordinary" best practices that enhance program effectiveness. The final section summarizes recommendations to donors from Chapters 2 to 5.

6.1. Eight Essential Best Practices

Four of eight *essential best practices* concern "institutional design" questions from Chapter 2. The other four relate to the categories of test procedures and emission standards (Chapter 3), enforcement and compliance promotion (Chapter 4), and managing resources (Chapter 5).

Institutional Design

An I/M program should conduct inspections using "test-only" facilities. Policymakers must choose between a relatively small number of centralized or "test-only" facilities, and a relatively large number decentralized or "test-and-repair" facilities. Advantages of the former approach include the ability to spread costs over a high volume of inspections, and achieve a low cost per inspection. (Alternatively, test-only facilities can afford more costly, sophisticated test equipment by the ability to spread costs.) Oversight of the facilities by government is also relatively easy due to their small number.

Government should set the policy framework and provide overall management of the I/M program while private contractors perform the actual inspections. This conclusion likely will disturb those believe that every public service should be performed by a government employee. However, expert opinion is unified on the desirability of private firms performing this role under the oversight of a governmental body. In general, this conclusion is driven by the same reasoning that underlies the broader privatization movement affecting energy, water, transportation, and other sectors: many services of a public nature are best delivered by a private firm accountable to the government rather than by a state-owned entity that essentially holds a perpetual monopoly in providing the service. The latter organizational form often suffers from low technical competence and a general inability to punish poor performance or fraud at the individual employee level and the organizational level as a whole. A capital-starved public monopoly can be subject to budgetary pressures from external forces that threaten service quality and its ability to generate revenue, even if it is otherwise capable of providing that service in a financially viable manner.

Policymakers should exert strong oversight and institute a quality assurance (QA) program for the I/M program. There is no escaping the need to "inspect the inspectors." Effective oversight and QA is essential to deliver the actual emission reductions sought and help maintain public support for the program. Oversight and QA involve a set of highly technical tasks that can be performed by government (if the capacity exists) or contracting out in part.

Policymakers should implement I/M programs in a phased approach that allows learning, adaptation, and capacity building along the way. Ideally, I/M programs should begin with the vehicles that emit the most (due to their emission rates, high mileage, or both). A phase-in of stringency of emission standards should also be considered if standards would otherwise fail an unacceptably high percentage of vehicles or if capacity in the repair industry does not exist to repair vehicles to tighter standards.

Test Procedures and Emission Standards

Policymakers should set I/M emission standards based on statistics on the distribution of emission levels, analysis of what proper maintenance can achieve and how much it costs, and prudent judgment on what level of standards will command political support. The pollutants covered will vary for gas versus diesel engines (CO/HC/NOx versus PM/smoke/NOx). A very tough standard that many vehicles flunk could erode support, as could a very easy standard that made the I/M program appear ineffectual). When phasing-in standards, policymakers should set standards or "cut-points" so that 15 to 20 percent of vehicles fail. However, this rate could be higher or lower depending on technical and cost factors. As emission standards for new vehicles are tightened, policymakers should set standards for these vehicles that are appropriately stringent, reflecting newer technology and improved emissions performance.

Enforcement and Compliance Promotion

Policymakers should make I/M compliance a requirement for being able to operate a vehicle, and enforce this requirement with an effective, periodic vehicle registration system. This linkage is a powerful tool for promoting compliance with I/M requirements, and a similar linkage is recommended to safety inspections. Government records of vehicle ownership are a building block of a functioning society. Accurate tracking of the status and owners of vehicles can assist in urban planning, tax collection, accident and crime investigation, as well as air emission inventories and I/M compliance. Given these multiple benefits of periodic vehicle registration, policymakers should put in a foundation of periodic vehicle registration before or concurrent with the effort to launch or strengthen an I/M program.

Managing Resources

Policymakers should set inspection fees at levels that will support costs of the recommended design of I/M programs set forth here, i.e., privately operated test-only centers with strong oversight and quality assurance components. Although the resulting fees may appear high, they are likely to be affordable to the citizens that own vehicles. Subsidies of initial capital costs for land or fixed facilities could be considered but inspection fees absolutely must cover ongoing operating costs.

Policymakers should ensure that all the actors in an I/M program have the capacity to carry out their roles, paying special attention to the vehicle service sector. Policymakers often neglect the critical task of building capacity to provide the “M”–the maintenance and repairs for vehicles that fail I/M tests. Donors and vehicle manufacturers are often willing to provide training and policymakers should seek their involvement in capacity-building in the vehicle service sector.

6.2. Best Practices

Additional “ordinary” best practices fall in the same four categories noted above. All can improve I/M program effectiveness.

Institutional design

Policymakers should consider the following practices in engaging private contractors to assist in implementing I/M programs:

- In order to bring their expertise and capital, encourage international I/M firms to partner with local firms in the bidding process.
- Make awards to a single firm (rather than multiple firms) operating within a jurisdiction (i.e., state or metropolitan region). Encourage competition by making awards in more than one jurisdiction, and by ensuring that an incumbent firm does not have an unfair advantage when re-bidding a concession.
- Contract lengths should be seven years or longer.
- Provide for appropriate inflation-indexing or wage-indexing of inspection fees.
- Consider government ownership of land and buildings for test-only I/M centers, either at the outset or at the end of the first concession.
- Provide appropriate risk management contract provisions to account for the possibility of the actual number of inspections being far different from the forecast number.

National policymakers should establish an I/M policy framework; state and local governments should tailor some program details within this framework to address specific conditions within regions or cities. The I/M framework should be part of a larger policy framework that addresses vehicle emissions in an integrated manner. I/M program elements should account for new vehicle emission standards, equipment warranties, and fuel standards, all of which are typically set at the national level. Coordination improves I/M effectiveness.

Policymakers should integrate an I/M program with safety inspections. Safety problems pose risks of a similar magnitude as air pollution and deserve to be addressed with the same rigor. Government can achieve “economies of scope” in addressing both in an integrated way. The efficiencies will be manifest in shared costs for the two programs (e.g., land, facilities, staff) and in allowing drivers to get tested for both in a single trip.

Test Procedures and Emission Standards

Policymakers should base emission standards on fleet characterization studies. They should secure data on how many vehicles are plying the roads of a state or city, along with their types, ages, the quantities of pollutants they are emitting, and the number of miles they travel. This exercise is known as fleet characterization. In addition to aiding the process of setting standards, the data is essential to estimating total vehicle emissions and making decisions such as how many test facilities will be needed.

With regard to emission test procedures, policymakers should closely monitor the development and availability of PM meters in the next one to two years. As noted above, PM meters suitable for I/M programs are likely to become available in that time period. This could change dramatically what constitutes “best practices” in test procedures, especially for diesel trucks but potentially for 2&3 wheelers and automobiles as well. Until PM meters become available, policymakers should apply the following test procedures:

- **Specify no-load testing for 2&3 wheelers.** Policymakers should consider adding a “high idle” and/or opacity test to a simple idle test for 2&3 wheelers. Loaded test procedures are under development and should be considered when available.
- **Specify no-load testing for cars that are not equipped with catalytic converters, and loaded testing for cars with this emission control technology.** Using dynamometers, test facility staff, even those with low technical skill, are capable of conducting short steady-state/single-load tests, achieving acceptable accuracy in measurement and holding costs down. Transient loaded tests (those that run the vehicle through simulated driving cycles and loads) are longer and more accurate, but are costlier and require relatively skilled staff. These tests might be deferred in developing countries until conditions warrant.
- **Specify snap-idle testing using the Society of Automotive Engineers (SAE) J1667 method for commercial diesel vehicles.** Some policymakers have opted for more costly loaded testing, seeking greater accuracy and reduction of fraud, however, it is unclear whether the added costs are justified.

Policymakers should set the required frequency of inspections by balancing technical, economic, and political factors. Six months to two years is a reasonable range (with an option for a somewhat longer initial period for new cars in which emissions performance is not expected to deteriorate much in the early years). Policymakers should examine how fast vehicle emission performance deteriorates, and how this varies with age or vehicle type. Economic factors include number of test centers and lanes needed which is a function, in part, of frequency. Political factors include what frequency drivers are willing to tolerate without undermining support for the program.

Enforcement and Compliance Promotion

Policymakers should apply common sense in design and location of I/M stickers that indicate compliance. Stickers must be resistant to forgery and to degradation in sunlight. I/M stickers should be large enough so police can determine the expiration date at a short distance. Color coding can assist in conveying the date. A rule should determine the location of stickers (e.g. front or rear windshield). For 2&3 wheelers without windscreens, I/M stickers should be placed on a designated spot on the frame. Where I/M is required for vehicle registration, a sticker indicating registration makes a separate I/M sticker unnecessary.

Roadside emission testing is a useful enforcement tool to complement others. The primary function of roadside testing should be the identification of gross polluting vehicles. Policymakers should consider the option of using private contractors to conduct such testing with police accompaniment.

Policymakers should devote appropriate resources to public awareness campaigns to promote compliance. Awareness campaigns should educate the public on I/M requirements, including linkage to vehicle registration (if applicable). Campaigns can also tout the public benefits of I/M (in terms of reduce air pollution and better health) or the private benefit. A well-tuned vehicle typically burns less fuel and saves money. Proper adjustment of an engine can improve fuel efficiency by 5 to 15 percent.

Managing Resources

Policymakers should ensure the ongoing education of citizens on the benefits of I/M programs to build and maintain political support. Environmental and public health officials and NGOs should be enlisted in this effort.

6.3. Recommendations to Donors

Donors are already very active in the I/M arena in various countries. Many of the recommendations below address “public goods” that donors can create through research and analysis.

Program Evaluation

Donors should consider funding more rigorous program evaluations along with the data collection efforts that would support them. Policymakers need better data on air quality benefits and on cost-effectiveness of various policy tools for reducing air pollution.

Institutional Design

Donors should consider funding the creation model tender (or Request for Proposal) that policymakers could then tailor to their circumstances. Also useful would be model policy guidelines on conducting the bidding process, selecting the contractor, and implementing an I/M contract.

Where donors have leverage with policymakers, they should use it to ensure that the bidding process is fair, transparent, and effective.

Donors should support exploration of "one-stop" government facilities for emission and safety inspections as well as vehicle registration. This approach deserves support given its promise to improve air quality, safety, and vehicle registration.

Test Procedures and Emission Standards

Donors should support the development of I/M test procedures and standards for PM that take advantage of PM meters that will soon become commercially available. Currently, policymakers lack resilient and reliable instruments for measuring PM in an I/M setting, and have relied on a proxy: measurements of smoke opacity. This is likely to change in the next one to two years, and donors should gear up for the data gathering and analysis that will be necessary to refine test procedures and establish cut-points for diesel engines (at a minimum) and potentially gasoline engines as well.

Managing Resources

Donors should assist policymakers in ensuring that they have sufficient capacity to carry out their own roles. Engaging independent experts is a demonstrated method of having access to the needed technical knowledge.

APPENDIX A. AIR QUALITY BENEFITS

Ideally policymakers should know the cost-effectiveness of different air pollution control options as they design strategies to improve air quality. Policymakers should have reasonable estimates of how much vehicle pollution will decrease as a result of I/M and how much it will cost. This would allow comparison with other options, guiding the stringency, mix, and sequencing of different control options.

Unfortunately, there is a paucity of good estimates for the air quality impact of I/M systems. In part this reflects the fact that quantification of emissions from non-point sources (and measures to reduce them) is always difficult. With respect to the developing world, there have been few programs worth studying because of the low success rate to date. Nonetheless, this is an area where donors should invest some resources in better informing policymakers what they can expect from an I/M program.

Existing studies suggest that a successful I/M program can decrease an automobile fleet's annual emissions of HC or CO by as little as a few percentage points or as much as 10 to 20 percent. NOx emission reductions are likely to be less than ten percent. Cumulatively over several years, an I/M program can reduce HC or CO emissions by over a third and NOx emissions by ten percent. These estimates should be treated as a starting point for better estimates to guide developing countries.

A.1.   Estimates from the United States

Some detailed study of I/M impacts has occurred in the United States where there has been some pressure to examine actual impacts compared to the impacts estimated when the programs were designed. Given controversies over I/M effectiveness that surfaced in the mid-1990s, the National Research Council (NRC) conducted a review of I/M programs for cars and light trucks, including studies of the effects on vehicle emissions.[199]

The NRC examined the official USEPA models used to forecast I/M impacts and compared some of the early forecasts with studies of I/M impacts based on actual emissions data. The NRC concluded actual air pollution reductions ranged from zero to one-half of what the early models indicated, with lower figures associated with test-and-repair centers using no-load testing, and higher figures associated with test-only centers using loaded testing. Later versions of the USEPA models have produced lower estimates. The NRC's review of state studies of I/M impacts for cars showed some clustering of results:[200]

- Three recent studies of I/M impacts in Arizona resulted in fairly consistent estimates of HC reductions (13-14 percent) and NOx reductions (7-8 percent).
- A recent California study produced similar estimates of a 17 percent HC reduction and a 9 percent NOx reduction.

[199] National Research Council, *Evaluating Vehicle Emissions Inspections and Maintenance Programs*. Washington DC: National Academy Press, 2001.
[200] Estimates are typically annual figures. Op.cit., pp. 76-89.

- Several studies of CO reductions in Colorado produced a large range of estimates: 4-17 percent.
- Two studies for Georgia found CO reductions of 7-11 percent.

Other studies have cited a range of 5 to 30 percent for CO and HC reductions, and up to 10 percent for NOx reductions.[201]

The NRC noted the need for much better data to evaluate I/M programs, and emphasized its overall endorsement of I/M activities:

> *"Despite the smaller-than-forecasted benefits from I/M programs, the [NRC] still sees a great need for programs that repair or eliminate high-emissions vehicles… from the fleet, given the major influence of this small fraction of the fleet on total emissions and air quality."*[202]

A.2. Estimates from British Columbia

British Columbia (Canada) launched an I/M program in 1992 called AirCare. A private contractor operates the program and regularly conducts detailed scientific reviews to assess overall program effectiveness and report on total reductions in vehicle emissions attributed to the program. The AirCare program is considered by many to have the most in-depth technical reviews in the I/M industry.[203] A 2001 study of the first eight years of operation of the program produced the following estimates of reductions of three major pollutants from the automobile fleet:

Pollutant	*Annual Decrease in Any Given year*	*Cumulative Reduction 1992-2001*
HC	3%-10%	34%
CO	3%-9%	38%
NOx	1%-2%	10%

A.3. Estimates from Mexico City and Santiago

Mexico City undertook a host of actions to reduce air pollution beginning in the late 1980s. The actions included the I/M program described in this report, as well as tightened standards for new vehicles and industrial sources. The overall program has been successful in decreasing concentrations of key pollutants during the period 1990 to 2001 including PM-10, CO, NOx, ozone, as along with lead and SO2.[204] Some remote sensing has been done periodically which has shown a marked drop in vehicle emissions but the conclusions are not definitive.[205]

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201 MECA, Clean Air Facts, undated.

202 Op. cit., pp. 2-3. The NRC noted that the disparity between modeled and actual impact is related to a regulatory disincentive for states (implementing I/M programs under the national Clean Air Act) to be over-optimistic in forecasting I/M-related emission reductions.

203 Michael Walsh, personal communication. See <www.aircare.ca>. Click on "News & Publications", then on "Reports & Public Info."

204 Menedez, Fernando, 2002.

205 John Rogers, personal communication.

I/M was first introduced in Chile in 1977 but was not very effective. In 1994 the program was strengthened and is viewed now as relatively effective. With this step and others beginning in the late 1980s, Santiago, Chile, began to make progress on reducing PM levels. From 1990 to 2001, PM levels dropped from more than 100 $\mu g/m^2$ to less 65 $\mu g/m^2$. The I/M program undoubtedly contributed to this along with retirement of 3,000 highly polluting buses and controls on stationary sources.[206]

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[206] Kolke, 2002, op. cit., p. 17-18.

APPENDIX B. CASE STUDY OF MEXICO CITY

Air pollution is a chronic problem in Mexico City, one of the largest cities in the world with 20 million people. Ozone levels are often very high, exacerbated by Mexico City's high altitude and susceptibility to severe thermal inversions in the winter (having a bowl-like geography similar to Los Angeles). More than 3 million cars and 30,000 diesel vehicles are prime culprits in making the city's air unhealthy.

For more than 15 years, Mexico City has implemented an I/M program. It is not only among the longest running programs, but it is also regarded as one of the most successful in the developing world. The primary reason for success is that program has evolved. It has discarded what didn't work; it has discovered problems and implemented solutions. A brief history of Mexico City's I/M program for cars illustrates this key attribute.

B.1. I/M for Automobiles: A Brief History

In 1988 Mexico City launched an I/M program for automobiles for vehicles of a certain age. Initially, the city used publicly-operated test-only centers to conduct the inspections, but soon authorized test-and-repair centers as well, thus allowing a "hybrid" system to develop. In 1991 Mexico City authorized privately-operated test centers and, within two years, 24 were in operation. At the same time, 500 test-and-repair centers had been licensed and the public test-only centers had been phased out due to lobbying by private garages.

Problems with the performance of the test-and-repair centers developed quickly. These centers began competing for business by lowering the price of inspections and giving false "passes" to drivers. No effective oversight system was in place to detect the cheating. Soon an estimated 50 percent of vehicles inspected in test-and-repair centers were getting I/M certificates irrespective of their emissions.

Responding to these widely perceived problems, the government completely overhauled the I/M program in 1996, eliminating the test-and-repair centers and increasing the number of test-only centers. A much stronger system of oversight and quality assurance was also instituted and the number of automobiles failing the test more than doubled.

In 1997 Mexico City moved to loaded (dynamometer based) testing for automobiles using the acceleration simulation mode. This change led to more accurate, replicable test results and allowed tighter emission standards. Loaded testing also allowed policymakers to tackle the "lean and late" method of cheating. In 2000 Mexico City added NOx standards to the existing CO and HC standards. As noted in Chapter 3, NOx testing can detect the "lean and late" syndrome and it has proved effective in Mexico City. The government found, however, that the NOx standard led to such a high failure rate that additional fine-tuning was needed. Rather than explicitly change the standard, the city modified the testing protocol to allow more vehicles to pass.

Throughout this period, Mexico City also found that it needed to license additional test-only centers in an effort to balance public convenience with the profitability of the centers. Too few centers led to long lines and irate drivers. Too many centers led to fee revenues being spread too thin, creating incentives to compete for business that could lead to fraud. The need for oversight and auditing never disappeared, but “fat and happy” test centers were less likely to cheat.

B.2. Best Practices as Illustrated by Mexico City

Mexico City’s successful I/M program demonstrates the importance of many of best practices cited in this report. The sections below examine these practices using the same framework as the body of the report: institutional design, test procedures and emission standards, compliance promotion and enforcement, and managing resources.

B.2.1. Institutional Design

Mexico City is one of the few jurisdictions to have tried both test-only and test-and-repair designs. Its experience, noted above, provides compelling evidence of the superiority of the test-only approach. Mexico City also had brief experience with publicly operated test-only centers before switching to privately operated centers, but no concrete lessons can be drawn in this instance.

Mexico City has instilled a system of oversight and quality assurance that should serve as a role model for all developing countries. Here are some of the key elements:

- Within the test-only centers, there is centralized operation. Staff in a central room see the emission test results while the employee in the test lane conducting the test is “blind” to the results, thus discouraging any tampering with the test equipment or vehicle or otherwise manipulating the test.
- Tests are computer controlled, and all data are recorded electronically. There is no paper recordkeeping that invites fraud or inadvertent error.
- Test centers relay data to a central authority in real time, as generated. Elaborate electronic security measures discourage data tampering.
- The data allow remote electronic auditing of test centers and even of individual employees.
- Remote video surveillance and recording provides an additional check on performance.
- Independent and frequent calibration audits of test centers ensures that test equipment is properly maintained and provides accurate emission measurements.

A final aspect of institutional design used by Mexico City is a careful and strategic phase-in of I/M, coupled with constant evaluation and evolution. This is illustrated in many ways:

- Mexico City has always focused on cars and light-duty gasoline-powered trucks. This priority reflects the fact that 2&3 wheelers make up a very small portion of the fleet and, initially, there were few intra-city diesel trucks.
- Mexico City briefly brought 2&3 wheelers into the I/M program in 1996-1997. Policymakers found the no-load test of little value and dropped the idea, showing the system can experiment, adapt, and evolve.

- The use of dynamometers was phased-in, focusing first in 1993 on high-mileage commercial vehicles (taxis and light trucks). In 1996 it was extended to private cars as well.[207]
- The emission standards were phased-in with respect to their stringency, growing tighter over time and ultimately prohibiting, in effect, some older cars from operating in Mexico City (see Box B-1).

BOX B-1. MEXICO CITY'S PHASE-IN OF TIGHTER STANDARDS FOR CO

Mexico City gradually tightened both CO and HC standards in the 1990s, putting more pressure on older vehicles in particular. The progression of the CO standard for automobiles is shown below.

	CO Standard for Automobiles (%)			
Model Year	*1994*	*1996*	*July 1996*	*1999*
1979 and earlier	6.0	4.0	3.5	3.0
1980—1986	4.0	3.5	3.5	3.0
1987—1990	3.0	2.5	3.0	3.0
1991—1993	3.0	2.5	2.0	2.0
1994 and later	2.0	1.0	1.0	2.0

Source: World Bank Energy Sector Management Assistance Programme, *Mexican Energy Environment Review*, May 2001, p. 64. Note: The table omits "One" and "Zero" classifications.

B.2.2. Test Procedures and Emission Standards

Mexico City has generated an ongoing fleet characterization because of its computerized record-keeping. Accurate records of emissions, vehicle type, age, etc. allow policymakers to set cut-points that put pressure on drivers to maintain their vehicles while not leading so many cars to fail that the program loses public support.

In adopting testing procedures, Mexico City has been a pioneer. By adopting a NOx standard and using loaded testing, policymakers have more accurately measured and eliminated automobile emissions "lean and late" manipulation.[208] Currently Mexico City requires inspection every 6 months, up from its original requirement of once a year.

B.2.3. Compliance Promotion and Enforcement

Mexico City does not link vehicle registration to I/M status, thus not conforming to what this report labels an essential best practice (and proving that there is an exception to every rule). The I/M program seems to have an embedded a culture of compliance through the threat of police action alone. Mexico City requires highly visible windshield stickers, and sets high fines for not displaying the sticker. This combination has created a dynamic that encourages compliance despite some degree of police corruption. Police

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[207] Lopez, Alejandro, Paper presented to TRB Economic Development Conference, May 5-7, 2002, pp.8-9.
[208] For a detailed history of tests and standards, see MEER, pp. 55-65.

inclined to solicit bribes see an avenue for making money because they know that the "opportunity cost" for drivers is high and they can extract large bribes to ignore a vehicle without an I/M sticker. Drivers know this and it leads many to comply rather than face the possibility of having to pay multiple bribes.[209]

In the late 1990's, perceptions of traffic corruption led Mexico City to take enforcement responsibility away from the traffic police and give it instead to a new "Ecological Police" unit. This created a noticeable drop in compliance of about 700,000 vehicles.[210]

Mexico City does not use roadside emission checks in enforcement, in contrast to many other jurisdictions. Policymakers have concluded that oversight is extremely difficult and the portable testing equipment used gives too much discretion to the technician applying the test.

Safety and emissions inspections are not combined in Mexico City. A safety inspection system for commercial vehicles pre-dated emissions testing, but it was highly corrupt. Policymakers chose not to risk "contaminating" the I/M program by integrating it with the safety inspection system.[211]

B.2.4. Managing Resources

Mexico City has demonstrated best practices in creating financially viable, privatized test centers funded by a reliable stream of inspection fees that result from an effective compliance scheme. This has allowed a steady increase over the years in the number of test centers (roughly tripling in the 1990's) and in the sophistication of the test equipment and associated hardware and software. It is frankly difficult to imagine this happening within a public sector budgeting process.

Policymakers have maintained a fairly high level of public support for the I/M program by reacting to, and fixing, problems. Public support fell sharply in the early 1990's when test-and-repair centers allowed a high level of fraud, but Mexico City eliminated those centers, taking some political heat from these businesses in the process.

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[209] The fine for automobiles caught without a sticker is about \$80; the going rate for a bribe is about \$40. John Rogers, personal communication.
[210] John Rogers, personal communication.
[211] John Rogers, personal communication.

APPENDIX C. CASE STUDY OF DELHI

Delhi, like all major Indian cities, has severe air quality problems, and the transport sector is a major factor. In addition to cars and diesel trucks and buses, large numbers of two- and three-wheel vehicles ply the streets of Indian cities, many with aging two-stroke engines with high emissions. Two-stroke scooters are the "mini-vans" for many middle class Indian families, carrying up to five passengers.[212]

There appear to be more in-depth studies of the Indian I/M system than for any other developing country. These studies, commissioned by government, donors, or NGOs, all the reach the same conclusion: for the most part, the program has failed to control emissions from in-use vehicles. The Appendix is based largely on these studies and the personal experience of the authors.[213]

C.1. I/M in India: An Overview

India instituted a national I/M program in 1990. Commercial vehicles (trucks, buses, and taxis) are covered under the Inspection and Certification (I&C) program which aims to ensure both emissions control and safety. Private automobiles and 2&3 wheelers are covered under the Pollution Under Control (PUC) program which aims to control emissions only. Both programs are plagued by poor quality personnel and test equipment, low compliance rates, and corruption. Despite these widely acknowledged failures and despite the many calls for reform, the programs have barely changed since their inception. This inability to adapt or evolve in the face of obvious problems is a problem in itself.

A rough estimate from a 2002 study suggests that no more than 15 percent of drivers get a PUC test, and those that do can easily pass the test without truly controlling their emissions.[214] Currently, the Delhi Transport Department estimates a compliance level of about 40 percent[215] with modest growth in recent years due largely to enforcement drives. Good estimates are hard to obtain for several reasons including the lack of good fleet data. There is little doubt that many drivers buy a certificate without ever being tested or simply ignore the PUC requirements altogether. The Transport Department also estimates that between 50 to 70 percent of commercial vehicles report for I&C tests.[216] However, the I&C program appears blatantly corrupt and ineffectual.[217]

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[212] Five appears to be the absolute maximum with the father driving, one child straddling the scooter in front of him, a second child sitting behind, and the mother sitting sidesaddle on the very back with an infant in her arms.

[213] John Rogers, 2002, op. cit. TERI, *Regulatory and Management Options for Inspection and Maintenance Centres*, New Delhi: Tata Energy Research Institute, 2002. Erlandsson, L. and M. Walsh, *Motor Vehicle Inspection in the National Capitol Area (NCR) of India: A Plan for Progress*, prepared for the Center for Science and Environment, March 7, 2003. For most of 1999, the author was affiliated with the Tata Energy Research Institute. He devoted substantial time working with the Society of Indian Automobile Manufacturers in their efforts to strengthen I/M programs in India.

[214] John Rogers, 2002, op. cit.

[215] Society of Indian Automobile Manufacturers, personal communication.

[216] Society of Indian Automobile Manufacturers, personal communication.

[217] Rogers, John, 2002, op. cit.

A growing awareness of Delhi's severe air pollution problems led to some bold steps in the areas of tighter standards for new vehicles, forced retirement of older vehicles, reductions in lead and sulfur in conventional fuels, and mandatory switches to CNG in buses and some taxis. However, the PUC and I&C systems have been highly resistant to change. NGOs such as TERI[218] and the Center for Science and the Environment have advocated reforms for many years. TERI's diagnosis concluded:

> *[T]he current vehicle inspection system in India is ineffective….The inspectors are largely unskilled; the procedure for inspection is discretionary; and the inspection centers are ill-equipped to carry out proper inspection. Finally, there is no mechanism for auditing the performance of these centres. Therefore, there is need for an effective institutional and regulatory framework for managing inspection centres in India.*[219]

Starting in the late 1990s, the Society of Indian Automobile Manufacturers (SIAM) began to take steps to try to improve the PUC program. This trade association saw some of its private interests and the public interest converge in more effective I/M programs. SIAM staged a series of I/M camps as described in Chapter 4. It engaged in various capacity-building exercises and has piloted an approach to improve quality assurance and data management (see Section C.2.3 below).

The momentum for change is now quite strong due in part to national government endorsement in 2003 of the recommendations of body of experts known as the Mashelkar Committee.[220] Among a multitude of conclusions on vehicle and fuel policies, the Mashelkar Committee called for a series of steps to strengthen I/M programs in India, many of which would be consistent with the best practices described in this report (see concluding section).

C.2. Best Practices Absent in India

Many of the best practices cited in this report are absent in India. The sections below examine actual practices in India using the same framework as the body of the report: institutional design, test procedures and emission standards, compliance promotion and enforcement, and managing resources.

C.2.1. Institutional Design

India has blurred the line between "test-only" and "test-and-repair" designs in its approach to authorizing PUC test centers. Any repair shop or gasoline station can become a PUC testing center if it owns an emission analyzer and has a qualified mechanic. Officially, these centers do testing only, but in practice they typically provide maintenance as well to help the vehicle pass the test legitimately, or they perform "adjustments" to pass the test fraudulently. Therefore, in practice the PUC centers function more as "test-and-repair" centers. Indeed, it is common practice for the tester to

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218 Formerly Tata Energy Research Institute, now The Energy and Resources Institute (TERI).

219 TERI, Sustainable Transport Projects in Large Indian Cities, I/M report summary Available at: <www.teriin.org/urban/stplic.htm>. Full report Available at: <www.teriin.org/reports/rep172/rep172.pdf>.

220 Government of India, Report of the Expert Committee on Auto Fuel Policy, August 2002.

adjust the air-fuel mixture on-the-spot to help pass the test (for a charge of 5 rupees on top of the test fee of 25 rupees).[221] Some PUC centers test gasoline vehicles only while other centers also conduct the more complex test (free-acceleration) required of diesel vehicles.

The Indian government places no limit on the number of authorized PUC test centers. In Delhi, their number has grown to over 400. This greatly complicates any efforts at oversight and quality assurance.

The design of the Inspection & Certification (I&C) program is also somewhat blurred. The Regional Transport Office (RTO) operates a single test-only center in Delhi (and a similar arrangement exists in other major cities). Although commercial vehicles must obtain their safety inspection in this center, they have the option of doing the emission testing there or in the test-and-repair PUC centers.

Sadly, evidence indicates that there is widespread and longstanding corruption in the publicly-operated test-only centers, with inspectors doing little more than extorting bribes and granting I&C certificates regardless of the vehicle condition. One examination of a sample of I&C certificates found that in most cases they contained no results of emission or safety inspections, suggesting that many certificates are sold without even pretending to conduct inspections. A bribe of several hundred rupees is all that is needed to get an I&C certificate.[222]

The Delhi test center appears to conduct some emission testing, but not consistently and its equipment is in no better shape than the PUC test centers. Surveying several Indian cities, one consultant found test equipment in such bad condition that little real testing for emissions or safety could be done even if corruption were not a problem.[223]

There is no effective system of oversight and quality assurance for the PUC or I&C systems. Deficient elements in India include:

- The person conducting the test is not “blind” to the test results. This allows him to tamper with the test equipment or vehicle or otherwise manipulate the test.
- Tests are manually operated, and data are recorded by hand. Paper record keeping invites fraud or inadvertent error.
- Test centers do not relay data to a central authority in paper or electronic form, and can easily issue fraudulent certificates.
- The lack of any centrally-collected data prohibits any remote auditing of test centers or individual employees.
- With numerous PUC test-and-repair centers, remote video surveillance is impossible.
- There are no independent calibration audits of test centers to ensure that test equipment is properly maintained and providing accurate emission measurements. Few centers even have a maintenance contract with the equipment supplier.

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221 Rogers, John, 2002, op. cit. p. 9.
222 Rogers, John, 2002, op. cit.
223 Rogers, John, 2002, op. cit., pp. 18-21.

In Delhi, four government employees have responsibility for inspecting over 400 PUC centers, checking that equipment is working and that technicians are authorized and following proper procedures.[224] However, this constitutes only a tiny step toward true oversight and QA. SIAM has piloted a more sophisticated approach that takes the first steps toward computerized data entry and record keeping. The Mashelkar Committee has endorsed its adoption.

In principle, there is a rational division of labor among the national and state governments: the national government sets minimum emission standards and equipment and test specifications, and state government implements the program with the option of setting stricter standards.

Another aspect of institutional design largely ignored in India is the phase-in of I/M, coupled with constant evaluation and evolution. Essentially India set up I/M systems for all vehicles at once, and set standards that have not tightened over time. It did not set up means of evaluating performance and adapting and evolving. The result has been a stagnant and ineffectual I/M system.

C.2.2. Test Procedures and Emission Standards

Fleet characterization has been a challenge for Indian policymakers due to the absence of two key inputs: annual vehicle registration information and accurate emissions data. Vehicles are registered just once when they are new or brought into a new jurisdiction. Ostensibly, they re-register after 15 years. The lack of accurate records of emissions, vehicle type, age, etc. means policymakers do not have a solid basis for revising cut-points to put pressure on drivers to maintain their vehicles. Efforts by SIAM, USAID, and others described in the preceding chapters should result in better data, but they are an inferior substitute for the kind of ongoing data collection and analysis seen in other countries.

With regard to test procedures, Delhi and other Indian cities have used the most common no-load tests from the outset: idle emission testing for gasoline vehicles and snap acceleration tests for diesel vehicles. There has been little interest among policymakers in moving toward loaded testing. In the case of PUC testing, the institutional design virtually precludes loaded testing–where would the capital come from for dynamometers? In the case of the I&C system, in theory, the government-operated test-only centers could switch to loaded testing; but that system appears trapped in a web of corruption.

Ironically, India has set the toughest emission standards in the world for new 2&3 wheelers, while its PUC standards for in-use 2&3 wheelers are among the weakest. The national government set PUC and I&C standards in 1986 and they were not revised or updated until 2004. For 18 years, three simple standards applied:

- 4.5 percent CO for 2&3 wheelers
- 3.0 percent CO for cars and other gasoline vehicles

[224] For example, technicians rarely use extension pipes in measuring 2/3 wheeler emissions when there is a likelihood of dilution of the exhaust stream (Rajat Nandi, personal communication).

- 65 opacity for all diesel vehicles measured in Hartridge Smoke Units (HSU)[225]

This is far from best practice. Most countries apply an HC standard to gasoline vehicles, and many distinguish cars with and without catalytic converters. Many have age brackets for different vehicles reflecting the fact that age and age-correlated technology will affect the emissions performance a given vehicle can attain. In 2004, I/M standards were tightened (see Box C-1). HC standards were also added, and some variation by and age and technology now applies.

BOX C-1. INDIA'S NEW I/M STANDARDS

Vehicle Type	*CO Standard (% at idle)*	*HC (ppm)*
2&3 Wheeler		
Before Mar. 31, 2000	4.5	9000
After Mar. 31, 2000 (2-stroke)	3.5	6000
After Mar. 31, 2000 (4-stroke)	3.5	4500
Automobiles		
With catalytic converters	0.5	750
Without catalytic converters	3.0	1500

Diesel Trucks: 65 HSU or 2.45 light absorption coefficient (1/m).
With OBD: check for correct operation of emissions control system (and OBD system)

Standards are also designated for vehicles run on compressed natural gas and liquefied petroleum gas. States now have the option of adding a lambda test for gasoline engines. The new standards also describe test procedures in more detail, including requiring a 15 minute warm-up period for gasoline engines and a 60 degree oil temperature for diesel engines.

Source: Central Motor Vehicles (First Amendment) Rule, 2004.

National guidelines require PUC and I&C inspection at least every 6 months. In what seems to be a symbolic act of stringency, Delhi has chosen to require PUC inspections every 3 months.

C.2.3. Compliance Promotion and Enforcement

The lack of annual vehicle registration takes away one important potential tool for compliance promotion: making vehicle registration contingent on holding a valid PUC certificate. Delhi (and Mumbai) have experimented with an alternative: making gasoline purchase contingent on holding a PUC certificate. This did not work well. The private sector filling stations saw no benefit to themselves of making their sales less plentiful and less convenient.

Delhi has also promoted compliance through I/M camps (see Box C-2). However, despite their good intentions, they have not been staged broadly enough or consistently enough to have an impact on compliance or actual emissions.

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225 For a discussion of opacity measured in percent versus HSU, see Weaver C. and L. Chan, op. cit., pp. 33-36.

BOX C-2. DELHI'S FIRST "I/M CAMP"

Recognizing low compliance levels with the PUC program, for many years, Indian vehicle manufacturers have promoted compliance by staging "pollution control camps" in major cities. These camps have provided free emission tests and a free PUC certificates to those vehicles that pass. Government has collaborated in this effort in various ways, including granting the manufacturers the authority to issue PUC certificates at the camps.

The companies also recognized that another obstacle to improving air quality in Indian cities is the lack of reliable data on the emissions from in-use vehicles. In attempting to estimate emission inventories, analysts inside and outside of government are hampered by poor data on fleet composition, emissions per kilometer, kilometers traveled, etc. Policy makers also lack data that could guide standard setting, enforcement efforts, or voluntary program design.

Recognizing the twin problems of a weak PUC program and unreliable data, the Society of Indian Automobile Manufacturers (SIAM) and TERI saw a way to make progress on both. As a starting point, the two organizations decided to focus on two-wheelers in Delhi. SIAM outlined a project that would: educate the public about the benefits of inspection and maintenance (I/M); conduct voluntary I/M camps; and gather extensive emission data. The project's goals were to:

- Reduce significantly emissions from the vehicles participating in the I/M camps.
- Contribute to greater citizen knowledge and awareness of the private and public benefits of I/M.
- Build up the human and institutional capacity of government, businesses, and NGOs to conduct I/M programs.
- Create a database to help provide:
    - better estimates of the total emissions from two-wheelers;
    - better estimates of the emissions reductions attributable to I/M programs, both voluntary and regulatory;
    - better estimates of the cost-effectiveness of such programs; and
    - a solid basis for design of future I/M programs and vehicle components.

With these goals outlined, SIAM launched a unique collaborative effort involving business, government, and non-governmental organizations (NGOs). SIAM recruited all seven two-wheeler manufacturers in India to participate. Other partners included: Automotive Research Association of India (ARAI), Central Pollution Control Board, the Delhi Government, Indian Oil Corporation, Development Alternatives, U.S Agency for International Development (USAID), and Oak Ridge National Laboratory (U.S.).

The I/M camps were formally launched on November 11, 1999 by Delhi's Chief Minister. During the following three weeks, I/M camps were conducted simultaneously at four prominent sites in different parts of Delhi. After six days of operations, and two days off, the mps would move to four new locations, thus a total of 12 locations were covered over three weeks. Newspaper and radio advertising, along with street banners and posters, attracted drivers to the camps.

Just as in past pollution check camps conducted by a single company, the I/M camps offered free emission tests to all participants and issued free PUC certificates to qualifying vehicles. However, the I/M camps added the following components:

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- Vehicles that initially did not pass the PUC emission test received free maintenance from company mechanics. First, a mechanic adjusted the carburetor and retested the vehicle. If it still did not pass the PUC test, the mechanic cleaned and adjusted the spark plug, cleaned the air filter, and retested again.
- Drivers had the opportunity to undergo a safety check as well, covering items such as brakes, clutch, lights, and tires.
- An unprecedented quantity of data was collected from each participating vehicle. Data collected included:
  - Driver demographics (age, occupation, driving habits, etc.).
  - Vehicle characteristics (type of vehicle, age, type and size of engine, etc.).
  - Measurements of CO and hydrocarbon (HC) emissions both before and after any maintenance performed.
  - Smoke opacity measurements were collected for a sample of two-wheelers participating in the camps.
  - Dealers' service centers conducted fuel efficiency tests on several hundred two-wheelers around the city while also collecting driver, vehicle, CO, and HC data as described above.
- Following the camps, SIAM studied how emission performance declines over time. SIAM contacted a sample of several hundred drivers and performed emission tests on their two-wheelers at specified intervals.

The I/M camps attracted over 65,000 participants, a number greater than any previous pollution check camp. Some vehicle owners were attracted to the camps by the tangible benefits of participating. Others participated "involuntarily" as Delhi police assisted in waving drivers into the camps who would otherwise have driven by. This increased the likelihood that the data represents a good cross-section of vehicles. Anecdotal evidence from comment cards filled out by some drivers indicated a high level of satisfaction. Speakers at the inauguration such as the Chief Minister and SIAM's president indicated their commitment to sustain the effort to improve the PUC program and strengthen I/M in India.

SIAM went on to stage more I/M camps in other majors cities in the following years.

Source: Karl Hausker, personal experience.

On the enforcement front, an important tool is also missing: a visible PUC sticker appropriate for display on a car or 2&3 wheeler with a clear indication of its expiration date. Instead, Delhi issues a paper certificate for the driver to keep in the vehicle and a sticker appropriate for a car windshield (without easily determined expiration date). There is no sticker available that is appropriate for a 2&3 wheeler. Therefore, traffic police cannot easily identify cars or 2&3 wheelers that do not have a valid PUC certificate.

Delhi's Transport Department has enforcement teams to check vehicles for valid PUC certificates. Vehicles can be stopped at random or on the basis of visible smoke. Vehicles without a valid certificate are subject to a fine. If a visibly smoking vehicle is pulled over and it has a valid PUC certificate, then the vehicle owner is directed to reduce the emissions, undertake a fresh test, and report to the RTO within seven days. Delhi carries out periodic enforcement drives preceded by advertising in the media aimed at drivers warning them that they may be at risk.

Anecdotal evidence suggests that most violators pay an “informal” fine rather than receiving a formal citation for violating PUC requirements.[226] Enforcement in Delhi appears more rigorous than most of other Indian cities as evidenced by a smaller number of visibly smoking vehicles. As was the case in Mexico City, it appears that inadvertently petty corruption can be harnessed to help reduce emissions.

C.2.4. Managing Resources

In Delhi and throughout India, government sets the levels of inspection fees. These controlled prices are quite low, ranging from 20 to 70 rupees depending on the type of vehicle (about $0.50 to $1.50 in U.S. currency). These fees are apparently high enough to attract repair shops and gasoline stations to set up a PUC testing operation under existing policy. However, these fee levels are incapable of supporting a strong I/M program conforming to the best practices described in this report (at least $10 per inspection or more as noted in Chapter 5). Any shift toward best practices would necessitate higher fees which could require educating drivers as to their need. Higher fees might be balanced by reducing the frequency of inspection to only once per year.

Among commercial vehicles, the black market prices of I&C certificates are considerably higher than official fees, indicating an ability-to-pay much higher than current fee levels. Government does not receive any of the meager fee revenue from PUC centers thus there are no dedicated funds for oversight of the program.

Institutional capacity remains a problem in general. Consultants generally have found poorly trained staff at the PUC and I&C centers, and there are no systemic efforts to build capacity among the key players.

Policymakers have done little to cultivate public support for the I/M program. It is widely viewed as ineffectual. SIAM has found that its pilot computerized PUC centers have generated a lot of interest and may help change the public perception of the program.

C.3. New Directions

The Mashelkar Committee recommendations have the potential to significantly strengthen I/M in India. Among the key conclusions consistent with best practices in this report are:

- Separate the test function from the repair function.
- Bring in private firms for testing and quality assurance under government oversight.
- Move from no-load to loaded testing.
- Make frequency of testing a function of age.
- Put greater emphasis on capacity building and public awareness.

The Mashelkar Committee proposed some strengthening of standards for gasoline vehicles with catalytic converters, adding HC standards (9000 ppm for 2&3 wheelers and 750 ppm for cars) and tightening the CO standards (3.5 percent for 2&3 wheelers and

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[226] Rogers, John, 2002, op. cit., p. 12.

0.5 percent for cars). With some minor changes, these proposals were adopted in 2004 (see Box C-2 above). However, 0.5 percent CO standard lies outside the measurement accuracy of PUC test equipment and the other cut-points are not based on the fleet characterization data that are available.[227]

With regard to compliance promotion, the Mashelkar Committee proposed to make annual vehicle insurance contingent on holding an I/M certificate. Although there is precedent for such linkage, it seems most likely to succeed when coupled also to an effective system of periodic vehicle registration.

[227] Rogers, John, op. cit., p. 15.

LIST OF ABBREVIATIONS

ADB	Asian Development Bank
CAI	Clean Air Initiative
CAIP	Cairo Air Improvement Project
CO	Carbon monoxide
CO2	Carbon dioxide
EU	European Union
GTZ	Gesellschaft fur Technische Zusammenarbeit (German international development assistance agency)
HC	Hydrocarbons
HSU	Hartridge Smoke Units
I/M	Inspection and maintenance
ISO	International Organization of Standards
NOx	Nitrogen oxides
O2	Oxygen
OBD	On-board diagnostics
PM	Particulate matter
PUC	Pollution Under Control
ppm	Parts per million
QA	Quality assurance
rpm	Revolutions per minute
SIAM	Society of Indian Automobile Manufacturers
US	United States
USAID	U.S. Agency for International Development
USEPA	U.S. Environmental Protection Agency

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